TESTING THE TEILHARDIAN FOUNDATIONS

by George A. Riggan

Teilhard's Constructive Aim and Method

Christianity in Crisis—a Proposed Resolution. "Despite a certain renewal of its hold upon the conservative (or *undeveloped*) elements in the world population, Christianity is decidedly and quite obviously losing its prestige and its attraction for the most influential and progressive portion of humanity. Though Christianity still partially shelters, it no longer covers, nor satisfies, nor guides the modern soul. This holds true not only among pagans and simple believers, but even at the heart of the religious orders." Thus in 1953 Teilhard de Chardin characterized the crisis in Christian faith.[1]

Yet Teilhard himself saw in that crisis no reason to abandon the Christian faith. He remained until his death in 1955 a Jesuit, obedient to his superiors even when they forbade him to publish the philosophico-theological essays that he esteemed the best fruit of his twofold career in science and religion.

He perceived the crisis, therefore, not as challenging the essential wisdom of the Judeo-Christian tradition, but rather as demanding translations of that wisdom in terms of the current scientific world view. On his view, the validity of Christian symbols is now obscured by their close connection with a pre-evolutionary cosmology—once viable but now obsolete. He sought, therefore, to couple those symbols with an evolutionary or "genetic" understanding of man and his world. In effect, he regarded his theological work as "nothing but the transposition into cosmogenic dimensions of the traditional view expressed in cosmic terms: Creation, Spirit, Evil, God (and more specifically, original sin, the Cross, the Resurrection, the Parousia, Charity . . .)—all these notions, once they are transposed to a 'genesis' dimension, become amazingly clear and coherent."[2]

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The need for some such transposition or translation of biblical wisdom is clear enough, though the work itself is beset with difficulties and pitfalls. To decode the biblical message as it stands in tradition, one must first learn to think like a Hebrew—becoming in some sense a Jew, taking as his own history that of the ancient Hebrew-Jewish people. Students preparing for the ministry spend three years or more in seminary learning to think that way, and all too often those years are not enough. If the churches must give every member the equivalent of three years in seminary in order to transmit the life wisdom of the biblical heritage, the case would seem to be hopeless. It is a merit and a risk of Teilhard's synthesis of science and theology that he takes responsibility for this first step in decoding the message.

Yet thinking like a Hebrew is only the first step. At the risk of misconstruing the message itself, the decoder has further to distinguish the essence of a growing and ever changing tradition, leaving aside what has proved to be incidental and obsolete. Next, he has to perceive, and to overcome as best he can, a certain narrow ethnocentrism in ancient Hebrew-Jewish thought. Finally he has the problem of translation itself—the quest among new thought forms for equivalents of idioms in an ancient world view.

For Teilhard, the core of the tradition is simply stated: "The essence of Christianity is nothing more or less than belief in the unification of the world in God through the incarnation."[3] But the meaning of this formula, commonly associated with a prescientific world view, Teilhard defines in terms of scientific cosmology and anthropology: "It is clear," he declares, "that the incarnation could find for its expression nothing except symbols of a juridical nature, so long as human society remained in the 'neolithic,' familial stage of its development (that is to say, until the dawn of the modern scientific-industrial phase). But since the contemporary discovery of the great unities and vast energies of the cosmos, a new and more satisfying meaning for the old words is beginning to take shape. In order to be Alpha and Omega, Christ must become co-extensive with the physical immensities of time and space, yet without losing his human particularity."[4]

Christocentric, yes! But the Teilhardian vision of Christ aims to be free from the distortion produced in much of the biblical tradition by a myopic ethnocentrism. Traditional Christologies are rooted largely in the evolution of Hebraic thought as to the meanings of Hebrew history. Teilhard's understanding of what he calls the "Christic" is rooted as well in the phenomena of biological and social evolution of the entire human species. Insofar as he has successfully transplanted the Christic idea, a person influenced by scientific understandings of human origins no longer need acquire a Hebrew-Jewish outlook in order to get something of the biblical message. Put in another way, the Teilhardian translation aims at presenting claims of the biblical tradition directly to anyone informed by the rudiments of a scientific self-understanding.

We should add that Teilhard does not disparage the ethnic as such. There is no way to be a person apart from membership in some ethnic group. But he does find that scientific views of man tend to liberate from ethnic provincialisms. Referring on occasion to correspondence with fellow scientists regarding a conference on the sciences of man, he wrote with obvious relief: "I do not yet know what this will bring, but it is a change from the tedious atmosphere of the 'Maccabees' and of ethnology."[5]

The proposed Teilhardian resolution of the crisis in Christianity intends far more, however, than simply a translation of tradition. He aims at a synthesis of theology and the sciences, a new scientific theology based upon evidence independent of the Judeo-Christian literary tradition. He seeks to show that certain scientifically observable trends in human evolution point, by logical extrapolation, toward a future for mankind quite similar to that envisioned by Christian faith. He does not claim that his allegedly scientific predictions and the expectations of Christian faith coincide. He argues only that they tend to converge in the foreseeable future.

Scientists and theologians unfavorable to any marriage between sciences and religion dismiss the Teilhardian project out of hand. His work is welcomed, however, by scientists and theologians alike who see the need for and possibility of some synthesis between the two fields. Yet some of those favorably disposed toward such a synthesis remain critical of major elements in Teilhard's important pioneering effort.

Scientific Phenomenology—a Theological Method. "Evolution," Teilhard observes, "has long since ceased to be an hypothesis, and become *a general condition of knowledge* (an additional *dimension*) which henceforth all hypotheses must satisfy."[6] He points out that, from an evolutionary point of view, even physics and chemistry have become historical sciences.[7] All the sciences deal with a phenomenal world that affords no absolute points of reference, either in space or in time, because that world is constantly changing. Scientific laws are no more, and no less, than descriptions of patterns or regularities in the successive occurrence of phenomena—regularities capable of provisional verification, at least, by reference back to the phenomenal flux itself.[8] Incidentally, he claims that, for scientist and historian alike, the long-term drifts in the phenomenal universe provide more adequate frames of reference, more dependable laws, than do the short-term rhythms and cycles, in spite of the fact that the former are more difficult to observe and measure than are the latter.[9]

He undertakes, therefore, to work out a theology that will be scientific in the sense that its conclusions will be derived by extrapolation solely from scientifically verifiable successions and interdependencies among phenomena. In other words, his new theology claims to chart logically inferred and experimentally verified interconnections among phenomena, and then simply to prolong the lines of continuity thus exposed. "If this, . . . then that"—either concurrently or in regular time sequence, exemplifying what he calls *une loi experimental de récurrence*.[10] Moreover, when he promises to "stick strictly to the examination and arrangement of phenomena," he has in mind to make inferences only from what is perceptible, tangible, photographable.[11] This exceptional and exuberant promise to draw inferences only from physical phenomena, however, simply does not jibe with his analysis of phenomenal occurrences in general.

All phenomena, he holds, have two aspects: an outside and an inside. "Coextensive with their *without* [*dehors*], there is a *within* [*dedans*] of things." Viewed from without, objects are determined; viewed from within, they are conscious and free. Indeed, consciousness (*conscience*),[12] spontaneity, the "within," are but three expressions for one and the same thing.[13] To these three, "psychic" should be added as a fourth equivalent term;[14] indeed, as we shall see, "spirit" might be named as a fifth. "For the physicist, until now at least, nothing exists legitimately other than the 'without' of things. The same intellectual attitude is still permissible for the bacteriologist, whose cultures (despite certain major difficulties) are treated as laboratory reagents. But the attitude is already much more difficult in reference to the plant world. It tends to become a gamble in the case of the biologist concerned with the behavior of insects or Coelenterata. It seems simply futile in the case of vertebrates. Finally, it breaks down completely with man, in whom the existence of an 'interior' can no longer be evaded; for in him that interior becomes the object of a direct intuition and the substance of all knowledge."[15]

Thus from the appearance of consciousness in man during the later stages of evolution, the inference is drawn that consciousness is either latently or overtly present in all physical phenomena. The atomic elements and their simple compounds have a "poor within," so poor that they exhibit no signs of consciousness visible to man. The potency of a particular consciousness is alleged, however, to be "inversely proportional to the simplicity of the material compound for which it is the lining." Expressed obversely, this alleged correlation yields the so-called *law of complexity/consciousness:* that is to say, consciousness is directly proportional to physical complexity. For, he concludes in summary, "Spiritual perfection (or conscious centreity) and material synthesis (or complexity) are but two faces or correlative parts of one and the same phenomenon."[16]

It should be acknowledged, however, that Teilhard does not infer this sweeping panpsychism[17] solely from physical evidence. The inference depends upon consciousness itself as an experience *sui generis.*

The actual appearance of consciousness is a phenomenon peculiar to the person who experiences it. Its presence in other persons and in animals is, from the empirical viewpoint, an unverifiable inference, Teilhard's views to the contrary notwithstanding. Through symbols, one can report the experience and talk about it with others. Many of its experienced or reported physical concomitants can be experimentally examined and verified. But direct verification of the reported contents of another consciousness remains, until now at any rate, impossible. And until now, someone else's consciousness as such can be neither perceived by any of the five senses nor photographed—neither directly communicated to another nor directly examined by another.

Teilhard recognizes that his phenomenology is not that of Husserl or Merleau-Ponty. He even appears disinclined to learn from them. Such phenomenologists have usurped their title, he holds, insofar as they ignore a salient dimension of every phenomenon. He agrees that phenomena do depend upon being-perceived-by-an-individual consciousness, and that they are in that sense subjective. But consciousness, when it turns upon itself, becomes aware of being-itself-a-phenomenon objectively dependent upon a cosmic evolutionary process. "I do not understand," he complains, "how any one can call himself a phenomenologist and write whole books without ever mentioning or touching on cosmogenesis and evolution."[18]

Even though it be granted that Teilhard's evolutionary approach to the phenomenon of consciousness redresses a historical overemphasis on existential subjectivity among phenomenologists, we must argue later that his own work suffers the opposite imbalance. In spite of much talk about the psychic and spiritual, he stresses the biophysical aspects of consciousness to the neglect of the other dimensions of cognition, symbolism, and valuation. Because he largely ignores the insights of existentialism and more especially those of depth psychology, he is basically unaware of a bias in his own conclusions, for example, with reference to the future of human evolution. His allegedly scientific predictions are too often determined, not by verifiable cosmogenetic drifts, as he thinks, but by his own psychological and existential history.

Though his inductive conclusions add up to what he calls a realistic ultraphysics, he disavows all recourse to traditional metaphysics[19] and even to philosophy![20] Possibly the philosophy he has a mind to reject is no more than the classic metaphysics of his Roman Catholic tradition. But serious disavowal of recourse to any philosophy can only mean that the philosophic presuppositions underlying his understanding and use of scientific method remain, not simply unexamined, but even unrecognized. The latter seems to be the more likely case. By no means do we wish to suggest that the fruitfulness of a scientific approach depends upon an examination, or even the recognition, of its philosophic presuppositions. In any event, Teilhard firmly proposes to derive his new theology without invoking any such notion as absolute good, causality, or finality. "A law of experimental recurrence, a rule of succession within duration: just that is what we offer to the positivist wisdom of our century."[21]

Although he tries to avoid their methods in his own theological work, Teilhard evidently supposes that traditional philosophies and theologies have their own ways of getting at "the whole of things." Investigations in philosophy and in religion, as he sees them, range beyond the logic of the phenomenal, invoking reasons of a higher order. By his scientific approach, he hopes to serve the older disciplines in two ways: first, by discerning as accurately as possible what he takes to be the actual trend of all phenomena to converge toward organic unity; second, by marking off within the phenomenal spectrum those discontinuities (*coupures*) appropriately demanded, he holds, both by philosophical and by religious thought in consequence of their wider range and higher order of reason.[22] In other words, by his examination of phenomenal evidence, he seeks at one stroke to establish two kinds of theology: his own, based on scientifically demonstrable continuities; and a supernaturalistic theology, based on scientifically demonstrable gaps within the phenomenal continuum.

His sometimes contradictory uses of evidence, of course, are historically intelligible, even though they are methodologically indefensible. For by such vacillation he tries, impossibly, both to demonstrate his obedience as a Jesuit to the rigorous demands of theological orthodoxy prior to Vatican Council II, and to develop at the same time a theology of his own from a forthrightly scientific perspective. Traditional theologians are free, he holds, to posit special interventions that effect revolutionary transformations "beneath the phenomenal veil." They may have evidence, on transexperimental authority, that all of the human species are descended from one man, Adam, and one woman, Eve. They can appeal to a supernatural revelation of man's future destiny. They can do any or all of this and more,[23] but when they do, they are no longer working on the phenomenal plane or within the world view of the sciences where he chooses to remain. Yet it remains the announced purpose of his extrapolations to demonstrate that the sciences, philosophy, and religion—though they never merge—tend toward a distantly foreseeable convergence, like the meeting of meridians at the poles of the earth.[24]

Even at this point it becomes clear that Teilhard did not achieve a comprehensively critical reinterpretation of his own philosophic and theological tradition. Certain special claims of that tradition, no matter how he handles them, will prove to be irreconcilable with the contemporary scientific world view. We should remember, however, that before Pope John and the Vatican Council II, Teilhard's work was influential in transforming the climate of Roman Catholicism. The wide and prolonged impact of his thought suggests that, in spite of obvious mistakes, his pioneering effort contributes substantially to the dialogue between theology and the sciences. We are here concerned more with that dialogue than with the internal history of Catholic thought. In that continuing interchange between sciences and theology, incidental and inevitable mistakes can be informative no less than positive contributions may be.

Teilhard's endeavor poses one central problem that is neither philosophic nor theological in character. It can be put in the form of a final question: How dependable is his scientific judgment outside paleontology, his own field of specialization? His theology derives specifically from phenomena related to the origin and development of the human species.[25] It becomes ever more evident, however, that every science contributes decisively to the understanding of these phenomena—ranging all the way from physics and chemistry to psychology, anthropology, and sociology. While he is pledged by his method to consider all things from atom to man solely as phenomena, when it comes to the human, he insists on dealing with what he considers the *whole* phenomenon of man.[26] In practice, this means that he repeatedly argues for admitting into the sciences alleged facts hitherto ignored or excluded by a majority of his fellow scientists. Though he seeks to persuade us that his conclusions are reached by a rigorously scientific method, he himself acknowledges that his interpretation of the facts is widely regarded as eccentric, imaginative, and poetic.[27]

A non-scientist, such as I, faces at this point an awesome hurdle. Somehow, by appeal to current literature in the sciences, he must decide, for himself at least, which findings adduced by Teilhard are sufficiently tested to be generally acceptable among eminent scientists. Most scientists, excepting those who are also theologians, would face a comparable difficulty in examining the theological dimensions of his synthesis. One value of his pioneering contribution is its challenge to laymen to make just such excursions both into theology and into the sciences. It ordinarily follows, however, that a critical examination of his work must be burdened with frequent appeals in one field or another to views that conflict with Teilhard's, with the consequent demand for some sort of evaluation. This essay is no exception to that rule.

Energy of the Upward Spiral toward Omega (God)

The Flow of Energy toward Death and toward Life. Energy moves throughout the universe, as Teilhard supposes, along two fundamental axes. These two movements, drifts, or trends, taken together, set the limits for all human thought and action, indeed, for the existence of life itself. There is, first, the slow dispersion and dissipation of available energy defined by the second law of thermodynamics—technically, the drift from a low-entropy to a high-entropy system. The tendency toward increased entropy can also be described as a drift from highly improbable and orderly arrangements toward equilibrium in a state of maximum probability and disorder. It is frequently predicted that this entropic drift will lead, in the course of many billions of years, to what is popularly called the "heat death" of the universe. Teilhard holds that there is a second and countervailing drift discernible in the evolution of life. In its evolutionary trend, energy drifts generally, though by no means irreversibly, toward living systems of increasingly low entropy; that is to say, toward arrangements that are increasingly ordered and improbable. The most controversial of Teilhard's scientific theories have to do with the interpretation of these two movements of energy. Incidentally, the language in which he speaks of energy is highly unorthodox—even poetic—rather than scientific.

Teilhard insists that from the beginning modern science has been too exclusively concerned with increasing entropy and the second law of thermodynamics. "Now," he says, "should be the time to recognize that 'transversally' [perpendicularly?] . . . to an irresistible relaxation of universal energy, and conjointly with that relaxation, there exists a second and no less irresistible current, forcing this same energy, as it relaxes, to make a long circuit into the increasingly complex." Orthogenesis is his controversial label for this second fundamental drift or current.[28] The argument for orthogenesis is basic in the Teilhardian synthesis.

Teilhard's Thesis in Outline. I shall show that Teilhard's thesis, thus foreshadowed, can be summarized briefly and substantially as follows:

1. Energy: The primary axis along which energy moves throughout the universe is the one that becomes evident in the evolution of life; the second law of thermodynamics describes a secondary and dependent movement.[29]

2. Mechanisms of Evolution: With the appearance of human reflection (self-consciousness), evolution entered into a radically new phase, in which the single and irresistible thrust of the whole evolutionary process for the first time became evident—another way of saying that evolution is orthogenetic.[30]

3. Orthogenesis: The concept of evolution as a process predirected toward a single goal. The irreversible tendency of the multitude of human minds to converge in co-reflection, best exemplified in the planetary character of the total scientific enterprise,[31] is currently the leading edge or the arrow of the evolutionary process.[32]

4. The Future of Evolution and of Man: The lines along which human minds are converging can be extended by extrapolation toward their meeting in a theoretic point, Omega, the concept of which operates in the sciences, according to Teilhard, in a way analogous to the operation of the God concept in Christian theology.[33] In point Omega, the peak of hominization,[34] all human psyches will become organically socialized, communalized, totalized in a state of ultra- or super-reflection;[35] but in that state the individual psyche, far from being depersonalized, will be integrated and fulfilled.[36]

The long circuit into the increasingly complex, through which relaxing energy is irresistibly forced to make its way, turns out to be a long upward spiral that converges toward point Omega, otherwise defined as God. This brief paraphrase of Teilhard's own language succinctly summarizes his synthesis of the sciences with theology.

5. Two Derivations of Omega: In what amounts to an addendum to his own synthesis, he observes that the scientifically predictable characteristics of the evolutionary process at point Omega closely parallel New Testament prophetic descriptions of the eschatological return of Jesus Christ, who is also called in apocalyptic literature Alpha and Omega, the beginning and the end (Rev. 22:15). Thus Teilhard underscores the fact that his (allegedly) scientific predictions concerning the end of the world bear strong resemblance to biblical prophecies of the same event. He himself calls attention to "a revealing correspondence between the features or patterns of the two opposed Omegas: the one postulated by modern science, the other verified by Christian mysticism."[37]

Most scientists and most theologians, alike, will wince at this bald outline of Teilhard's thesis, though often they may wince for quite different reasons. Why, then, pursue the matter further? That question may be met by still another query, in two parts: Can the Teilhardian thesis be amended, or is any attempt at such a synthesis fatally flawed from the outset? An answer would seem to require, as a first step, an examination of the scientific aspects of the Teilhardian model to determine as clearly as possible the consensus among scientists with reference to the theories he takes to be foundational for a scientific theology.

That examination may well open up with this observation: Teilhard's passionate interest in predictions of the heat death of the universe leads him, if not to misunderstanding, then certainly to curious interpretations of the physical laws from which the predictions are commonly derived. A sketch of more conventional understandings of entropy may serve to highlight some of his less orthodox views.

Entropy and the Second Law of Thermodynamics. Entropy was first investigated in classical thermodynamics as a heat phenomenon. The thermal entropy of a system, in effect, is the quantity of its energy unavailable for doing work. The earliest quantifications of the entropy of various substances depended on the fact that a measured heat input, or output, produces quite different changes in temperature, depending on the substance involved. The thermal entropy of any substance may be expressed mathematically as a function of heat input (or output) and of temperature.[38]

According to the first law of thermodynamics, the total mass-energy involved in any isolated physical or chemical action is constant throughout the action. According to the second law, however, heat always shows a tendency within isolated systems to equalize temperature differences by passing spontaneously from the hotter to the colder bodies in such a way that no reverse flow can bring the bodies back to their initial temperatures.[39]

Stated in terms of thermal entropy, the second law holds that as any closed system approaches equilibrium, the entropy of the whole system becomes increasingly greater than the combined entropies of its constituent parts before the internal transfers of energy started. An increase in entropy, however, is also a reduction of energy available for work. Thus, while the total mass-energy of a complex remains constant throughout its internal changes, any net shift of the whole system from lower to higher entropy in the course of these changes cannot be reversed except by an input of energy from sources outside.

So far we have considered only the classical method for calculating entropy—a method based on macroscopic thermal measurements.[40] Identical values for thermal entropy can be derived by applying statistical probability theory to data regarding populations of energy levels in a system. This means that thermal entropy becomes, from a microscopic and a statistical point of view, a measure of disorder among energy states.

At this point a complication arises. Once entropy is interpreted as a quantitative measure of disorder, several different kinds of entropy can be distinguished. Statistical mechanics deals with conformational as well as with thermal entropy in physical systems. Information theory concerns itself with informational entropy, defined as a quantification of disorder in systems designed to transmit, store, and retrieve information.[41] Since living organisms may be viewed as self-replicating systems for the storage, transmission, and retrieval of genetic information, biologists are increasingly attentive to the relationships between informational and other forms of entropy.

The Entropy of Living Systems and the Second Law. Specific consideration of the second law in reference to the entropy of living organisms is warranted by the fact that Teilhard's views on the subject are more than a bit unusual.

Living organisms may be described as self-maintaining and self-reproducing systems or regions of decreased entropy. The organism as a whole, and all of its parts down to and including the unit cell, comprise a vast number of atoms and molecules, all arranged with a precision and complexity that are marvelous because so highly improbable.

The living system maintains itself by feeding upon low-entropy components of its environment, the food material depending on the nature of the feeding organism. This exchange of energy and "information" from the environment to the organism, however, tends to increase the entropy of the organism itself. The latter, as long as it lives, is able to discharge this increased entropy back into the environment in the form of heat and other waste products of nutrition and respiration. When the increased entropy from feeding can no longer be discharged as fast as it builds up, the organism begins to die. Death may be defined as a critical net increase of entropy resulting eventually in the total disintegration of the organism. Even species are not exempt. The two million or so species now inhabiting the earth[42] comprise but a very small percentage of the millions of species that have become extinct in the course of evolution.

Thus all life is governed by what Lindsay has called the thermodynamic imperative; every organism, including man, is genetically instructed to "consume entropy," to use another of his metaphors.[43] The genetically encoded instruction to maintain and even to increase local order can be neglected by any organism, or by any species, only at the peril of its own extinction.

Scientists are generally agreed, however, that the reduction of entropy in living systems and by the processes of evolution implies no threat to the validity of the second law of thermodynamics. Any local decrease in entropy, with its attendant increase in order, is generally accompanied by a corresponding or greater increase in entropy elsewhere in the universe—whether the increase be conformational, thermal, or informational.[44] In other words: "Systems in nature move spontaneously from order to disorder, from lesser to greater randomness, or toward the state of maximum probability."[45] The law holds for organic and inorganic systems alike. "Even in the case of living things, the inexorable increase in entropy goes on; the second law always wins in the end."[46]

Extrapolations of the law of increasing entropy to the entire universe usually proceed on the assumption that the physical world is a closed system. If that assumption is granted, and if due allowance is made for the Einsteinian equivalence of mass and energy, the nineteenth-century summary of the first and second laws by Rudolph Clausius still holds: "The energy of the universe is constant. The entropy of the universe tends toward a maximum."[47] As entropy goes up in accordance with the second law, available energy runs out. Assuming, again, that the universe is a closed system, the universal drift of energy toward ever more probable states spells eventual doom for all the complex and statistically improbable organizations of energy in systems of life.

Teilhard is well aware that a vast majority of scientists regard the evolutionary process, with its proliferation of improbable living systems, as no more than "a simple eddy upon the majestic wave of increasing entropy."[48] Although he notes that eminent scientists, among them Harold Blum and Joseph Needham,[49] share the prevailing view, he himself seeks to prove the contrary case.

Teilhard on Two Kinds of Energy. How, then, does Teilhard set about demonstrating that the law of life (the law of complexity/consciousness), rather than the second law of thermodynamics, defines the major axis along which energy moves universally? The trick (*astuce*), he says, is to distinguish two kinds of energy: a primary sort, psychical or radial energy; and and a secondary sort, physical or tangential energy.[50] Radial energy and tangential energy, as their alternate naming indicates (psychical, physical), correspond respectively to the "within" and the "without" of every phenomenon.[51] Thus every time Teilhard speaks of radial, axial, psychical, or spiritual energy, he has in mind energy of the first sort. He may even refer to it as the energy of consciousness, or of reflection. What he calls tangential or physical energy is admittedly the only kind with which the majority of scientists are at all concerned.[52]

According to his own summary, he holds that: (1) radial energy and tangential energy are not directly transformable from one into the other; (2) they are interdependent in operation and in their evolution; (3) the radial increases with the arrangement of the tangential; (4) the tangential arranges itself only as it is "activated" (*activé*) by the radial.[53] Parenthetically, this curious notion of a sort of energy that has no "arrangement," no structure, except as it is "activated" by energy of another sort derives from his panpsychism. The latter itself represents his efforts to achieve a unified theory of energy.[54] Yet his panpsychistic monism, as we shall see, tends to break down when he comes to deal with the predicted states of energy at the end of the world.

His conclusion that radial energy is directly proportional to physical arrangement (the law of complexity/consciousness) is repeatedly alleged to rest on empirical evidence related to the appearance of consciousness and of reflection in the late stages of evolution. He concedes that there can be no direct evidence of radial energy at the inorganic level.[55] Yet the fact that the "within" of pre-living matter is "too poor" to give perceptible confirmation of its existence by no means invalidates other data requiring, in Teilhard's view, the theoretically inevitable inference that radial energy exists also at the inorganic level. He insists, in effect, that a full appraisal of his theories with reference to energy and the second law must comprehend as well his distinctive interpretations of the evolutionary process. He himself does not hesitate, however, to outline the monumental reversal of thermodynamic theory that would follow were his views concerning the origins of life and consciousness found to be generally acceptable among scientists. The outline of that reversal, rather than the evidences adduced for it, engages us at present.

"Arrangement" is the key concept in the Teilhardian model of cosmic thermodynamics. He even proposes to distinguish two subtypes of tangential energy, which he names "radiation" energy and the energy of "arrangement," respectively.[56] In view of his statement, noted above, that "tangential energy arranges itself only as it is activated by the radial or non-physical," this talk of a tangential (i.e., physical) energy of arrangement is beyond my comprehension. He posits, nevertheless, "the intervention of an arrangement" as the connecting link between radial (psychical) and tangential (physical) energy. His consequent observation indicates something of the general direction in which his argument is moving. Through certain arrangements, he adds, as much as you like of radial energy can be linked with as little as you like of tangential energy, "for the achievement of a most highly perfected arrangement may only require an extremely small amount of work."[57]

If I read Teilhard correctly, at least part of what he has in mind when he talks of radial, spiritual, or psychic energy may be equated with "information" or "information content" in the sense that has been made increasingly precise by recent advances in information theory. To get at the meaning of his conclusion that consciousness is proportional to physical complexity all the way from atom to man, we may ask a question: In what way is the fertilized egg that develops into a human adult more complex than, say, a paramecium? A biologist answers that the human zygote has richer and more complicated genetical instruction, or information, than the paramecium.[58] The question next arises as to the relation between informational order and other types of order—thermal, for example. The vast disproportion between the two is suggested by the following equation, in which I_B represents information in bits, and C_D, calories per degree Kelvin: $I_B/C_D = 4 \times 10^{23}/1$. This means that an increase in information by roughly 10^{21} bits must be compensated by an increase in thermal entropy at least equivalent to the input of one calorie of heat at approximately room temperature (300° Kelvin).[59] Thus an efficient system may produce an enormous increase in information at astonishingly low cost in thermal energy.

If Teilhard intends to do no more than stress the slight increase of entropy consequent upon certain vast increases in information,[60] no exception need be taken. But he confuses everything by appealing to an imponderable radial energy that supposedly "activates" improbable physical arrangements. From this linguistic confusion, he advances to the conclusion that, although tangential energy obeys the laws of thermodynamics, radial energy "escapes from entropy."[61] In other words, if I correctly understand him, molecular conformations and populations of energy levels are subject to the second law, but information is not. Evidence developed since his death refutes the latter conclusion.

Teilhard's basic misunderstanding of entropy, suggested by remarks like those above, is elsewhere more clearly apparent. He takes the theory that the universe is in process of explosive expansion from a primordial cosmic egg, for example, as evidence that the dissipation of energy predicted by the second law is *not* taking place.[62] Astronomers, on the other hand, even those who are seeking empirical evidence of "continuous creation," take the data on which the big-bang theory is based as a powerful indication that the second law holds throughout the observable universe.[63]

His views further imply a constant increase in both kinds of cosmic energy, as he freely admits. An increase of whatever magnitude in radial (psychical, spiritual) energy would be of no consequence to the physical sciences, of course, for on his assumptions, radial energy cannot be observed from a purely external point of view. Alleged increases in the second subvariety of physical energy (what he calls the "tangential energy of arrangement"), on the other hand, have serious implications for the physical sciences. These latter increases challenge the fundamental assumption that the total mass-energy involved in any physical or chemical action remains constant throughout the action. The consequences of this direct contradiction of the first law of thermodynamics, he hastens to assure us, are by no means so serious as at first they seem to be. Increasingly improbable molecular arrangements, he observes, yield no *appreciable* increase in physical energy, except at the very highest levels of complexity—he has in mind, among other things, the complex molecular structure of the human brain. "For less complex arrangements, and that means for an approximately constant number of initial particles in the universe, the sum of cosmic tangential energies remains practically and statistically invariable during the course of their transformations. And that," he adds, "is all that science requires."[64]

Teilhard's revisions of thermodynamic laws derive, we are reminded, from his interpretation of man's place in the process of evolution. His interpretation of evolution leads to a still more exotic theory in thermodynamics.

> Finally, from the viewpoint of energetics, everything happens as if the universe were propagating itself, not solely along a single axis, but rather along two conjoined axes: one, the axis of greatest probability (entropy), and the other that of the greatest complexity (life). Consciousness develops all along as a function of entropy in keeping with the requirements of thermodynamics, but finally it escapes disorganization by a specific effect of reflection [human self-consciousness], either as a distinct second kind of energy, or as an interiorized fraction of ordinary energy.[65]

At this point, Teilhard abandons his striving after a unified theory of energy. In the end-stage of the evolutionary process, at point Omega, radial energy predictably will separate from tangential energy.[66] The eschatological release of spiritual energy from bondage to the physical will be no halfway affair. As he sees it, the physical world will disintegrate in accordance with the second law. The indestructible spiritual realm will exist entirely independently of the physical. Consciousness will no longer be proportional to complexity of molecular arrangements, for the partnership of complexity/consciousness will break up to release in the free state "a thinking without brain" (*une pensée sans cerveau*).[67] He is even willing to speculate that "physical energy is nothing else than psychic energy *materialized*."[68]

In spite of Teilhard's insistence that his thermodynamic theories rest on scientifically verifiable data related to the evolutionary origins of life and of consciousness, his bold speculations sound more like tongue-in-cheek science fiction. In effect, he replies that all creative advances in the sciences originate in fantasies of the scientific imagination, as indeed they may. The difference between pure fantasy and a radically new scientific theory is that the latter fantasy, unlike the former, is formulated with a view to its verification or falsification by reference to publicly accessible phenomena.

Teilhard's panpsychism remains by that test an unscientific fantasy, at least insofar as he rests his case upon data related to energy states.[69] Yet he obviously considers his model of the cosmos to be a scientifically veriable theory with reference to the laws both of thermodynamics and of biological evolution. "I simply ask of those who would call my interpretation of the facts fanciful or poetic: Show me another perspective that more completely and naturally integrates the extraordinary (and misunderstood) phenomenon of man into the framework of our biology and energetics, and I will adopt it."[70]

While he fails to set man within the framework of a new scientific and panpsychistic "energetics," Teilhard's speculations do dramatize a widely recognized fact: Living organisms, together with the physical systems out of which they evolved, exemplify a continuing evolution of certain systems toward increasingly low informational entropy, even though the energy exchanges attending this process produce a net increase of entropy within the environment of such systems. The future of all life, including the human, is conditioned by these two physical tendencies: one, an evolution of energy states in the direction of maximum probability; the other, a dependent counter-evolution of certain physical and biophysical systems in the general direction of greater improbability. Teilhard's challenge calls next, therefore, for an investigation to determine just how his theory of biological evolution compares with alternative theories.

The Evolutionary Origins of Life and of Species

Teilhard's Debt to Lamarck and to Darwin. The Teilhardian theory of evolution attempts to synthesize two accounts of evolution that have long been in conflict—one tracing its origin to J. B. de Monet Lamarck, the other to Charles Darwin.[71] Teilhard's thought is dominated by the tradition that leads from Buffon through Lamarck to neo-Lamarckism and eventually to Lysenkoism. More directly, he is influenced by the neo-Lamarckism of the French biologist, Lucien Cuénot, and by the vitalism of Henri Bergson.[72] The secondary influence upon Teilhardian evolutionism derives from Darwin, neo-Darwinian mutationism, and the latest Darwinian development, sometimes called the synthetic theory of evolution. The latter theory, worked out cooperatively by a number of scientists, embodies results of research in all of the life sciences, ranging from paleontology and taxonomy to biophysics, genetics, and ecology.[73]

Neo-Lamarckian theories hold, generally, that evolution takes place through *predirected* genetic mutations. In brief, the interplay between an organism and its environment is said to imprint new genetic instructions upon the chromosomes from which the next generation will be born.[74] The synthetic or, as I shall call it, the biophysical theory holds that evolution proceeds by *random* genetic mutations that are naturally *selected* after they make their appearance. The drama of the controversy, and of Teilhard's attempted synthesis, lies behind these generalizations. He holds that the two theories, far from being antithetical, are actually complementary and "symbiotic." Darwinian explanations of speciation and of consciousness have, on his understanding, at least a provisional and limited validity.[75] He sees Darwinian and Lamarckian theories, in fact, as corresponding to the inner and outer aspects of the phenomena with which they deal. Thus, on his understanding, neo-Darwinism reflects the external, determined, physical aspect of things; neo-Lamarckism, the internal, psychical, conscious, and free.

The Biophysical Theory of Life's Origins. Teilhard does not pretend, of course, to describe the distant past as it really happened.[76] The picture that he repeatedly sketches of the dawn of life and of speciation in the Paleozoic era[77] depicts probabilities as they appeared to him in the light of then current scientific knowledge. Since he holds that "psychical energy" gives no direct evidence of its existence at the level of pre-life, his approach to the origins of life is largely biophysical and Darwinian. Not unexpectedly, therefore, his views on the subject, as outlined in the next few paragraphs, anticipate advances in biophysics that have come since his death in 1955.

From quantum physics he derives the notion that the energy of the cosmos appears already in its primordial form to be granulated or corpusculated—as in photons, electrons, protons, neutrons, and the like. Starting at the level of the atom, however, he distinguishes two directions in which supergranulation proceeds.[78] Gravity is an indispensible factor in both processes. In the process of pseudo-corpuscularization, matter is collected by gravitational effect into mere aggregates, ranging in size from a few atoms to asteroids, planets, stars, and galaxies. In the atomic microcosm, distances are measured in angstroms and picometers; in the galactic macrocosm, distances between particles are measured in light-years, and the universe itself appears to be a gas composed of stars. Within this "astronomic" series, ranging from the infinitely small to the infinitely large, man seems to be lost and insignificant.

In what he calls the process of true corpuscularization (eu-corpuscularization, or molecularization), matter arranges itself *apparently* through electromagnetic effect into little closed systems, more and more complicated, and centered in such way that within every system each particle relates organically to the whole and so performs in the system at a level impossible for such a particle in isolation or in simple juxtaposition with other such particles. Eu-corpuscularization generates what Teilhard calls the axis of complexification. Parenthetically, Teilhard is allowing for another and more cherished point of view when he speaks of complexification as *apparently* the effect of physical energy. From his vitalistic outlook, discussed above, he views complex molecular arrangements as basically an effect of radial or psychical energy (see above).

The movement of matter along the axis toward increasingly complex arrangements, according to Teilhard, is secondarily also a consequence of physical gravity. In a planet such as earth, gravity largely determines the arrangement of matter into a series of concentric spheres: the innermost barysphere, enclosed successively by the lighter lithosphere, the hydrosphere, and the atmosphere. If any planetary mass is too small and its gravitational field consequently too slight, the elements of the hydrosphere and of the atmosphere are dissipated into space and the evolution of life becomes impossible.

In keeping with this holistic approach to the structure of the planet, Teilhard early adopted the term "biosphere" to denominate the evolving and earth-encircling complex of relationships among living organisms and between them and their inorganic environment. He himself coined the word "noosphere" from *nous* (Greek for "mind"), to signify the earth-enveloping network of phenomena related to the emergence of human consciousness and to the evolution of human cultures. As he sees it, the past, and continuing, evolution of both the biosphere and the noosphere depends on the spheric, compressive effect of the earth's gravity. Thus among the more arresting of Teilhard's insights is the observation that physical gravity produces specifiable effects in the evolution of all earth systems, whether they be geological, oceanographic, meteorological, biological, or cultural.

He observes further that, simply from an external and purely biophysical perspective, both the evolution of life from pre-living matter and the subsequent differentiation of species appear to be consequences of the interplay of astronomically large numbers of elementary particles held together by gravity on the surface of a sphere (the earth) within suitable ranges of temperature and for enormous time spans —leading (by random mutation and natural selection) to the statistically predictable, even though highly improbable, arrangements observed in living organisms.[79]

Along the axis of complexification, therefore, he discerns three successive series of arrangement exhibited in the course of cosmic evolution: (1) starting with the microcosmic, the whole atomic series, generated by relatively few combinations of electrons, protons, and neutrons; (2) the whole molecular series (molecules, monomers, polymers), produced by combinations of atoms the numbers and interrelations of which, at the level of organic chemistry, rapidly achieve astronomic proportions; (3) finally, the whole zoological series, produced by molecular combinations ranging by stages from the single cell all the way to man and the whale, each specimen of which appears to the observant beholder as a super-molecule or super-corpuscle.[80]

Since Teilhard's death in 1955, advances in biophysics have tended further to confirm and to extend the prevailing theories of his time as to the origin of life from inorganic elements.[81] These advances contribute substantially, moreover, to the foundations of any theology *that proposes to speak in terms of a scientific world view.*

In the short time since his death, the DNA (deoxyribonucleic acid) molecule, comprising phosphates, sugars, and nucleotide bases, has yielded some secrets of the language in which is encoded instructions controlling the building and function of every kind of living substance from cells to whole organisms.[82]

The four letters in the alphabet of that language—the nucleotide bases A(denine), C(ytosine), G(uanine), T(hymine)—are known to combine in triplets to make up a vocabulary of no more than sixty-four words of three letters each. The words vary, however, in arrangement and number, depending on whether the DNA is that, for example, of an amoeba or a man. From this limited vocabulary, therefore, the possible number of specific messages is astronomic, because the sequence in which the words are strung out and the number of words to a message are indefinitely variable.

The DNA message generally takes the shape of an interlocked two-stranded spiral or helix. In consequence of specific affinities, every "A" molecule in one strand of the double helix tends to be paired with a "T" molecule in the opposite strand; likewise, every "C" tends to be paired with a "G" nucleotide.

Cytosine's affinity for guanine and adenine's double affinity for either thymine or uracil opens up two possibilities, when the two strands of a DNA helix unzip and separate. The first possibility is that, by pairing up appropriately with free nucleotides of the DNA alphabet, the molecules in each strand will replicate the strand from which they have just separated. Thus one DNA double helix, by the separation and replication of its two strands, becomes two double helixes of the same pattern; the message duplicates itself.

The second possibility, when a DNA helix unzips, is that the molecules of the separated strand will attract their respective opposites from free nucleotides in the closely related alphabet of ribonucleic acid. The messenger RNA chain thus formed, when loosed from its DNA template, will then instruct the assembly of amino acids to form the protein specified by the particular strand of DNA. Thus messages in the language of DNA are translated by the messenger RNA into blood, bone, nerve, and muscle.

Arthur Kornberg discovered in 1957 that, when appropriate nucleotide bases are simply mixed together in a test tube and heated for a few hours, they will arrange themselves in random DNA sequences.[83]

Scientists do not yet know enough about these processes to synthesize living compounds out of purely inorganic elements. However, in laboratory duplications of conditions presumed to have existed on the primeval earth, some of the building blocks of nucleic acid (letters of the language of life), some amino acids (building blocks for all proteins), as well as formaldehyde and acetic acid have arisen spontaneously from inorganic molecules of water, ammonia, and methane. There is little doubt that spontaneous synthesis of self-replicating (living) compounds, although it has not yet taken place in the laboratory, could have occurred under conditions prevailing on the surface of the earth during a span of several billion years.[84]

The Synthetic (Biophysical) Theory of Species Evolution. It is quite understandable that, in his effort to integrate the two into a single theory, Teilhard should set forth both Darwinian and Lamarckian views of evolution in a somewhat original way. The following brief outline of the synthetic theory of evolution is offered in order that his variations upon post-Darwinian developments may be the more plainly evident. Certain advances in biophysics and genetics that have taken place since his death are reflected in this sketch of the theory.

The synthetic or biophysical theory integrates four processes: (1) replication of DNA messenger RNA molecules, discussed above; (2) random genetic mutations and, in the case of sexually reproducing systems, haphazard recombination of genes in mating; (3) isolation of relatively small populations out of homogeneous zoological groups; (4) natural selection by differential reproduction of the mutant genes in any isolated gene pool. Since the replication of DNA and RNA molecules has just been dealt with, we move at once to the second of the four processes: random mutations in genes—those complex, self-replicating DNA chains within the helix that determine specific hereditary characteristics.

Possibilities for research upon the mechanisms of genetic mutation were opened up by Morgan and his colleagues, between 1910 and 1935, in experiments on populations of the vinegar fly, *Drosophila melanogaster*.[85] Morgan himself first demonstrated that genes are carried in the chromosomes.[86] Among other findings were these: Genes occur in sets, linked, as it were, in chain formation. In bisexual mating, the sex of the offspring is determined by genes in two chromosomes, X and Y. Infertile eggs normally carry one X chromosome; spermatozoa, either an X or a Y chromosome in approximately equal distributions. Daughters have normally two X chromosomes, one derived from the mother, the other from the father; they have normally no Y chromosome. Sons have normally an X from the mother and a Y from the father. Sex-linked traits, such as color blindness, occur in successive generations in distributions deviating only slightly from the distributions theoretically predictable on the basis of Mendelian law.

C. B. Bridges, who studied with Morgan, turned his attention to the theoretically exceptional combinations of hereditary characteristics in populations of the same fly. He found that the deviant distributions could be accounted for on two assumptions. The daughters with exceptional sex-linked traits seemed to have come from exceptional eggs bearing two X chromosomes from the mother, fertilized by spermatozoa bearing a Y chromosome from the father. If that were the case, then the cells of such daughters must carry two X chromosomes to account for their femaleness and an unheard-of Y chromosome as well. The microscope verified the prediction. The sons with exceptional sex-linked traits seemed to have come from eggs bearing no X chromosomes, fertilized by X-bearing spermatozoa. If so, then they must have in their cells a single X chromosome and no Y chromosome. Again the microscope verified the predicted anomaly. Observations have even confirmed theoretic predictions concerning chromosomatic structures in offspring from matings of such genetically deviant sons and daughters.[87] Most significantly, the experiments demonstrated that the genetic mutations called for by evolutionary theory do actually occur in connection with the reshuffling of chromosomes during the process of indirect cell division.

Attention next turned toward the chemistry and physics of mutation. Herman Joseph Muller achieved a breakthrough in 1928, by exposing colonies of *Drosophila melanogaster* to X-rays, thereby increasing enormously both the rate and variety of mutations. A number of agents that increase rates of mutation have since been found, among them ultraviolet light, cosmic rays and other high-energy radiation, and chemical compounds such as acridine and certain nitrites. Under laboratory conditions, controlled exposure of various organisms to such agents produces mutations, purely random in kind, but highly predictable in their increased frequency. Applied to human populations, projected mutation rates are quite significant, even though less dependable. Careful estimates, involving an admittedly wide margin of uncertainty, indicate, for example, that atomic bomb explosions to 1966 may have raised the worldwide mutation rate by one-tenth of 1 per cent, increasing by 3,000 each year the number of people who will be born with, or develop, significant genetic defects—since perhaps ninety-nine out of one hundred mutations impair rather than improve the functioning of the organism.[88]

In the meantime, the secrets of the nucleic acids began to yield to biophysical and biochemical research that culminated in the Crick-Watson model of the DNA double helix discussed above. The random character of mutations could then be related to chance deletions, substitutions, and scramblings of letters and words in the message encoded in DNA.[89]

Genetic mutations provide the raw material for the evolution of new species, defined as zoological groups possessing distinctive sets of genetic traits that maintain themselves through successive generations. The amazingly complex process of speciation, however, cannot be explained by random mutations alone. The number of genes normally carried by any organism varies from species to species, as does the rate of mutation. The human individual, for example, is estimated to receive a total of not less than ten thousand genes from his two parents. Any specific gene in the total human set will mutate probably once in every one hundred thousand generations, a conservative estimate, indicating from one point of view an astonishingly accurate reproductive system. Yet since there are ten thousand or more genes in the typical human set, about one out of every five individuals passes on a mutant gene that he did not receive from his parents.[90]

The mutations involved in producing a new species, however, are vastly more numerous than the few that might originate with any two individuals. The combination of various mutant genes in a new species, moreover, is quite specific; their arrangement, exact. The origin of new species becomes largely unintelligible, therefore, when reproduction is viewed simply as either the self-replication of a single asexual organism or the bisexual mating of two individuals. By mating with another of the opposite sex, a particular genotype (here defined as the total set of genes inherited by, and determining, one individual of a species) might conceivably produce a new species, but the astronomic odds against such an event make its occurrence virtually impossible.

An individual's genetic inheritance, however, comes, not simply from his parents, but from a host of ancestors. Any particular bisexual mating produces, therefore, a single random sampling of a gene pool—the dynamic, hence ever changing, totality of the genes inherited and existing in the chromosomes of all living individuals of a species. A single generation becomes in effect a multiple random sampling of the same pool. A gene pool of considerable size, having a long reproductive history, alone can provide the vast numbers and varieties of genes required for the production of a new species. Thus the understanding of biological evolution is logically approached through the study of individuals as members of population systems. Such systems transmit genetic information for millions of years, preserving as well a certain increment of substitutions, deletions, and recombinations of words and letters incident to the transmission of the genetic message through so many generations. Yet the wonder remains that, even in a gene pool enduring for thousands of generations, just the right mutant genes could ever arise and combine to form a new species.

The isolation of small populations of known sizes within the laboratory has supplied quantitative information concerning frequencies of mutation, rates at which specific mutant genes spread through systems, selective pressures against survival of various mutant genes under controlled conditions, and other related phenomena. On the basis of such empirical evidence, Fisher, Haldane, and Wright, among others, have worked out mathematical models of population systems, both to determine theoretic consequences of mutation and reproduction at specified rates in populations of various sizes, and to determine indirectly and theoretically certain parameters within which selection operates.

Though they differ in certain respects, such ideal models concur in making several fundamental predictions which have in turn been subjected to further experimental testing.[91]

Such studies make it clear that evolution would have been virtually impossible were it not for the partial reproductive isolation in nature of small-to-intermediate population systems. A mutant gene can be widely diffused through a gene pool of intermediate size, and the pool enriched or burdened by a variety of mutations, more rapidly than is the case for enormous and widely scattered total population of a species. In excessively large populations, theoretic limits of which depend on a number of empirical variables, a mutant gene tends to drop out rather than to be fixed in the genetic pool.

So-called sampling errors also become genetically significant in small and intermediate populations.[92] If any generation passes on genes in exact proportion to their numbers in the parental pool, the next generation is statistically a completely unbiased sample of the parental gene pool. Precisely representative samplings are theoretically most rare exceptions. Yet in enormous gene pools, local sampling deviations and the sampling errors of particular generations tend to cancel out and the pool to stabilize. In isolated colonies, however, sampling errors in a succession of generations may give rise to a genetic drift that in time can become irreversible. Genetic drift in quite small populations leads usually to extinction, occasionally to rapid speciation. Variation, however, provides only the raw material for evolution. Mutations and sampling errors are random processes, moving haphazardly in many directions, hence in no particular direction.

But certain directed genetic trends have also turned up in experiments on isolated colonies as a result of small changes in laboratory conditions. In other words, natural selection, the fourth process integrated into the synthetic or biophysical theory of evolution, has been experimentally demonstrated.

Differential reproduction by natural selection of mutant genes in an isolated gene pool has been beautifully exemplified in two experiments on *Drosophila melanogaster.*[93] In one case, long-winged flies were mixed with others bearing only vestigial wings, and the colony was supplied with food insufficient to satisfy fully the needs of every larva. After several generations, the wingless flies had been selected out, demonstrating that the mutant gene for that trait carries a slight disadvantage in competition for scarce food. In a second instance, wingless flies survived better than normal flies when a comparable mix was subjected for several generations to a constant airstream.

From Fisher's work, it appears that, in wild populations of intermediate size, mutant genes conferring even very small advantage will establish themselves in a few generations, while mutations of neutral advantage have little chance, and those of the slightest disadvantage virtually no chance, of surviving.[94]

Possibilities for environmental feedback upon partially isolated genetic systems in nature, and the consequent varieties and intensities of selective pressure accounted for by the synthetic theory, are enormous. Simply by way of general illustration: Two colonies of an aquatic species migrate, one up a river system of steady flow, the other up a system subject to alternate flood and long drought. Random mutations in the second population will be under pressure favoring evolution toward an amphibious species. Again, a species migrates into two widely separated regions, in one of which their predators differ widely from those in the other region. Pressure for adaptation will select in the two regions quite different genetic mutations, whatever they chance to be. Incidentally, as members of a mammalian species, human beings owe a debt of gratitude to predatory dinosaurs for their unintended aid in developing the earliest mammalian brain systems, from which our own are descended.[95] Likewise, pressure upon an omnivorous species isolated in an ecology of abundant forage, but of scarce prey, will favor mutations adaptive to the new food supply.

Parenthetically, it is worth noting that accumulated information concerning selective factors in various environments now permits highly reliable predictions as to detailed anatomical and physiological features (relative size of head, rate of heartbeat, life expectancy, etc.) to be expected of a new genus that might turn up in a designated region of the earth.[96]

To understand the biophysical account of the production of new species by natural selection, we have only to remember that selection acts upon a gene pool, not simply to discard disadvantageous mutations, but also to feed back advantageous mutant genes into the pool. To illustrate the creative effects of such selection, Simpson has proposed a deliberately and highly oversimplified analogy:[97] A large pool of all letters in the alphabet has selective pressure against every letter except those in the word "cat." For the letters *C, A,* and *T,* the pressure is positive. Three-letter samplings are repeatedly drawn from the pool. The probability of turning up *C, A,* and *T* in just that order is at first very small indeed. But incorrect letters in every sampling are discarded, and correct ones are continually fed back into the pool—singly or in whatever combination they come up. As the incorrect letters disappear, the pool becomes enriched in the letters *C, A,* and *T,* singly and in combinations of CA, *CT, AC,* AT, *TC, TA.* Eventually the probability becomes very great that the three letters will turn up in proper sequence to create "CAT," not once only, but many times.

Scientists adhering to the synthetic theory argue from evidence that nothing is required to explain biological evolution beyond the four processes earlier named: genetic replication, variation through mutation and recombination, partial isolation of statistically optimal population systems, and natural selection. On this understanding, selection is a highly complex ecological phenomenon—a continuing and often self-accelerating (autocatalytic), feedback interaction between a multigeneration gene pool and its total environment. Evolutionary raw material is provided by purely random processes—mutation, sampling, recombination, genetic drift, and the like—but the shaping of the material is no chance phenomenon.[98] Selection is a highly directive and regular process. Quite small differences in selective pressure upon a mutant gene in nature determine whether it stays in or goes out.

Teilhard's Reconciliation of Darwin with Lamarck. "[Man] is nothing else than evolution become conscious of itself." In this arresting phrase, borrowed from Julian Huxley, Teilhard announces man's unique place in the process of evolution.[99] In other words, since evolution produced the human species, man's investigation of the process of evolution becomes the first instance in which the process examines itself and is aware of doing so.

Reflection, defined either as the passage of an organism from the conscious state to the self-conscious state,[100] or as the "squaring of consciousness" (consciousness of consciousness),[101] Teilhard takes to be the distinguishing characteristic of the human species. Man alone of all animals universalizes and foresees;[102] that is to say, man alone devises, tests, and modifies symbols to communicate, record, and predict his experiences.

It follows that, for Teilhard, scientific research becomes a specialized variety of evolution that moves, gropingly (*à tâton*), toward better biological adaptation. In that groping, evolution comes not only to self-awareness, but also to a measure of deliberate self-control.[103] "By reflecting on itself in man, therefore, evolution does not become merely conscious of itself. By the same act, it becomes in some degree additionally capable of directing and accelerating itself."[104] By producing man, the process has moved from pre-conscious to conscious self-determination, with the consequence that man becomes, through his knowledge of its past, partly responsible for the future outcome of evolution.[105] Thus the appearance of man and of human reflection, some hundreds of thousands of years ago, marked an evolutionary breakthrough second only to the evolution of life from inorganic matter. "With the 'squaring of consciousness,' nothing less than an entirely new kind of life (a second species of life) began its own special evolution on our planet in the Pliocene epoch."[106] To use still another of Teilhard's favorite metaphors, with the appearance of reflection, evolution rebounded[107] or enfolded[108] upon itself.

To support his thesis that evolution is "a cosmic movement folding in upon itself," Teilhard is willing to adopt provisionally either of two fundamental viewpoints: one materialistic, the other spiritualistic. An alternative third approach, based on a misreading of the Heisenberg principle of indeterminacy, turns out to be a variation on his spiritualistic account.[109]

Materialism may here be read as Darwinism. For in speaking of the materialistic approach, as in the instance above, Teilhard has in mind his version of the synthetic or biophysical theory of evolution: random molecular combinations naturally selected in the direction of generally increasing complexity and adaptation. He usually prefers, however, to translate the theory into the language of his own panpsychistic world view, according to which consciousness becomes a generalized term equivalent to the "within" of things. His translations of the synthetic theory in "psychistic" terms, however, often omit any reference to natural selection, and thus they overlook what is taken by the theory to be the principal determinant of evolution. In this way Teilhard can interpret the materialist or biophysical theory as implying "a continual increase of consciousness in the world consequent upon a continual increase in complexity (achieved by chance)"[110]—as if natural selection were not at all involved. This repeated oversight in his explanations of the biophysical theory will prove to be significant in shaping his own theory of evolution.

Not surprisingly, Teilhard credits the biophysical theory with its greatest success in explaining the origin of life from inorganic matter,[111] for on his theory the "radial energy" of consciousness gives no perceptible evidence of its existence at that level. He concedes, however, that well beyond that level biophysics continues to give an integrated and fairly comprehensive picture of evolution.

From the biophysical or materialist standpoint, for example, the correlation between consciousness and physical complexity, observed in the functions of the human brain, leads to the inference "that the phenomena of life and consciousness, until now so difficult to localize in the universe, might well be nothing else than the properties peculiar to matter when carried to very high degrees of arrangement and centration."[112] So also, from this point of view, human self-consciousness itself can be explained by "some ingenious, trick connection-and-arrangement of neurons that distinguishes the reflective brain of man from the non-reflective brain of the chimpanzee," let us say.[113]

Teilhard advances such biophysical explanations of consciousness, however, always with grave reservations. Acceptance of his own interpretations of it demands radical modification of the synthetic theory of evolution. Possibly certain of his cherished theological convictions are offended by what he takes to be the excessive materialism of the viewpoint. Be that as it may. From a purely scientific standpoint, his objections to the synthetic theory seem to rest upon a basic misunderstanding.

When arguing for modification of the synthetic theory, as we shall see, he characteristically contends that evolution cannot be the product of pure chance. However slight its bearing on the theory in question, the contention itself is correct enough. The odds against a purely accidental assembly of large numbers of atoms into the exact arrangement of any living organism, however simple, are astronomically high. Statistically, such an accident becomes virtually impossible. Yet the process of evolution had produced countless billions of individual organisms, the species of which alone number well into the millions. Teilhard has every reason to think that evolution is something other than a purely random process.

But why suppose, in the first place, that the biophysical theory pictures evolution as a purely random process? Yet despite overwhelming evidence to the contrary, Teilhard repeatedly states or implies that natural selection is a matter of pure chance.[114] His thesis is illustratively summarized as follows:

> Throughout a first and immensely long period (pre-life) chance alone, so far as we can judge, seems to have governed the formation of the first complexes. At a higher level (pre-human life) there stretches a wide, disputed zone in which, according to some (the neo-Darwinians), the weaving of the biosphere is again to be explained by *chance alone (automatically selected chances)*; according to others (the neo-Lamarckians) still by chance, but in this instance chance seized and used by a principle of internal self-organization.[115]

Teilhard errs when here and elsewhere he takes automatic or natural selection (applied to chance mutations or whatever) to be a synonym for pure chance. By way of historical background, the above summary was written by Teilhard in 1949. Its underlying assumption, that selection is a random process, overlooks the work done during the previous decades by Fisher, Haldane, and Wright; and it completely ignores the laboratory studies underlying their theoretic models. The biophysical theory, as Teilhard himself sometimes acknowledges, conceives selection to be at once determinate, directional, and directive. There is no evidence that the basic process is consciously purposive. There is, further, no need to invoke a supernatural Determiner or Director of evolution. For scientific purposes, the process of selection is the object of study and in itself explanation enough.[116]

The erroneous interpretation of natural selection as "evolution by chance alone" has become a neo-Lamarckian cliché.[117] Delsol's unfavorable critique of the synthetic theory, in his article on "The Mechanisms of Evolution," affords numerous examples of the cliché at work. His misunderstanding is repeatedly and vigorously challenged in parenthetical statements inserted into the article by editors of the English edition of the *Encyclopedia of the Life Sciences*[118]—a most unusual and revealing editorial procedure.

The *spiritualistic* of panpsychistic view of evolution is advanced by Teilhard,[119] then, as a neo-Lamarckian revision of Darwinian evolutionary theory.[120]

By opting for a neo-Lamarckian outlook, Teilhard joined a small and diminishing group of scientists who share the view that nutritional, informational, and other interchanges between an organism and its environment imprint new genetic instructions upon the chromosomes from which the next generation will be born. The theory holds, in other words, that any organism (phenotype), by its behavior in relation to its total physical and social environment, directly modifies the particular set of genes (genotype) received from its parents and transmitted to its offspring. More briefly, Lamarckism argues for the genetic transmission of characteristics acquired by the phenotype through use and development or disuse and atrophy of its organic functions. Teilhard himself contends, mistakenly, that the nesting and hunting activities of social insects clearly evidence genetic transmission of learned behavior at the prehuman level.[121]

Thanks in large part to his misunderstanding of natural selection, Teilhard's argument for a neo-Lamarckian transformation of Darwinism runs, on occasion, as follows: Neo-Darwinian biology, like Newtonian physics, accounts more or less adequately for a wide range of phenomena. But just as the discovery of atomic radioactivity necessitated the Einsteinian model in theoretical physics, so a proper evaluation of self-reflective consciousness demands a model of the universe more inclusive than the biophysical—a model reconstructed along neo-Lamarckian lines.[122] "So materialistic were the first evolutionists, it did not occur to them that their scientific intelligence had, in itself, anything to do with evolution."[123] Teilhardian theory differs from traditional Lamarckism in its forthright insistence on the central role of consciousness in the entire evolutionary process: "Consciousness is nothing less than the heart and substance of life in evolution."[124]

In revising the synthetic theory, Teilhard seeks to show that (1) all of the apparently random processes—atomic, molecular, and genetic—which provide the raw material for evolution are actually expressions of consciousness, and (2) the consequent process of selection, to some degree and at all levels, is also consciously purposive. He contends for this revision in much the same way that he argues for his singular views on the nature of energy.

He first observes that evolution overcomes the statistical odds against the occurrence of its highly complex combinations by "a multi-billion trial and error process"—a conclusion quite in line with the synthetic theory. He concedes, moreover, that until it reaches the level of human reflection, this process of groping (*tâtonnement*) appears to be quite unplanned and fortuitous.[125]

But if one takes, as he does, the Lamarckian position that learned characteristics are genetically transmissible, then the "fanning out" (*éventail*) of human ideas and institutions in the process of cultural evolution becomes itself a strictly "biological phenomenon," a form of biological mutation, in fact.[126] In the evolution of culture, or what he calls the weaving of the noosphere, evolutionary groping is marked by human "invention," that is to say, by purpose and inner direction.[127] By slurring over the differences between genetic and cultural process, he concludes that human invention "can legitimately be regarded as the extension in reflective form of the obscure mechanism by which each new form has ever sprung forth upon the tree of life." Invention becomes a synonym for both genetic and cultural trial and error (*tâtonnement*), and "the instinctive gropings of the first cell link up with the scientific gropings within our laboratories." He insists, moreover, that his reference to genetic mutation as a process of invention is "no mere metaphor, but an analogy founded in nature."[128] His spiritualistic alternative to materialistic Darwinism implies, therefore, "a continual increase of (planned) complexity, consequent upon a continual increase of (gradually emergent) consciousness."[129] He holds, in fact, that "the history of life is no more than a movement of consciousness veiled by morphology."[130]

This means, however, that selection no less than mutation is "biologically purposive," subject to free choice and inner direction.[131] Sometimes, in response to attacks upon his Lamarckism, he will concede that mutations proceed at random. But even then selection remains for him a psychic rather than a physical process. "It is really only through strokes of chance that life proceeds, but strokes of chance that are recognized and grasped—that is to say, psychically selected." After all, "if the tiger had elongated its fangs and sharpened its claws, is this not precisely because, in accordance with its line of descent, it has received, developed, and transmitted the 'soul of a carnivore'?" Lamarckian "anti-chance" is required, he argues, to supplement Darwinian random processes.[132]

Such words can be understood in their historical setting (1938) as a relevant protest against the earlier, widely current view that random mutations are sufficient to account for evolution. Yet later, when he has become acquainted with Simpson's work,[133] he continues to react so strongly against the obsolete mutationist view that he fails to grasp the concept of natural selection as the ordering and conserving factor in evolution. Thus as late as 1954, he still insists that "until we come close to man, the determinist driving force of mere natural selection can suffice, at a pinch, to account externally [i.e., physically] for the progress of life. But from the threshold of reflection onward at least—certainly no later, we must add to it, or substitute for it, the psychic power of invention, if we intend to explain the ascending progress of cosmic corpuscularization right up to its higher limits."[134]

Since Teilhard inclines always toward the view that genetic evolution and cultural evolution alike are biological processes depending invariably on invention (consciously purposive experimentation and selection) as their intrinsic source, we infer that the two processes are really to be taken as biological homologies, rather than as simple analogies. There is, however, no evidence that genetic evolution and cultural evolution possess precisely the same intrinsic cause and effect relationships. Lamarckism breaks down. On the evidence, the two processes are no more than loosely analogous, and inferences can properly be drawn from such analogies only with great attention to the significant differences.[135]

He really betrays his own case for treating genetic evolution and cultural evolution as homologous processes when he concedes that "In unthinking animals, we can only suspect this power of invention."[136] Suspicions and conjectures may guide research; they hardly constitute scientific evidence.

In summary, it is noteworthy that Teilhard does perceive evolution to be a process based on random mutation and conservative selection. In that general respect his views fall in line with prevalent evolutionary theory. His attempted synthesis of Darwinism with Lamarckism fails, however, in its account of the processes of mutation and selection. In effect, he himself acknowledges the failure: "In the present state of our knowledge, of course, we cannot dream of depicting the mechanisms of evolution in this interiorized, radial form."[137] The panpsychism underlying the synthesis has no more evidential support in biology than it has in thermodynamics. Likewise without confirming evidence is his central thesis that the phenotype acquires, by random probing of its environment, information that is genetically transmissible.

While the programs of research indicated by the biophysical theory of evolution are little more than well under way, the theory itself has already had remarkable confirmation, and it remains by all odds the most promising hypothesis for further exploring the processes of genetic mutation and consequent selection. It provides as well a sound theoretical basis for cautious exploration of analogies and differences between genetic and cultural transmission of information.

The Future Evolution of Man and the Cosmos

Evolution is orthogenetic, according to Teilhard, meaning that it is an integrated process moving basically in one direction only. He acknowledges that life tends to "ramify" in all directions. Evolution has consequently advanced by numerous "trials and errors," and these have indeed led to retrograde developments and even to the extinction of countless species. Yet he argues that the positive result of all evolutionary mutation and selection is a single thrust along one axis of movement. He proposes, moreover, to extrapolate past developments along that axis in order to predict the future course of evolution and thereby also the destiny of man and of the cosmos.

Argument for Orthogenesis. Teilhard's definitions of orthogenesis, and his arguments for it, are highly variable and ambiguous, owing chiefly to his unsuccessful effort to adapt Darwinian evolutionary theory to a Lamarckian framework. The arguments, in fact, characteristically and often expressly reflect his commitment to a Lamarckian point of view.[138]

In one of his latest essays (January 1955), he depicts orthogenesis as "directed transformation (to whatever degree and under whatever influence 'the direction' may manifest itself)."[139] As Simpson has noted, this definition could accommodate the biophysical theory of natural selection.[140] It could also just as readily accommodate Teilhard's theory that genetic mutation and selection are psychically predirected. A comparable ambiguity marks numerous earlier definitions of the term. Thus in 1938, he depicts it as "a law of directed complication that determines the culmination of that process in which we get first micro-molecules, then mega-molecules, and eventually the first cells." On the same page, he redefines it as "the manifest property of living matter to form a system within which terms succeed each other experimentally, following constantly increasing values of centro-complexity."[141] In 1947, he speaks of it as "a definite orientation regularizing the effects of chance in the play of heredity,"[142] and in 1951, as "the fundamental drift . . . toward corpuscular states ever more complex in their material arrangement, and psychologically more and more interiorized."[143]

As the context in every case makes clear, these definitions all imply what is sometimes also expressly stated; namely, that despite many false starts in its groping advance, the fundamental direction of evolution is along what he calls the axis of complexity/consciousness.[144] From that generalization, however, he leaps to the further conclusion that: "After the appearance of nervous systems, the axis of complexity/consciousness is usefully transposable into the axis of cephalization or cerebration."[145] That statement would seem to suggest that the single aim of evolution is to produce bigger and better brains. Teilhard himself supports the inference. "Considered in terms of the development of cerebral ganglia, life, all life, drifts more or less rapidly, but essentially like a single wave mounting always in the direction of larger brains."[146]

Evidence would seem to support his conviction that, since its first appearance, the total mass of brain matter within the biosphere has increased at an accelerated rate from one geological age to the next, either as a percentage of the biosphere itself or as an absolute quantity.[147] He clearly overrides the evidence, however, to reach even the tentative conclusion that "in the growing perfection and cephalization of the nervous system, we seem really to have a concrete and precise parameter" that allows us to perceive the absolute direction of evolution through the jungle of its living forms.[148] Yet with undaunted confidence he moves on from a tentative to an absolute judgment. "Among the infinite modalities in which the complication of life is dispersed, the differentiation of nerve tissue stands out . . . as a significant transformation. *It provides a direction, and consequently proves that evolution has a direction*."[149] He takes the development of brains to be the quintessential metamorphosis, the culminating phase of the whole evolutionary process.[150] He concludes, indeed, that "it is the nature of matter, when raised corpuscularly to a very high degree of complexity, to become centrated and interiorized, that is to say, to endow itself with consciousness. This means that the degree of consciousness attained by living creatures (from the moment, naturally, when it becomes discernible) may be used as a parameter to estimate the direction and speed of evolution (that is to say, of the cosmic coiling) in terms of absolute values."[151]

This view of evolution runs aground upon the fact that many of the most abundant species of organisms have neither nerve tissue nor brains. Teilhard anticipates and tries to meet this objection to his argument. "We obviously need not concern ourselves any more with the huge trunk of the vegetable kingdom," he declares. "They appear rather as the maid-servants than as the propagators of the ascent of life. In their vast domain there is nothing resembling nerves—and still less any cerebralization." In the same connection he also casually dismisses the coelenterates, the echinoderms, the sponges, and so on.[152]

Briefly, then, when he comes to apply this "parameter of cerebralization" to the process of evolution, Teilhard simply reads out of the evidence what he has previously read into it. Thus he discovers, *mirabile dictu,* that the axis of terrestrial evolution runs directly through the branch of the mammals,[153] more precisely through the order of primates, still more precisely through the family of anthropoids,[154] and specifically through the human species. He concedes that man can no longer be viewed as the center of the universe. But, on the alleged evidence that the central aim of evolution has been to develop brains capable of co-reflection, man becomes the "arrow" of the evolutionary process,[155] indeed, "the key to evolution,"[156] and its "only absolute parameter."[157]

On the basis of this conclusion and in support of it, for his argument is circular, Teilhard draws other sweeping generalizations about the orthogenetic character of evolution. As we have noted, he views the appearance of human reflection and the consequent weaving of the noosphere as processes in which evolution rebounds upon itself[158] in such a way as to become known to itself, self-directed, and self-accelerated. From the data underlying this suggestive metaphor, he makes three inferences: (1) In consequence of human co-reflection, mankind is a convergent species[159]—that is to say, human evolution tends toward ever increasing genetic and social integration, rather than toward biosocial isolation and consequent divergence. This tendency toward convergence, he holds, can be extrapolated toward a theoretically predictable endpoint of supra-reflection, called Omega.[160] (2) Human evolution provides a clue to the fact that cosmic evolution is also a convergent process[161] in which the entire universe moves toward point Omega. (3) The future evolution of man and of the cosmos will be determined principally by the mutation, selection, storage, and replication of cultural rather than of genetic information[162]—another conclusion shaped too largely by his Lamarckian and panpsychistic bias.

Parenthetically, his underlying argument for orthogenesis has been parodied by P. B. Medawar in a caustic review of Teilhard's major work, *The Phenomenon of Man.* "If we study the evolution of living things, organic evolution," he mimics, "we shall find that in every one of its lines, except only in those in which it does not occur, evolution is an evolution towards increasing complexity of the nervous system and cerebralization."[163] One should add that Dobzhansky and Huxley, among others, have conceded to the argument more than Medawar's caricature allows.[164] Moreover, Teilhard's case for orthogenesis is further clarified by his efforts to project from the history of evolution its future course. Any further appraisal of his general theory calls, therefore, for an examination of those predictions.

Future Evolution of Man and of the Cosmos. The cosmic drift toward complexity/consciousness, Teilhard holds, has so far produced no single organism more complex or more extensively conscious than the reflective human individual.[165] Individual reflection (consciousness of consciousness) was the original singularity of the human species.[166] Reflection, however, is a social as well as an individual phenomenon. The present singularity of the species is co-reflection—consciousness socially organized in the many languages and other institutions of human culture and civilization, including recent phenomenal advances in the sciences and in technology.[167] By extrapolation, he argues that the same orthogenetic process of complexification and psychic interiorization is both compelling and impelling mankind toward a biological paroxysm in which the species will become completely synthesized into a single biopsychical and ultrahuman organism, capable of ultrareflection or superconsciousness.[168]

Toward the end of the nineteenth century, he observes, Western civilization gave every indication of culminating in an individualism so radical as to threaten extinction of the species through fragmentation. The phylum was fast becoming a mere aggregate of self-centered individuals, lacking a "sense of the species," pressed by their expanding numbers into internecine strife for control of territory and natural resources. "This was the age of the rights of man (i.e., of the 'citizen') against the collectivity. The age of democracy, simplistically conceived as a system in which everything is for the individual and the individual is everything. The age of the superman, envisioned and awaited as one who would stand forth in solitude above the common herd."[169] Yet even at that time, he adds, there were signs that hominization was entering its second and semifinal phase of rapid socialization and totalization.

To describe the coming bio-social convergence of human consciousness, and its predicted consequences for cosmic and human evolution, Teilhard draws upon a variety of ponderous terms—several of his own invention. In his predictions he makes repeated use of such concepts as anthropogenesis,[170] collectivization,[171] hominization,[172] mechanization,[173] personalization[174] (eventuating eschatologically in supra-personalization[175]), socialization,[176] totalization,[177] and unanimization.[178]

There are two opposed estimates of this trend toward social convergence, he grants, one pessimistic and the other optimistic. On the first view, planetary collectivization is a brutally mechanizing and dehumanizing process. On the second, it is the mark and effect of biological superarrangement destined to ultrapersonalize us. On either view, he holds, there is no escape for us, for we are involved in a cosmic process.[179] "Beneath the obvious banality and superficiality that marks the technico-social exploitation of earth's resources, we see evolution itself, with its orientation toward the improbable, as it prolongs and accelerates itself beyond our little individual centers in the direction of a complexity/consciousness that is planetary in scope."[180]

When the facts are viewed shortsightedly, he concedes, the prophets of doom seem to be justified. They predict the rapid exhaustion of the food and industrial resources of the earth and proclaim the leveling and disappearance of the rich varieties of human culture. They point to warring nationalisms and to the mechanization of individual values and viewpoints not only by managed information but by our indispensable socioeconomic institutions as well.[181] At close range there is no missing the ugliness, vulgarity, pollution, and human servitude that have attended the growth of industrialism. Further, despite our efforts to extirpate it by the surgery of World War II, totalitarianism remains a terrifying and ever growing menace. Finally, the disquieting examples of the beehive and the anthill remind us that evolutionary socialization can lead to an enslavement from which the human species is by no means immune.[182] These and similar alarming symptoms "justify up to a point the instinctive reaction of apprehension and recoil that evidently drives so many human beings, faced with an inexorably mounting totalization of the noosphere, to take despairing refuge in now outmoded forms of individualism and nationalism."[183] While conceding that the validity of his own estimate of the trend still has not been absolutely demonstrated,[184] he argues that from a scientific viewpoint totalization proves to be a continuation of the same benign biological process that brought us into being.[185]

By his own declaration, he intends no metaphor when he insists that the forces of civilization are identical with those of biological evolution. "Natural evolution and cultural evolution are but one."[186] He holds, in fact, that the formulation of this identity has for biology a significance comparable to that of the equations of Lorenz and Einstein for modern physics.[187] Thus he takes socialization, "technification," and scientific research to be simply prolongations of biological evolution along the axis of complexity/consciousness.[188] He even speaks of improved communication and co-operative research as producing a "gray matter" of the species, a "noospheric brain—the organ of collective human thought."[189] Collectivization becomes for him "an irresistible physical process."[190]

Viewed in this perspective, "the progressively more complete industrialization of the earth is nothing other than the humano-collective form of a universal process of vitalization that can only lead to interiorization and freedom, provided we know the right way in which to approach it."[191] Naturally our hearts rebel at the prospect of a bourgeois Golden Age that promises no more than abundance and consequent euphoria.[192] Yet "nothing is more unfair or more useless than to protest and fight against the increasing leisure towards which the machine is inexorably leading us."[193] The right approach to industrialization, then, is to treat it as a case of biological groping raised to the level of scientific research, reflectively adaptive not only to human survival but also to the highest possible human well-being.[194]

What is called for is faith in the enfolding evolutionary process, for we ourselves are caught up in the game, and we help to determine its outcome. "Depending upon whether or not we have faith in it [*croirons*], the totalizing process, from which there is no escape, will either infuse new life into us or destroy us."[195]

Further information about the process, he insists, will allay many of our fears. The anthill model of social organization, for example, becomes less terrifying when we remember the difference between men and social insects. The psychisms of insects are mechanistic, i.e., genetically determined instinctual drives; the psychism of man is "unanimizable," i.e., capable of motivation by reflective insight responding to universal principles of intelligibility, meaning, and value.[196]

He coined the terms "unanimize" and "unanimization" to suggest that human social integration, when it proceeds according to the inherent logic of increasing complexity/consciousness, has an affective, as well as an intellective, aspect.[197] For on his view human co-reflection unifies not only by intellection, but by *conspiration* (sympathy)—a passionate aspect that comes to highest expression in a sense of the species.[198]

Knowledge of the difference between men and insects, alone, is not enough to save us from totalitarianism. We find Teilhard proposing, as of 1945, that we are in no position fairly to judge whether the recent totalitarian experiments produced, on balance, a greater degree of enslavement or a higher level of spiritualization. He ventures, however, that "in so far as these first attempts may have tended dangerously toward the sub-human regime or state of the anthill or termitary, it is not the principle of totalization itself that is at fault, but only the blundering and incomplete way in which it has been applied."[199] He later decides that the net results of Communism and of National-Socialism are ghastly. He suggests, however, that monstrous as it is, modern totalitarianism is a distortion of something magnificent and quite near the truth.[200] For totalization, as distinct from its totalitarian distortion, by nature both differentiates and personalizes what it unites.[201] Man's problem is to bring his action into conformity with its demands.

In his "Sketch of a Personal Universe," Teilhard proposes to construct a model of the physical universe around the human person selected as the one element typical of the whole cosmic system. He pledges to complete the project without straying from the realm of scientific fact.[202] In at least two later essays, entitled "Human Energy,"[203] and "The Human Rebound of Evolution,"[204] he takes other purportedly scientific approaches to essentially the same project. His panpsychistic Lamarckism leads him to the conclusion that the process of personalization constitutes, not a metaphysical, but a physical boundary condition analogous to space and time.[205] He finds, in fact, that the degree of its personalization (*degré de personalité*) or, what adds up to the same thing, the degree of its centration (*centréité*) provides the sole parameter by which we can measure the "absolute biological value" of any subsystem in the evolutionary process.[206]

He proceeds to the rhetorical question: "What name, in accord with our system, should be given to this physico-moral energy of personalization to which all the activities manifested by the stuff of the universe are to be finally reduced?" Subject to a sufficient extension of its meaning, the answer is love.[207] In this extended meaning, "and from the point of view of physics, love is an expression of the interior face of that affinity which attracts and binds together the elements of the whole world, *center to center*."[208] At the pre-living and pre-human levels, this bonding is not strictly love. It is rather an obscure intersympathy which is transformed into love at the level of human reflection.[209] But if there were no propensity to unite at the level of the molecule, it would be physically impossible for love to appear at a higher level in hominized form.[210]

From such language it is possible to infer a reduction of human love to biophysical terms. Teilhard's meaning, however, is rather in the direction of an idealistic vitalism, even toward spiritualism. From his point of view, in fact, "there is nothing in the universe except Spirit in various states or degrees of organization of plurality."[211] That is to say, physical energy is psychic energy materialized.[212]

He takes love at the human level in three meanings: the sexual, the human (or societal), and the cosmic.[213] It is inexact, he observes, to regard the individual "thinking monad" as constituting the universe in microcosm. The "complete human molecule" comprises the masculine and feminine sexual couple—something more complex and hence more spiritual than the individual person."[214] The law of increasing complexification determines in turn that "the couple will find internal equilibrium only in a third who lies ahead of them." The one ahead to whom the sexual couple looks for completion, however, is not so much the child of that union as it is point Omega, the center in which all persons will find eventual fulfillment. Thus it turns out that love is a relationship among three parties: man, woman, and God. Incidentally, Teilhard's understanding of sexual purity gives further indication of his Catholic background. "The world is divinized, not by suppression, but by sublimation."[215]

As the microcosmic unit, however, the sexual couple is set amid a society of persons. "Hence the energy of personalization manifest in passionate love must be completed by another attraction, that draws the totality of human molecules each one to all the others. This cohesive attraction is love in the human sense."[216] "Nothing is precious except what is thine in others and what is theirs in thee."[217]

Human love in the cosmic sense he defines as that more or less vague affinity that binds us psychologically to the whole in which we are enveloped.[218] Thus both sexual and societal love find their completion in cosmic love.

But love in its cosmic meaning, we are repeatedly told, is manifest universally, not simply in the human species. Love energizes the evolution of the cosmos.[219] "Drawn by the forces of love, the fragments of the world seek each other out in order that the world may actually come to pass. Physical energy is but the reverse face, the shadow, of love.[220] Hence love of this sort "is a love that constructs the universe physically"[221] and moves it toward its consummation.

Point Omega. That the universe will eventually come to focus in a single point, Omega, remains a hypothesis.[222] The hypothesis, Teilhard also concedes, has still to be consolidated by further scientific investigation. In discussing the characteristics of that universal focus, he moves admittedly into the frontiers of science where we are still not sure of our way.[223] On the other hand, he implies that the evidence from which his predictions are extrapolated compares favorably with the evidence supporting Lemaître's hypothesis that the universe originated from a primordial atom, or cosmic egg.[224] Viewing his work in this way, he further insists that these extrapolations from the sciences with reference to point Omega constitute no metaphysics, but only an "ultraphysics,"[225] by which might be understood a sober and compelling scientific speculation.

His "experimental law of recurrence," otherwise called the law of complexity/consciousness, yields by extrapolation a variety of characteristics theoretically attributable to Omega. Chief among them are personality, autonomous individuality, partial actuality, partial transcendence,[226] and a most important fifth attribute, that of irreversibility.

First, *personality*. He argues that (1) centreity is what makes beings personal and (2) Omega is supremely centered and hence consummately personal.[227] The question remains: Personal in what sense?

Second, *autonomous individuality*. The mechanism of complexification and centrogenesis determines that no higher organic whole can emerge in the evolutionary process, according to Teilhard, unless it both respects and fulfils the centric potentialities of the elements upon which its own complexity is founded[228]—a conclusion, by the way, which strictly speaking rules out the possibility that a totalitarian state could ever arise! Cosmic evolution as a whole is working out in the human species a project in personalization. If the process is moving toward an impersonal collective, however, it will depersonalize us—destroy rather than fulfil our potentialities as persons. Hence it follows that Omega must be in the true sense a person,[229] "possessing its own proper ego, distinct from ours."[230]

The dynamics of love, Teilhard argues, also require that Omega shall be a person. It is a descriptive law of integrative evolution that union (i.e., synthesis) differentiates and personalizes what is united.[231] The universality of this law means, however, that evolution is energized by love; for neither force nor obligation, but love alone can personalize and superhumanize.[232] "But there is no true love in an atmosphere, however warm, of an impersonal collective. Love can neither be born nor stabilized, unless it finds a heart and a face." The psychic mechanism of an enfolding cosmos points ultimately, he again concludes, not to a centered system of centers, but to a Center of centers[233]—in other words, to a Person.[234] He even goes so far as to say that, on condition that the Whole is identified in the only place and under the only form in which it actually exists—namely, in point Omega—"The Whole alone is ultimately and fully personal."[235]

Omega is *partially actual*—capable, that is to say, of acting upon us now as a present reality.[236] Central to Teilhard's understanding of evolution is the thesis that the convergence of the human species is only now under way; its totalization is still in process. This view suggests that Omega may be only a recurring historical possibility, and never a securely permanent actuality. Against that conclusion he demurs: "For its maintenance and functioning, the noosphere *physically* requires the existence within the universe of a real pole of psychic convergence: a Center different from all the centers which it super-centers by assimilating them to itself; a Person distinct from all the persons whom it fulfills by uniting them. The world would not function if there did not exist somewhere ahead of time and space a cosmic point Omega of total synthesis."[237] Unhappily, Teilhard makes no effort to explain scientifically what it means to predicate existence beyond space and time.

Omega is *partially transcendent,* that is to say, partially independent of the evolution that culminates in it.[238] Immanent in the process, indeed. But under its evolutive aspect, Omega discloses but half itself. "While standing as the last term in the series, it is at the same time outside all series."[239]

Finally, Omega is *irreversible.* By Teilhard's definition, any process is reversible if it comprises only a precarious arrangement of particles that by nature are liable to disintegrate.[240] A discredited vitalism underlies his argument for Omega's irreversibility—the notion that "a taste for life" is the mainspring that moves and directs the universe along its principal axis of complexity/consciousness.[241] "If the pole of psychic convergence toward which matter gravitates, in the course of arranging itself," he argues, "were nothing other, or nothing more, than the totalized, impersonal, and reversible grouping of all the grains of cosmic thought reflected momentarily in one another—then the world's enfolding upon itself would succumb in self-disgust, in exact step with evolution's becoming more clearly aware, as it advanced, of the dead-end toward which it was heading."[242] Or as he puts the argument elsewhere: "In a universe that has become conscious of the future, the cosmic enfolding would be arrested immediately, by the within, before the despairing eventuality of total death."[243] Consequently, Omega must be irreversible and imperishable. Any other alternative involves the absurdity of a universe that has succeeded in giving birth to reflection, only to discover itself powerless to satisfy requirements for the fulfilment of that to which it has given birth.[244] "To satisfy the ultimate requirements of our action, Omega must be independent of the collapse of the forces of which evolution is woven."[245]

Noteworthy, in view of his proposal to synthesize theology and the sciences, is the ambiguity of Teilhard's language in reference to point Omega and the processes leading to it. Sometimes his language suggests that hominization, communalization, or totalization, whatever it be called, is precisely an aspect of evolution itself. Those of his propositions which work in this way meet the formal requirements, at least, of a method consistent with his endeavor to construct a "scientific" theology. He can even speak of the "cosmic movement of complexity/consciousness that creates us,"[246] and often seems to imply that some aspect of evolution is man's only possible creator and redeemer.

In context, however, his propositions take on a far more traditionally theological cast, as he himself makes quite plain. An anonymous critic, taking exception to his evolutionary theology, attacked him in a pamphlet entitled *L'évolution rédemptrice du Père Teilhard de Chardin.* Curiously enough, a hasty bibliographer of Jesuit works attributed the pamphlet to Teilhard himself. In a rejoinder in *Études,* Teilhard disclaimed authorship and went on to say:

The title itself is sufficient to show how hopelessly [the author] has misunderstood me. He implies that in my view the cosmic future will have some sort of immanent saving virtue in itself, whereas in everything I have written, I have always insisted that the redeeming properties of evolution must flow from a personal and transcendent Christic center. . . . He could hardly miss the point more completely.[247]

It is true that he insists upon viewing God from an evolutionary point of view. "God is no longer conceivable (either structurally or dynamically) except in so far as . . . he coincides (without becoming confused) with the Center of cosmogenetic convergence. For if God did not now appear to us in this exact and supreme point at which nature is even now becoming knit together before our eyes, our capacity for love would inevitably gravitate no longer toward him (absurd situation), but toward another 'god'."[248]

God for him is the eschatological goal toward which, according to his argument, evolution is demonstrably moving. Yet he explicitly repudiates the inference that his theology attributes to evolution "an immanent saving virtue." Inconsistent with his scientific approach to theology? Indeed! The same inconsistency leads him to reject the conclusion, implicit in his phenomenology, that from a scientific point of view God must be identified with the creativity of the evolutonary process as such. His predictions with reference to point Omega emphatically are not extrapolated from the prevailing biophysical interpretation of evolution. They revive an outmoded neo-Lamarckian vitalism and are determined more by a Christian supernaturalism than by scientific evidence.

He freely admits that his conceptions have been largely influenced by dogmatic Christian theism. In an epilogue to *The Phenomenon of Man,* for example, he exults:

The universe fulfilling itself in a synthesis of centers in perfect conformity with the laws of union. God the Center of centers. In that final vision Christian dogma culminates. So exactly, so perfectly does this correspond with point Omega that doubtless I should never have ventured to envisage the latter, or to formulate the hypothesis rationally, except that I had found in my consciousness as a believer not only its speculative model but also its living reality.[249]

Then, too, he implies that his identification of the Christ of revelation with the Omega of evolution was at first a mere hunch, confirmed in subsequent scientific investigation.[250]

There is no objection, of course, to a support of religious faith by scientific evidence. The synthesis is embarrassed, however, by the fact that Teilhard deceives himself as to what constitutes scientific evidence. He persuades himself, for example, that man's distaste for even the remotest prospect of total death constitutes "very strong proof" that the evolutionary process will ultimately and absolutely triumph over the second law of thermodynamics.[251] Against such pseudo-science he himself raises the devastating objection: "Since when," he asks, "can our desires have become a measure of reality?"[252] Yet he proceeds as though he had answered the question merely by raising it. The question becomes in fact its own answer. He actually supports the thesis of an irreversible Omega by contending that: "Ultimately the best guarantee that a thing should happen is that it appears to us as vitally necessary." He makes this contention, moreover, in a major essay which he insists is to be read "purely and simply as scientific treatise."[253]

In the same essay he tries to show that man's dissolution at death is only an illusion. Immortality becomes for him another biological singularity of the human species:

> By death in the animal the radial is reabsorbed into the tangential, while in man the radial escapes and is liberated from the tangential. It thus escapes from entropy by returning to Omega, which becomes the hominization of death itself. . . . One by one all around us, like a continual exhalation, souls are breaking away, bearing upwards their incommunicable burden of consciousness.[254]

Here again Teilhard insists upon an intimate relationship between Christian faith and his understanding of the biological sciences:

> From the Christian point of view (which coincides in this respect with the biological viewpoint appropriately carried out to the conclusion implicit in its requirements) the engathering of the Spirit, gradually accomplished in the course of the spiralling of the universe, occurs in two tempos and by two stages—by slow "evaporation" (individual deaths); and simultaneously, by incorporation into the collective human organism (the mystic body) whose maturation will be completed only at the end of time through the Parousia.[255]

He recognizes the gulf that separates his work from that of his fellow scientists. In the course of an argument that the life sciences require the postulate of an irreversible evolutionary process, he faces up to the scientific implications of his thesis:

I am as well aware as anyone of the fantastic element in these prospects to which our spirit finds itself impelled by this fundamental need. The ultimate break-up of the partnership complexity/consciousness, to release in the free state a thinking without brain. The escape of some part of the *Weltsoff* from entropy (see fig. 17). All this, in the eyes of science today, seems impossible to accept. But on the other hand how can we deny the possibility that it is true without at the same time stopping the ascending movement of the entire world (by disactivation, I repeat) in its human leading shoot?[256]

Yet clearly he regards his own work as initiating a revolution in the contemporary life sciences, and he rests his case upon his theory that evolution is essentially a spiritual process in the course of which radial energy (technically, information) is moving toward a pure state in which it will be completely dissociated from energy in all other forms.[257] Whatever their status in Catholic dogma, extrapolations such as these have scientific standing only in science fiction.

The significance of the Teilhardian synthesis, however, can by no means be measured solely by the inadequacies of its scientific foundation. In the first place, the official ban against publication of those works setting forth the synthesis probably magnified their influence in Catholic circles, after Teilhard proceeded to circulate them privately despite the ban. Furthermore, his bold proposal to translate the Gospel in evolutionary terms stirred up a discussion that helped both to prepare the way for Vatican Council II and to move Catholic theology toward the twentieth century. Let American Protestants be not proud, for tolerance of evolutionary theory is but recent among them—evidence the Scopes trial in Tennessee in the third decade of this century.

The very strictures under which Teilhard worked serve in part to measure the success of his pioneering effort. That the following words from the encyclical, *Humani Generis,* for example, were promulgated by Pius XII as late as August 12, 1950, seems now in the light of intervening events to be almost incredible:

The teaching of the Church leaves the doctrine of Evolution an open question, as long as it confines its speculations to the development, from other living matter already in existence, of the human body. (That souls are immediately created by God, is a view which the Catholic faith imposes on us.) In the present state of scientific and theological opinion, the question may be legitimately canvassed by research, and by discussions between experts on both sides. At the same time, the reasons for and against either view must be weighed and adjudged with all seriousness, fairness, and restraint; and there must be a readiness on all sides to accept the arbitrament of the Church, as being entrusted by Christ with the right to interpret the Scriptures and the duty of safeguarding the doctrines of the faith.[258]

Finally, the synthesis is not wholly without scientific merit. Harsh reviews of it, such as those of Medawar and Simpson,[259] are partially balanced by the restrained approval of other outstanding scientists, among them Dobzhansky, Huxley, and Needham,[260] who commonly stress that his work should be read as that of a poet and mystic, as well as a scientist.

With all his poetry and mysticism, Teilhard remains a consistent evolutionist, always viewing man as a participant in the process and subject to its laws.[261] Further, his insistence on orthogenesis never obscures the fact that evolution entails both mutation and selection. Although he lacked familiarity with modern biology,[262] he brought to evolutionary theory from paleontology a needed holistic emphasis. As Dobzhansky notes, the method of reducing scientific data to their microstates has great intrinsic merit and has yielded enormous dividends. The odds, however, are against the successful reduction of all biological —let alone psychological and sociological—phenomena to chemical and then to physical terms, mainly because the results would be so cumbersome as to be meaningless. There is still continuing need to balance reductionistic approaches by organismic ones.[263] To the latter Teilhard makes a contribution in evolutionary theory.

The singular significance of the abortive Teilhardian synthesis, however, is the very undertaking to establish scientific foundations for a naturalistic theology. Teilhard in fact thoroughly compromises his often announced intention to remain within a scientific frame of reference. Consequently he evades the very conclusions implicit in an adequately scientific approach to such a project. Yet despite all of this he manages to suggest the guidelines for a theology based on the recognition that mutation and natural selection, and the evolutionary direction produced by their operation not only have created man, but have determined as well the conditions under which man must work out his historical destiny.

Amendment of the synthesis, to bring it closer into line with Teilhard's announced intention, requires first a reconstruction of its scientific foundations in conformity with prevailing evolutionary theory. That reconstruction entails the following major surgery: (1) Abandon an ultimately dualistic theory of energy, and accept instead a monistic theory in line with quantum mechanics, thermodynamics, and information theory. (2) Abandon Lamarckism, and accept the synthetic or biophysical account of evolution as a process of random genetic mutation and consequent natural selection—constituting at most an autocatalytic, self-programming process of innovative or dynamic homeostasis.[264] (3) Abandon the notion that evolution is orthogenetically predirected toward a single form of life. (4) Acknowledge that man's future in the evolutionary process depends on the interplay between genetic and cultural evolution, but recognize, also, with Alfred Emerson and others, that genetic and cultural processes are biological analogies and not, as Teilhard supposes, biological homologies.[265] (5) Abandon the thesis that evolution is demonstrably aware of its own processes elsewhere than in man. (6) Abandon the idea that cultural evolution is about to produce a new species of men, existing as minds without brains and as souls without physical bodies, totally integrated in a point Omega defined as the scientific equivalent of the Second Person in the Christian Trinity.

The question then becomes: What are the theological consequences of retranslating Christian theism from a biblical into such a contemporary scientific world view? This much is clear at once. In any such translation, mutation and consequent selection function, both in biological systems and by analogous extension in cultural systems, as the God that created us and that sets the conditions within which individually and collectively we must work out our salvation or damnation. What such a view of God means for religious faith and for our systems of value needs further exploration from many quarters, scientific and theological.

More can be said about God, of course, than can be said from the self-limited perspective of the sciences. Let it be said. But if we ignore the inexorable demands placed upon us by the processes of mutation and of natural selection, or if we scorn those processes as monstrously threatening and wasteful, we thereby commit ourselves to unwitting abuses of technology and culture—abuses which will dehumanize our species and hasten the extinction of all life upon the earth.

NOTES

Citations of primary sources are made wherever possible in reference to the collected works of Teilhard de Chardin, Éditions du Seuil, for the complete listing of which see the Teilhardian bibliography elsewhere in this issue. Roman numerals specify volumes, arabic numerals the pages in the French edition. Arabic numerals in parentheses indicate corresponding pages in the English translation. Unless otherwise specified, translations of texts cited are my own.

1. Teilhard de Chardin, "Le Dieu de l'évolution," p. 1 of the typescript deposited in the Hammond Library, Chicago Theological Seminary, by George Crespy. This essay is scheduled to appear in the standard edition of his posthumous publications, *Oeuvres* (hereafter "*Oe.*"), Vol. XI, *Christianisme et Evolution* (Paris: Seuil).
2. From a letter of January 1, 1951, in part as quoted by Claude Cuénot, *Teilhard de Chardin, a Biographical Study* (Baltimore: Helicon Press, 1965), p. 273.
3. "Esquisse d'un univers personnel" (1936), *Oe.*, VI, 113.
4. *Ibid.*
5. From a letter of March 6, 1952, in part as quoted by Cuénot, *op. cit.*, p. 355.
6. *Oe.*, II, 298, n. 2 (211, n. 1).
7. *Ibid.*, VIII 38 (27).
8. Cf. his letter of May 18, 1954, in Cuénot, *op. cit.*, p. 369.
9. Letter of January 31, 1953, *ibid.*, p. 345.
10. *Oe*, V, 143, n. 1 (110, n. 1). Cf. *Oe*, VII, 105, and VI, 111.
11. *Ibid.*, III, 306 (217).
12. For the French word, *conscience*, there is no precise equivalent in English.
13. *Oe.*, I, 52–54 (56–57).
14. *Ibid.*, VIII, 34 (23). Cf. also II, 363, n. 1 (265, n. 1).
15. *Ibid.*, I, 51 (55).
16. *Ibid.*, I, 57 (60–61).
17. See *ibid.*, I, 62 (64).
18. Letter of April 11, 1953, to Claude Cuénot, as quoted by the latter, *op. cit.*, pp. 255–56. See also the excerpt from a letter of April 18, 1953, *ibid.*, p. 348.
19. See *Oe.*, VII, 105–6; VI, 111; III, 306 (217).
20. *Ibid.*, VI, 111.
21. *Ibid.*
22. Compare *ibid.*, I, 21–22 (29–30).
23. See the footnotes referred to in *Oe.*, I, 22, n. 1 (29, n. 1).
24. *Ibid.*, I, 22 (30).
25. *Ibid.*, I, 21 (29).
26. *Ibid.*
27. *Ibid.*, II, 296–97 (209–10).
28. *Ibid.*, II, 304 (215).
29. See *ibid.*, II, 363–64 (265–66).
30. Cf. *ibid.*, II, 298–321 (210–30); I, 180–210 (164–90); VIII, 67–80 (47–57); V, 279–82 (218–20).
31. *Ibid.*, VIII, 151–52 (105); I, 276–78 (248–50); V, 209–10 (162–63); and "On Visiting the Cyclotron," Cuénot, *op. cit.*, 342–43.
32. *Ibid.*, II, 173–74 (124–25), 322–37 (230–44); VIII, 150–60 (104–12); V, 208–10 (161–64), 317–24 (245–49).
33. *Ibid.*, I, 300–302 (270–72).
34. *Ibid.*, II, 340 (246).
35. *Ibid.*, II, 323, fig. 4 (232, fig. 19); 338–66 (244–69); I, 268–303 (257–72); VIII, 161–67 (112–17); V, 155–56 (122–23).
36. *Ibid.*, II, 368 (269).
37. "Le Dieu de l'évolution" (see n. 1 above) (typescript, p. 4). Cf. also *Cahiers Pierre Teilhard de Chardin* (Paris: Seuil, 1965), p. 23.
38. See Henry A. Bent, *The Second Law* (New York: Oxford University Press, 1965), p. 40.
39. Compare Rudolph Clausius, "Ueber die bewegende Kraft der Wärme und die Gesetze, welche sich daraus für die Wärmelehre selbst ableiten lassen," *Annalen der Physik und Chemie*, LXXIX (1850), 368–97; 500–524.
40. See Bent, *op. cit.*, p. 40.

41. See Norbert Wiener, *Cybernetics* (Cambridge, Mass.: M.I.T. Press, 1961 edition), pp. 64–65.

42. Theodosius Dobzhansky, *The Biology of Ultimate Concern* (New York: New American Library, 1967), p. 108.

43. Robert Bruce Lindsay, *The Role of Science in Civilization* (New York: Harper & Row, 1963), pp. 290 ff.

44. *Ibid.*, pp. 153 ff.

45. Erwin N. Hiebert, "The Uses and Abuses of Thermodynamics in Religion," *Daedalus*, XCV (1966), 1051. Compare Eddington's comment as reported in Bent, *op. cit.*, p. 308.

46. Lindsay, *op. cit.*, pp. 292–93; cf. Erwin Schrödinger, *What Is Life?* (Garden City, N. Y.: Doubleday Anchor Books, 1956), pp. 67–73.

47. R. Clausius, "Ueber verschiedene für die Anwendung bequeme Formen der Hauptgleichungen der mechanishen Wärmetheorie," *Annalen der Physik und Chemie*, CXXV (1865), 400: "Die Energie der Welt ist Constant. Die Entropie der Welt strebt einem Maximum zu."

48. *Oe.*, II, 318 (228).

49. *Ibid.*, VII, 344, n. 1.

50. *Ibid.*, II, 363, n. 1 (265, n. 1).

51. *Ibid.*, I, 60–64 (63–66).

52. *Ibid.*, I, 63 (65).

53. *Ibid.*, II, 363, n. 1 (265, n. 1).

54. *Ibid.*, I, 62 (64).

55. *Ibid.*, II, 363 (265).

56. *Ibid.*, I, 62, n. 1 (65, n. 1).

57. *Ibid.*, I, 63 (65).

58. I am indebted to P. B. Medawar for this illustrative insight into Teilhard. See his review of *The Phenomenon of Man*, in *Mind*, LXX (1961), 103.

59. These calculations, based upon a formula derived from L. Brillouin, *Science and Information Theory* (New York: Academic Press, 1956), were carried out by Donald R. Gentner, a biophysicist and Fellow of the Center for Advanced Study in Theology and the Sciences for 1967–68.

60. See, e.g., *Oe.*, III, 361 (254).

61. *Ibid.*, II, 263, n. 1 (265, n. 1).

62. *Ibid.*, VIII, 45 (32).

63. See Isaac Asimov, "Over the Edge of the Universe," *Harper's Magazine*, CCXXXIV (March, 1967), 97–106.

64. *Oe.*, I, 63 (65–66).

65. *Ibid.*, VII, 352.

66. *Ibid.*, II, 303, fig. 2; 357–66 (216, fig. 17; 260–68).

67. *Ibid.*, 262 (264).

68. *Ibid.*, VII, 127, n. 1.

69. Compare the critique of the Teilhardin "energetics" in George Gaylord Simpson, *This View of Life* (New York: Harcourt, Brace & World, Harbinger edition, 1963), pp. 227–28.

70. *Oe.*, II, 297 (210).

71. For a brief introduction to the history of the Lamarckian-Darwinian controversy, see Simpson, *op. cit.*, pp. 42–62 *et passim.*

72. The influence of Lucien Cuénot is acknowledged in *Oe.*, I, 145–46 (134–35), and correspondence preserved by Claude Cuénot, son of the biologist and Teilhard's biographer. See Cuénot, *op. cit.*, pp. 273–74. On his debt to Bergson, see Julian Huxley's Introduction to *The Phenomenon of Man* (New York: Harper & Row, 1959), p. 22, and Teilhard's letter of February 23, 1953, to Huxley, quoted by Cuénot, *op. cit.*, p. 304.

73. Among outstanding early expositions of the synthetic theory are those by Sir Julian Huxley, *Evolution: The Modern Synthesis* (London: Allen & Unwin, 1942), and George G. Simpson, *Tempo and Mode in Evolution* (New York: Columbia University Press, 1944). Simpson, in *This View of Life,* pp. 63–84 and 206–12, briefly summarizes the theory, and in the appendixes, pp. 290 and 299, suggests additional literature on the subject. Principal contributors to the theory are listed in Simpson, *The Meaning of Evolution* (New Haven, Conn.: Yale University Press, 1949), p. 277.

74. Cf. P. B. Medawar, *The Future of Man* (New York: New American Library, Mentor, 1959), pp. 86–87.

75. See, e.g., *Oe.,* I, 163, n. 1, only part of which is translated into the English (149, n. 1); also VIII, 49, 155–57 (35, 108–9).

76. *Ibid.,* I, 29 (35).

77. For example, *ibid.,* I, 77–178 (77–162); II, 299–312 (211–22); VIII, 25–112 (17–78).

78. Cf. *ibid.,* II, 299 ff. (211 ff.).

79. *Ibid.,* II, 299–304 (211–15).

80. *Ibid.,* II, 300 (212); cf. V, 278, n. 1 (217, n. 1).

81. See Hans Gaffron, "The Origin of Life," in Sol Tax (ed.), *Evolution after Darwin* (Chicago: University of Chicago Press, 1960), I, 39–82.

82. See George Beadle and Muriel Beadle, *The Language of Life* (Garden City, N.Y.: Doubleday & Co., 1966); Theodosius Dobzhansky, *Heredity and the Nature of Man* (New York: Harcourt, Brace & World, 1964); Alan Garen, "Sense and Nonsense in the Genetic Code," *Science,* CLX, April 12, 1968, 149–59.

83. See Beadle and Beadle, *op. cit.,* pp. 177–80.

84. *Ibid.,* pp. 211–13; Dobzhansky, *Heredity,* pp. 35–36; and Gaffron, *op. cit.,* pp. 78 ff.

85. Cf. Dobzhansky, *Heredity,* pp. 16 ff.; Beadle and Beadle, *op. cit.,* pp. 96–106.

86. Thomas Hunt Morgan, *The Physical Basis of Heredity* (Philadelphia: J. B. Lippincott Co., 1919).

87. Cf. Dobzhansky, *Heredity,* pp. 17–20. For reference to comparable anomalies in human genetics, see *ibid.,* p. 123.

88. Cf. Beadle and Beadle, *op. cit.,* pp. 118–19, 193, 197, 225–31.

89. Cf. Dobzhansky, *Heredity,* pp. 121–24.

90. See *ibid.,* pp. 119–21.

91. See Ronald A. Fisher, *The Genetical Theory of Natural Selection* (Oxford: Clarendon Press, 1930), pp. 70–120; John B. S. Haldane, *The Causes of Evolution* (London and New York: Longmans, Green & Co., 1932), pp. 83–110, 171–215. For a summary of these results, with special reference to the work of Sewall Wright, see Simpson, *Tempo and Mode,* pp. 65–96.

92. See Simpson, *This View of Life,* pp. 74–75.

93. Michel Delsol, "The Mechanisms of Evolution," *Encyclopedia of the Life Sciences;* trans. from the French (Garden City, N.Y.: Doubleday & Co., 1965), II, 32 and n. 5.

94. Fisher, *op. cit.,* pp. 76–78, 94.

95. See Alfred S. Romer, "Major Steps in Vertebrate Evolution," *Science,* CLXVIII (1967), 1629–37.

96. See Bernard Rensch, "The Laws of Evolution," in Sol Tax (ed.), *Evolution after Darwin,* I, 95–116.

97. Simpson, *This View of Life,* p. 208.

98. See *ibid.,* pp. 207–12.

99. *Oe.,* I, 244 (221).

100. *Ibid.,* VII, 352.

101. *Ibid.,* II, 313–14 (224–27).

102. *Ibid.*

103. Cf. *ibid.,* VIII, 151–57 (105–9); III, 329–30 (234–35); I, 248 (224).

104. *Ibid.*, II, 350 (254).
105. Cf. *ibid.*, I, 251 (226).
106. *Ibid.*, II, 317 (227); cf. I, 336–37 (303).
107. *Ibid.*, II, 217–26 (157–64), 317 (227); V, 251–71 (196–213); VIII, 154 (107), 159–60 (111).
108. *Ibid.*, VIII, 48 (34); I, 336 (302).
109. *Ibid.*, VIII, 49 (34 f.).
110. *Ibid.*
111. *Ibid.*, VIII, 155–56 (108); see also I, 336 (302–3).
112. *Ibid.*, II, 302 (214).
113. *Ibid.*, II, 316, n. 2 (226, n. 2).
114. See, e.g., *ibid.*, I, 163, n. 1 (149, n. 1); 336 f. and n. 1 (302 f. and n. 1); V, 257–59 (200–201).
115. *Ibid.*, VIII, 155–56 (108) (italics mine). The same argument is expanded in V, 257–59 (200–201). See also VIII, 173, n. 1 (121, n. 1).
116. See, e.g., Simpson, *The Meaning of Evolution*, p. 278; and Dobzhansky, *Heredity*, pp. 125–27.
117. Cf. Simpson, *This View of Life*, pp. 52–53, 179.
118. Delsol, *op. cit.*, *passim.*
119. See *Oe.*, VIII, 48 (34).
120. See *ibid.*, V, 257–59 (200–201).
121. *Ibid.*, II, 333 (240); cf. also *ibid.*, V, 209 and n. 1 (163 and n. 1); I, 164 (150–51).
122. Cf. *ibid.*, I, 51–52 (56–57); and VIII, 25–26 (17–18).
123. *Ibid.*, I, 243 (220).
124. *Ibid.*, I, 197 (178).
125. *Ibid.*, I, 336 (302).
126. See *ibid.*, I, 247 (223); and II, 335–37 (242–44).
127. *Ibid.*, V, 257–58 (200–201).
128. *Ibid.*, I, 248 ff. (224 ff.); cf. III, 221–22 (157–59).
129. *Ibid.*, VIII, 48 (34).
130. *Ibid.*, I, 184 (168).
131. Cf. *ibid.*, V, 257–58 (200–201).
132. *Ibid.*, I, 163, n. 1 and 164 (149, n. 1, and 150).
133. See *ibid.*, II, 335, n. 1 (242, n. 1).
134. *Ibid.*, VIII, 49 (35).
135. Compare Alfred E. Emerson, "Dynamic Homeostasis: A Unifying Principle in Organic, Social, and Ethical Evolution," *Scientific Monthly*, LXXVII, No. 2 (1954), 67–85; reprinted in *Zygon*, Vol. III (June, 1968).
136. *Oe.*, II, 349 (253) (1954); compare the earlier (1938) *Oe.*, I, 163, n. 1 (150, n. 1).
137. *Ibid.*, I, 165 (151).
138. See *ibid.*, 172–73 (123–24); III, 259 ff. (253 ff.); V, 256–58 (199–201) and 271 (212).
139. *Ibid.*, III, 384, n. 1 (261, n. 1).
140. Simpson, *This View of Life*, p. 229.
141. *Oe.*, I, 114 and n. 1 (108 and n. 1).
142. *Ibid.*, V, 204, n. 1 (158, n. 1).
143. *Ibid.*, VIII, 131 (90).
144. See *ibid.*, II, 304 (215); III, 389 f. (272 f.).
145. *Ibid.*, II, 304 (215). Compare *ibid.*, 195–96 (139).
146. *Ibid.*, IX, 199; cf. VIII, 158 (110).
147. *Ibid.*, II, 309 (220).
148. See *ibid.*, II, 196 (139).
149. *Ibid.*, I, 158 (146).
150. *Ibid.*, 165–66 (152).
151. *Ibid.*, V, 279 (218).

152. *Ibid.*, VIII, 70–72 (49–50).
153. *Ibid.*
154. *Ibid.*, 78 (55).
155. *Ibid.*, I, 249 (224).
156. *Ibid.*, III, 96 f. (66 f.).
157. *Ibid.*, VIII, 21 (15).
158. See pp. 275–91 above, and *Oe.* II, 217–26 (157–64), 317 (227); V, 223 (176 ff.), 251–71 (196–213); VIII (111).
159. *Oe.*, VII, 335–53. See also I, 267–68 (241–43); II, 338–66 (244–68); III, 193, n. 2 (138, n. 2); V, 317–36 (244–59), 371 ff. (284 ff.); VII, 331–32, 373–77; VIII, 158 ff. (110 ff.); IX, 248.
160. See, for example, *ibid.*, II, p. 323, fig. 4 (232, fig. 19).
161. *Ibid.*, V, 67 (46); VII, 214–19, 232–33, 295–309; VIII, 25–53 (17–36); 144–160 (100–112).
162. Cf. *ibid.*, III, 374, n. 1 (263, n. 1); V, 209–10 (162–63).
163. Medawar, in *Mind* (see n. 58 above), pp. 102–3.
164. See Dobzhansky, *Heredity*, pp. 151 ff., and *The Biology of Ultimate Concern* (see n. 42 above), pp. 108–37. See also Huxley, "Introduction," pp. 15 ff.
165. *Oe.*, II, 339 (245).
166. *Ibid.*, II, 312–21 (222–28); cf. *ibid.*, VIII, 89–112 (61–78).
167. *Ibid.*, II, 322–37 (230–44); cf. *ibid.*, 168 (119); 173–74 (125); 216 (156); VI, 71–89; VIII, 115–33 (79–92); 139–60 (96–112).
168. *Ibid.*, II, 338–66 (244–68); VIII, 161–73 (112–21).
169. *Ibid.*, VIII, 135–36 (94); cf. *ibid.*, 139–40 (96–97).
170. *Ibid.*, II, 173–74 (125); V, 341–42, 371–72 (262, 285); VIII, 19–20 (14–15).
171. *Ibid.*, V, 146 f. (113 f.); 161 ff. (126 ff.); 248 (194), 320 (245), 330 (254).
172. *Ibid.*, III, 75–112 (51–79); V, 255, 257 (198, 200); 294–98 (228–31); 380–81 (292).
173. *Ibid.*, V, 296–98 (229–31).
174. *Ibid.*, V, 265 (207); VI, 75–89; VIII, 139–73 (96–121).
175. *Ibid.*, VI, 180; cf. VIII, 161–67 (112–17).
176. *Ibid.*, I, 308–17 (277–85); 338–41 (304–7); II, 168 (119); 174 (125); 327–32 (235–39); III, 373–74 (262–63); 329 f. (234 f.); V, 58–60 (39–40); 63–65 (43–44); 208–10 (161–63), 271 (212), 282–85 (220–23), 329–30 (253–54); VI, 165–71; VIII, 115–24 (79–82); 139–73 (96–121).
177. *Ibid.*, I, 285–86 (257); II, 322 (230), 326 (234), 329 (237); V, 325–36 (249–59); VIII, 139–73 (96–121).
178. *Ibid.*, II, 352–56 (253–59); V, 365–74 (281–88).
179. *Ibid.*, V, 330 (254).
180. "Le Christique," scheduled for publication in *Oe.*, X (typescript, p. 4).
181. Cf. *Oe.*, II, 326 (234).
182. *Ibid.*, V, 325–26 (250).
183. *Ibid.*, VIII, 145–46 (100–101).
184. *Ibid.*, V, 330 (254).
185. See *ibid.*, VIII, 146–50 (101–4).
186. *Ibid.*, V, 393 (301).
187. *Ibid.*, III, 374 (263).
188. Cf. *ibid.*, V, 297–98 (231), and 257 (200).
189. *Ibid.*, II, 158–60 and n. 1 (110–11 and n. 1).
190. *Ibid.*, V, 161 ff. (126 ff.).
191. *Ibid.*, VIII, 151 (105).
192. *Ibid.*, V, 394–95 (303).
193. *Ibid.*, VIII, 150–51 (104).
194. *Ibid.*, VIII, 151–54 (105–7). Cf. V, *op. cit.*, 394–95 (303).
195. *Ibid.*, V, 333 (257).

196. Cf. *ibid.*, VIII, 145, n. 1 (101, n. 1); and V, 60 (40); 330 (254).
197. *Ibid.*, II, 352–56 (255–59); V, 365–74 (281–88).
198. Cf. *ibid.*, II, 352–53 (255, 257); and VI, 189–90.
199. *Ibid.*, V, 151–52 (118–19).
200. *Ibid.*, I, 285 (257).
201. Cf. *ibid.*, V, 330 (254).
202. *Ibid.*, VI, 70.
203. *Ibid.*, VI, 143–200 (August, 1937).
204. *Ibid.*, V, 251–71 (196–213) (September, 1947).
205. *Ibid.*, V, 265 (207).
206. *Ibid.*
207. *Ibid.*, VI, 90.
208. *Ibid.*, VII, 77.
209. *Ibid.*, VII, 125.
210. *Ibid.*, I, 294 (264).
211. *Ibid.*, VII, 132.
212. *Ibid.*, VII, 127–28, n. 1.
213. *Ibid.*, VI, 91 ff.
214. *Ibid.*, 93.
215. *Ibid.*, 94–95.
216. *Ibid.*, 97.
217. "Le Coeur de la matière" (typescript, p. 41).
218. *Oe.*, VI, 101.
219. *Ibid.*, VII, 126.
220. *Ibid.*, I, 294 (264–65).
221. *Ibid.*, VI, 90.
222. *Ibid.*, VIII, 166 (116); cf. "Le Christique," (typescript, p. 8).
223. *Oe.*, IX, 247.
224. *Ibid.*, VIII, 165–66 (115–16).
225. *Ibid.*, VI, 111; VII, 105–6.
226. *Ibid.*, VII, 103–134. The list varies. See also *ibid.*, I, 278–303 (268–72); and VI, 172–81.
227. *Ibid.*, VIII, 118.
228. *Ibid.*, VII, 118, 122 ff.
229. *Ibid.*, VI, 176–80.
230. *Ibid.*, VII, 118.
231. *Ibid.*, VII, 122–24; cf. V, 74 (53).
232. *Ibid.*, VII, 126.
233. "Comment Je Vois" (typescript, p. 14).
234. *Oe.*, VI, 176–80.
235. *Ibid.*, VII, 125.
236. *Ibid.*, VII, 118.
237. *Ibid.*, VI, 180; cf. I, 299–300 (269).
238. *Ibid.*, VII, 119.
239. *Ibid.*, I, 301 (270).
240. Cf. *ibid.*, VIII, 172 (120, n. 1).
241. *Ibid.*, VII, 243; cf. *ibid.*, 348.
242. *Ibid.*, VIII, 172 (120–21).
243. "Comment Je Vois" (typescript, p. 13).
244. *Oe.*, VI, 175–76.
245. *Ibid.*, I, 300 (270).
246. "Le Dieu de l'évolution" (see n. 1 above) (typescript, p. 4).
247. From Cuénot, *op. cit.*, p. 272.
248. "Le Dieu de l'évolution," p. 2.

249. *Oe.*, I, 328 (294).
250. Cf. "Le Christique" (n. 180 above), p. 8; and section II, above.
251. *Oe.*, III, 238, n. 1 (170, n. 1); cf. II, 359–64 (262–66).
252. *Ibid.*, II, 359 (262).
253. *Ibid.*, I, 259 (234); see also *ibid.*, 21 (29).
254. *Ibid.*, I, 302–3 (272).
255. *Ibid.*, V, 285, n. 1 (223, n. 1).
256. *Ibid.*, II, 362 (264). The translation is that of J. M. Cohen.
257. *Oe.*, II, 361–64 (264–66).
258. Translation from Anne Freemantle (ed.), *The Papal Encyclicals in Their Historical Context* (New York: New American Library, Mentor Religious Classics, 1956), p. 287.
259. Medawar, *op. cit.*, pp. 99–106; Simpson, *This View of Life*, pp. 224–32.
260. Theodosius Dobzhansky, *Mankind Evolving* (New Haven, Conn.: Yale University Press, 1962), pp. 347–48; also Dobzhansky, *Heredity*, pp. 151–52, 171; and *The Biology of Ultimate Concern*, pp. 114–37. See Huxley, "Introduction," and his tribute to Teilhard quoted by Cuénot, *op. cit.*, 303. See also the review of *The Phenomenon of Man* by Joseph Needham in *New Statesman*, 1959, LVIII, 632 ff.
261. Cf. Dobzhansky, *The Biology of Ultimate Concern*, p. 137.
262. Cf. Dobzhansky, *Mankind Evolving*, p. 347.
263. Dobzhansky, *Heredity*, pp. 75–77.
264. See Emerson, *op. cit.* (n. 135 above).
265. See *ibid.*