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THE COMBINATORIAL HIERARCHY - AN APPROACH TO OPEN EVOLUTION*

Pierre Noyes
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

A unified scientific philosophy based on evolutionary principles which can provide a framework within which physical, cosmological, biological and cultural evolution are described in the same terms could help meet the planetary crisis we face. The combinatorial hierarchy approach to basic discrete and sequential physical processes, which incorporates the essential evolutionary features of conserved information and selection in the presence of a random, novelty-producing background is proposed as a candidate for this framework, and briefly explained. Recent work shows that many aspects of particle physics and cosmology can be systematically understood in this way. A normative principle, based on the derived fact of a fixed past and uncertain future characterized by responsible moral choice is proposed as consistent with--but not derivable from--this philosophy.

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Ever since the classical work of Darwin and Wallace it has been clear that the biological evolution of increasingly complex systems can be understood in terms of "descent with modification" achieved through "natural selection." Descent implies a stable connection between past systems and their progeny. The source of modification was unknown until the discovery of mutation and the subsequent demonstration that mutations are in some sense both discrete and random. Since then "natural selection" can be viewed as selection for stability among a finite number of possibilities (or, more precisely, selection for a statistically determined distribution among these possibilities if we introduce the concept of a "quasi-species" [Eigen, 1979]) in the presence of a random background. Departure from this stable state in biological systems occurs primarily, perhaps invariably, due to the geographical isolation of small populations and subsequent "genetic drift"--the magnification of the consequences of statistical fluctuations in small number systems. Once this has gone far enough the process is irreversible.

The principles on which evolution is now seen to be based are more general than their origin in biology. Physical systems--galaxies, stars, planets, chemical complexes...--can also evolve in an irreversible manner. Since planetary surfaces set the stage for biological evolution, the evolution of these surfaces superimposes a secular change on the conditions for biological stability and hence becomes another source of evolutionary complexity. The differentiated biosphere can couple back into the physical conditions at the surface of the planet, as our oxygen atmosphere attests, yielding a still more complicated hierarchical pattern. As the ecology becomes more complex, social structure becomes an increasingly significant factor in biological adaptation and evolution. Because of the significant contribution of material culture to social evolution, particularly for our own species, the rate of change exponentiates and has reached such explosive proportions as to threaten the surface of the planet itself. In trying to assess the limits and potentials of this process--whether for example it should be viewed as a wildly aberrant statistical fluctuation, or as the start of a new level of hierarchical organization in which the immaterial, or "spiritual," aspects may be dominant and pregnant with transcendental consequences--we need a unified scientific philosophy into which the evolutionary generalizations arrived at first in separate disciplines can be integrated. In this paper we sketch how the combinatorial hierarchy approach to basic physical processes might possibly provide such a philosophy.

Although the advent of quantum mechanics, and more recently molecular biology, have provided much insight into the details of both cosmological and biological evolution, the quantum theory itself did not fit comfortably into the mechanistic background of nineteenth century physics. Even more than the theory of relativity, the facts uncovered by quantum mechanics have forced radical changes in our ways of thinking about the "physical world." Despite its technical success, this theory has left some physicists and many philosophers with an uncomfortable feeling that some basic unifying idea is still missing. The combinatorial hierarchy of [Bastin, 1966] was originally constructed as an attempt to model the development of hierarchical systems based on a single, discrete process called "discrimination." The initial aim was to find a structure with a small number of levels of rapidly increasing complexity; it was a surprise that the cardinal number sequence so generated (3, 10, 137, [$(256)^2$], $2^{127}-1 \approx 10^{38}$) is quantitatively close to the "scale constants" of physics describing superstrong, strong, electromagnetic [weak], and gravitational interactions. More recently it has been shown [Bastin, 1979] that the quantum numbers generated in this way can be interpreted at the first three levels as those corresponding to the conservation of charge, baryon number, lepton number and spin. By means of a more general "Theory of Indistinguishables" [Parker-Rhodes, 1978] in which the combinatorial hierarchy occupies a prominent place, Parker-Rhodes was led to a calculation of one of the best known numbers in physics--the proton-electron mass ratio--in uncanny agreement with experiment. Recent unpublished work [Bastin, 1980] provides a systematic approach to these developments which we summarize here.

The basic notation used to represent the hierarchy consists of strings of the existence symbols "0" and "1", of finite length. A string of nulls (0,0,0,....,0) represents nothing, so a string which contains at least one "1" (which we sometimes call a "Schnur," the German word for string) can be thought of as "the absence of nothing" [Thomas, 1979]. The basic process by which alone this approach attempts to explore the complexity of the universe is <u>discrimination</u> between Schnurs. Discrimination between two identical Schnurs yields nothing (i.e., the null string (0,0,..,0)). Discrimination between two different

Schnurs yields a third which is different from either. Technically this is achieved by adding the existence symbols of each (ordered) string elementwise (i.e., $(x_i)_n + (y_i)_n = (x_i + y_i)_n$) using addition mod two defined by $0+0=0$, $0+1=1$, $1+0=1$, $1+1=0$.

The condition needed for stabilization against a random background, which together with some discrete basis like that introduced above is an essential part of the structure needed for secular evolution, is called "discriminate closure." A set of Schnurs (of the same finite length n) is discriminately closed if (a) it contains only one Schnur or (b) if discrimination between any two Schnurs in the set yields a third (distinct) member of the set. We will give examples shortly.

All of this may sound hopelessly abstract as a basis for physics, let alone biology. We obviously need some point of contact with experiment before we can go on into the problems with which we started. But, if we are to achieve our aim of a unified theory, this point of contact can be made only once; the rest of the structure must then follow as a deductive consequence of our principles. The point of contact we choose is untraditional in terms of the historical route to quantum mechanics. We locate it in the scattering process between elementary particles as exemplified in practice in high energy experimental physics. Such processes, because of momentum and (asymptotic) energy conservation require a minimum of two particles in and two particles out to be observed. For n distinguishable particles the minimum number of "scattering amplitudes" or "exit channels" for a description of the scattering process is the number of ways n distinguishable objects can be partitioned into two clusters, namely $2^{(n-1)}-1$. One fascinating recent discovery about the hierarchy is that a closely related result emerges prior to the point at which we can talk about energy-momentum conservation, or even space-time. We now try to show this happens.

Suppose we start with the single Schnur (1). Discriminated against null it persists (1+0=1). Discriminated against a second Schnur we get null (1+1=0). So we can't "get off the ground." This is connected with the conventional result that there are no single particle scattering processes: $2^{(n-1)}-1=0$ for $n=1$, in particulate language we would say that an isolated particle persists unchanged, and that in an assemblage of completely identical particles with no structure, nothing changes. So we must start with $n=2$.

If we consider the two Schnurs (10) and (01), they generate by discrimination a third; (10) + (01) = (11). But taking additional Schnurs from our postulated random background, we also have the processes (11) + (10) = (01) and (11) + (01) = (10). Hence any two of the three possible Schnurs generates the third. We have found the discriminately closed subset, or DCsS, {(11), (10), (01)}; according to the definition above any one of the single Schnurs is itself a DCsS. To construct a hierarchy from this elementary starting point, we assume that these DCsS are the basic entities from which the second level is to be constructed. To be a proper basis, they must be linearly independent. For instance, at this first level (10) + (01) + (11) = (00), so only two of them are linearly independent; which two we choose as a basis doesn't matter. Similarly, as a basis for the second level, in addition to the

DCsS constructed above with three members, we can take any two singletons {(10)} and {(01)}, or {(11)} and {(10)}, or {(11)} and {(01)}; the third singleton is not linearly independent of the other two. To prove this, and to prove that any two are linearly independent of the DCsS with three members, we would have to introduce the concept of mapping, which would take us too far into the mathematical details for a paper of this length. The interested reader is referred to [Bastin, 1979] for these details. Here all we will use is the fact that the first level of the hierarchy contains three, and only three, linearly independent discriminately closed subsets, independent of the specific representation used.

Now we relate this result to particulate language. For $n = 2$ we could indeed talk about a $2^1 - 1 = 1$ scattering amplitude. But the conventional theory which allows us to talk in this way presupposes a "background"--for example, particle detectors--which allows us to register a change in state between the initial and the final situation. The two particles themselves do not suffice to provide this background. We have already seen that by discrimination we can generate a third system distinct from either. Does this suffice to provide the needed background? The answer is no, as we can illustrate both in classical and in quantum particle mechanics.

The classical paradigm we consider is two gravitating particles. If their total energy is positive, they approach each other and recede on hyperbolic orbits. If the total energy is negative, the two particles are bound in elliptical orbits, as in planet-star, planet-satellite, double star, ... systems. Counting the two particles as two and the bound system as the third, we have an abstract model for the situation of the three Schnurs of the lowest level. But in the classical model, it is impossible to get from the hyperbolic to the elliptical situation without the intervention of a fourth system.

The quantum mechanical situation is a little more subtle. There, thanks to the uncertainty principle in energy, we can have a "virtual" transition from two particles to the bound state ($2 \to 1$) or the breakup of the bound state ($1 \to 2$), but neither process can be observed asymptotically, e.g., as counts in spatially separated detectors, without the intervention of a fourth particle to satisfy the momentum-energy conservation laws in the asymptotic state. The transitions in which two combine to form a third are indeed abstractly modeled by the DCsS with three Schnurs at the lowest level, but we must assume such processes to be unobservable according to our interpretive postulate. Note also that discriminate closure makes this level stable in the presence of a random background.

The manner in which the construction of the combinatorial hierarchy meets the condition of observation, without doing violence to our unifying postulates, is profound. We must have at least two levels for a process to be observed. Because of the stability and linear independence of the first level, we can use three abstractly discrete, but not yet observed, discriminately closed subsets to construct a second level with $2^3 - 1 = 7$ discriminately closed subsets. The details of the construction have been spelled out [Bastin, 1979].

At this point it is convenient to view the existence symbols in the Schnurs as representing dichotomous quantum numbers. Then at the first level (10) could be for example a positive meson, (01), a negative meson and (11) the externally neutral combination of the two. When we go to the next level both the construction and our physical interpretation require us to use Schnurs of length $n = 4$; the two new positions could be interpreted as due to the introduction of a second dichotomous quantum number. Here the subtlety of the hierarchy construction enters with force. If we considered Schnurs of length four without restriction, we would have fifteen non-null possibilities. The requirement that the second level preserve the information about discriminate closure contained in the first level, together with its stability against a random background, restricts us to seven of these. If we now turn to particulate language, we find that these seven DCsS can be put into one-to-one correspondence with the $2^{4-1} - 1 = 7$ scattering amplitudes, or two cluster decompositions, of four distinguishable particles. Thus, although we can indeed think of a second independent dichotomous quantum number, we must think of only four of the fifteen possibilities as "elementary," and only the seven DCsS, or scattering amplitudes, constructed from some choice of these four, as forming the basis for the third level. As an example, we could take the second dichotomous variable as baryon number, and the four basic "particles" as a positive baryon, a negative antibaryon, a neutral baryon and a neutral antibaryon. Taking as a basis any three of these that include both possibilities of charge and baryon number we can then form three mesons, which are positive, negative or neutral. Now that we can have two exit clusters which differ from two entrance clusters we are in a position to view these processes as an abstract model of actual laboratory events. Of course such events require in practice a much more complicated "background" of description than the quantum number flow predicted by the hierarchy. But sequential processes exhibiting these quantum number flows are in fact observed.

To construct the third level of the hierarchy we use seven discriminately closed and linearly independent subsets from level two to form $2^7 - 1 = 127$ discriminately closed subsets at level three represented by Schnurs of length 16. These bring in two new dichotomous variables which we can take to be lepton number and spin. The rules by which we relate the existence symbols in the Schnurs to the quantum numbers [Bastin, 1979] guarantee that within these three levels all four discrete quantum numbers are conserved in any sequence of discriminations, so our interpretation connects the hierarchy to the four basic conservation laws--charge, baryon number, lepton number, and spin--on which all of elementary particle physics rests. Further, the construction requires that we have existence symbols in at least nine of the 16 positions in the basic Schnurs, which necessarily introduces an asymmetry between at least one of the dichotomous variables and the others. The compelling way to interpret this is that the eight basic particles which generate the $2^{8-1} - 1 = 127$ scattering amplitudes, and which (a general theorem) can be put into one to one correspondence with the 127 DCsS of level three, are the proton, neutron, and electron each with two spin states, a left-handed neutrino and a right-handed antineutrino. These are the stable (if we view the neutrons as constituents of nuclei) particles which suffice for atomic and nuclear physics up to the electron-positron pair production threshold of slightly over a million electron volts. While we cannot claim to have derived this interpretation as an inescapable consequence of the hierarchy construction, the fact that the construction supports such an interpretation, and more particularly that we are sure that some dichotomous variable will have to be treated asymmetrically, puts us in a strong position compared to conventional theories where the rigorous symmetry between particles and antiparticles makes it hard to understand why we live in a matter universe rather than in a statistical mixture (at sufficient separation) of matter and antimatter.

To go from these abstract ideas to the actual calculation of scattering amplitudes and comparison with experiment is still beyond us, but we can see a road which may lead us to this technically articulated theory. A clue of profound importance as to how to proceed is provided by Parker-Rhodes' [1978] calculation of m_p/m_e. In this he starts from abstract indistinguishables and the semantics needed to discuss them, and arrives at an articulated scheme which he connects to physics by different interpretive postulates than ours. Within this scheme he makes a statistical calculation of the mass of the electron as due to its electrostatic energy in such a way as to obtain the dimensionless ratio in full (eight significant figure) agreement with experiment. We have provided a rationalization of that calculation within the framework of the ideas developed above [Bastin, 1979], which gives us confidence that the dynamical scheme needed for a rigorous derivation of the result can be achieved. But first we must go from the abstract scattering amplitudes discussed above to the construction of some discrete equivalent to space-time! (Note that we reject from the outset any concept of an *a priori* continuum background independent of the basic discrete discrimination processes; for us "space-time" could at most be a mathematical convenience approximating a discrete theory, never a fundamental physical idea.)

A possible route from discrete statistical distributions to "space-time" is suggested by some unpublished work due to Stein [1978]. He shows that by looking at a "random walk" problem in terms of both sequential and "spatial" averages in a certain way, he can "derive" both the Lorentz transformation and the de Broglie wave packet spreading. The critical point in obtaining a limiting "velocity" for the Lorentz transformation is using the fact that probabilities are bounded by unity. To get from this to the "wave packet spreading" then involves an average reminiscent of Feynman's "sum over histories." Starting from this clue, Jones [1979]claims to have derived both the Lorentz transformation and the uncertainty and de Broglie relations (*without* showing that the "wavelength" refers to a repetitive phenomenon) in terms of arbitrary statistical distributions. While there appear to be technical difficulties with the proof [Kilmister, 1979], this looks like a promising route to pursue. It would allow us to identify the dimensional constants c and $\hbar$ with abstract mathematical constants in the theory.

Further, the quantum number interpretation developed above leaves us little doubt as to where the stable proton enters the formalism, and fixes the third dimensional constant m_p. Then the Parker-Rhodes calculation of m_p/m_e gives us a "floating yardstick" of known length. Before we can lay this out repetitively and actually measure macroscopic lengths by counting, however, we must first complete the hierarchy by constructing level four.

The construction proceeds as before. Using 127 linearly independent and discriminately closed subsets of level three, we obtain 127 linearly independent Schnurs of length 256. From these we can construct $2^{127} - 1 \approx 10^{38}$ discriminately closed subsets. However, since there are at most $(256)^2$ linearly independent mappings available, we can no longer continue the construction. Thus the hierarchy terminates with the fourth level. According to our interpretive postulate, this means that the systems whose description requires quantum numbers beyond those of baryon number, lepton number, charge, and spin <u>cannot</u> be stabilized. Thus we are allowed to say we have provided a framework for understanding why only the eight fermions listed in the discussion of level three are stable, and all other structures, obtainable from these by the materialization of energy as in high energy physics experiments, are ephemeral. Hence our scheme incorporates already at the elementary particle level both the basic stability of a finite number of entities and the random instability of more complicated structures. Note also that without referring to the "background" first encountered at level four, we cannot say whether we are dealing with particles or antiparticles; the latter, in isolation are just as stable as the former, which is our version of the CPT theorem. At level four we also have indications of SU_2, SU_3, and SU_6 structure from the construction, but these have yet to be worked out in detail. It is comforting that we know in advance that any of these higher symmetries will have to be incomplete, or "broken," which is the experimental situation, and that they will have a "weak" instability, again in accord with the facts.

If the program outlined above can be articulated, at this point we will have in hand abstract "Feynman diagrams" describing complicated elementary particle processes in terms of quantum numbers which can be identified in the laboratory, a sequential mesh of discriminations which satisfies a discrete version of the Lorentz transformations. If we have indeed also the de Broglie relation, we can go from this to the discrete version of special relativistic momentum-energy conservation. Further, now we are at level four, we can have internally in the diagrams points where particles and antiparticles "annihilate" to produce nulls, asymptotic energy and momentum being conserved by still further particles. The next step is to identify these nulls with nodes in a "wave function" and show that they are repetitive. The next step is to then identify some processes with the initiating events in "counts in detectors," and hence to show how interference patterns can be measured. An operational analysis of the "double slit" experiment using essentially only these ingredients, and which can easily be viewed as a macroscopic distance measurement, has already been provided [Noyes, 1979a]. Thus we see a route by which quantum mechanics can be reconstructed starting from the basic concept of discrimination and discriminate closure; whether this program will succeed lies in the uncertain future!

We are now in a position to understand more clearly why the connection pointed out by Bastin [1966] between the cumulative cardinal numbers of the hierarchy and the scale constants of physics comes about. Since our guiding postulate is stability against a random background, it is consistent for us to assume "equal a priori probability" in the absence of additional information. This "absence of additional information" restriction has particular force for us because of the constructive and recursive nature of our theory. At the first level we have already seen that there are only three possible scattering amplitudes or processes. Since there can be no additional structure in the absence of additional information, each of these processes has probability, or squared coupling constant 1/3, the "superstrong" constant to be assigned when we can specify only one dichotomous variable.

This system might seem too devoid of structure to have any exemplification, and indeed we have shown already that it cannot be observed until we embed it in level two. But there is a relevant paradigm in the relativistic "zero range scattering theory" developed by the author [Noyes, 1979b], starting from quite different considerations. The system considered is described by a single dichotomous variable, which we will call the particle-antiparticle dichotomy. It is shown that _if_ the particle and antiparticle have the same mass (CPT theorem for structureless particles) _and_ the particle and antiparticle bind to form a quantum again of the same mass _then_ the "bootstrap" requirement that the quantum and particle (or antiparticle) bind to form a "three body bound state" of the same mass as the particle (or antiparticle) is self-consistent independent of any dynamical considerations. Once this self-consistency requirement is met, it does not matter whether we start with particle and antiparticle, particle and quantum, or quantum and antiparticle, the same system results. In a random background each of the three possibilities will have the same "coupling constant" and each system will be present with the same probability. We see that in abstract terms this model provides a precise exemplification of the lowest level of the hierarchy.

At level two we might think that with seven scattering amplitudes we should assign a probability or scale constant of 1/7. Indeed if we started with three independent constituents, as does Enquist [1979], guided by "quark" ideas, this would be correct. He shows in this way that the 3 - 127 two level hierarchy can generate structures reminiscent of SU_2 and SU_3; he also discovers a better phenomenological mass formula for certain baryons than those achieved by more conventional approaches. But this two level structure is not sufficiently rich to describe the observed universe. From our own basic principles we can only reach the linearly independent basis of three by starting from the first level of the hierarchy construction. Then we can no longer claim the "absence of additional information." Further, because both levels are stabilized and we must go to level three in order to provide a "background" to differentiate between them (just as we must go to level two in order to count the three elements of level one), we cannot at level two assign any other scale constant than 1/10.

We note that this scale constant is quite consistent with the charge-baryon number interpretation of the first two dichotomous variables we used illustratively above. If we think of the nuclear force as mediated by pions, we would expect a scale constant of .08 = 1/12.5 rather than 1/10, so our result is not quantitatively reliable. But this is not surprising, since at level two we only have a generalized meson which cannot yet be identified with the pion. The m_π/m_p ratio of 1/7, which we can only hope to compute at a higher level, is at least of the right order as an estimate of the discrepancy between the two numbers.

If we now go on to level three we have 127 amplitudes. Once again these could only be counted at level four, and distinguished from the 3 amplitudes of level one and the 7 of level two in that richer context. Hence the proper scale constant to assign is 1/137. This is now a good first approximation to the electromagnetic scale constant, and comes in at the point where we have independent indications that we should be talking about neutrons, protons, electrons, and neutrinos. It also appears at the correct place for us to be able to interpret the Parker-Rhodes m_p/m_e calculation [1978]. Once we go on to level four we will be under the obligation to show that we can assign this constant to both electrons and neutrinos in a way consistent with the results achieved by the Weinberg-Salam weak-electromagnetic unification. We must also show that the corrections, anticipated to be of order $1/(256)^2$, will change 1/137 to the empirical value of the fine structure constant. Using $1/(256)^2$ is itself not a very good estimate of the weak scale constant $10^{-5}m_p$ (with $m=1$ in our units), differing by nearly 40 percent. This also will have to be understood and corrected. Finally, the estimate of the gravitational constant which applies to all particles of baryonic mass, $1/(2^{127}-1+137) \approx 10^{-38}$, is once more a reasonable estimate. To pin all this down and make it quantitative is the challenge which confronts our approach and on which we are working; clearly we can as a minimum claim to have reached a reasonable overall first approximation and some semi-quantitative results.

Once we can get the "elementary particle physics" straight, and carry through the reconstruction of quantum mechanics on a discrete basis along the lines already discussed in connection with the work of Stein and Jones, we can go on to cosmology and the evolution of physical systems. The starting point for the whole business would seem to be the $2^{256}-1$ possible distinct Schnurs of length 256 allowed in the whole scheme. The square of this number is then the number of possible initial discriminations, which according to our postulates must all occur with equal a priori probability. A theorem we have yet to prove is that when this "start up" is described in terms of our quantum number scheme, we will find that a conserved baryon number and lepton number of this magnitude are achieved; empirically this is the right order of magnitude for the number of electrons and protons in the observed universe. It must be at this point that the decision between a matter or an antimatter universe gets made. Of course which we call which is just a convention, but that we end up with one or the other is definitely not. It looks suspiciously like the "once for ever" selection discussed by Manfred Eigen in connection with the hypercycle, rather than like Darwinian selection; the connection may well prove worth pursuing. The initial presence of both particles and antiparticles provides plenty of energy for the "big bang," and if we have got our "elementary particle physics" and gravitational theory right, should then proceed along more or less conventional lines. So once we are past the initial stages, we do not anticipate that our approach will add much of a technical nature to the detailed discussion of cosmological, galactic, planetary, or biological evolution.

This brief description of the combinatorial hierarchy approach to basic physical processes is clearly in the nature of a progress report on a program that is still in its early stages. Yet we hope that even this sketch suffices to show that it is possible to construct a conceptual framework for physics which uses the same basic concepts as are required for biological evolution--discrete processes, conserved elements, and selection for stability against a random background. Nowhere along the way from the mathematics or physics through the cosmology to the current situation do we encounter a gap, or a conceptual leap from one set of principles to another. Thus we offer the combinatorial hierarchy as a candidate for the role of providing a unifying background from which to construct a scientific philosophy.

This brings us back to our starting point. We have now sketched a physical theory which, starting from very elementary processes, leads, we believe inevitably, to a universe like the one in which we find ourselves. But because of the long time scale, understanding this universe in detail becomes increasingly a historical problem--that is, a problem of determining what random events did in fact occur in the past, and how these sequential happenings led to the present situation. The events remain physical even though the shorthand language of description becomes progressively more geological, biological, cultural, and "spiritual" as we approach the present. Just what novelties emerged and when is a matter for research, but the emergence of novelty itself follows inevitably from our principles. Among these novelties is clearly our own theory, which is itself evolving!

For the author, the most important philosophical conclusion to be drawn from this scientific world view is that, though we can view the past as fixed, the most we can ever hope to predict scientifically about the future are probability ratios and not certainties. We learn from biology and cultural history that evolution has increasingly widened the ability to recognize new areas of choice, and the ability to devise new actions based on these new possibilities. Indeed we feel it proved that, at least up to the present, the evolution of intelligence has been a successful evolutionary strategy.

But intelligence by itself does not provide a normative principle. That comes more directly from our collective social and familial experience. In the case of man it is easy to show that we have been a cooperative, tool using species for millions of years, and that our cooperative institutions were the key to our selective advantage over anthropoids and other early hominids. Even after the radical change in population density which stemmed from the independent invention of food production in three widely separated parts of the planet about 11,000 years ago, cooperation rather than conflict was usually the rule. Conflict, represented by the hierarchical military state, started only _after_ the land usable with neolithic techniques had filled up and the expanding population had nowhere to go. So now we have the inescapable conflicts between the older virtues of cooperation, which still work much as they used to in groups of a few decades (the hunting band) and a few hundreds (the tribe), and the superposed and often militarized rules imposed from above on larger units. For the author, it seems obvious that the cooperative virtues are our basic standard, and the military "virtues" an aberration, resulting from an understandable, yet tragic, historical process. It also seems obvious that these military "virtues" are like to destroy the planet, unless we can turn our technology from competition to cooperation, both among ourselves and with the basic ecology which supports us. But he knows of no way to "derive" these normative standards from the scientific philosophy.

What can be said, however, is that once we have recognized the existence of normative choice as part of the world in which we live, there is no escaping it. Our science tells us that the future is _not_ determined, that our actions _can_ affect it, and that we can never be certain of the consequences of our action--or inaction. Thus we can never escape from the responsibility of moral choice, and the continual re-evaluation of the choices we make and the actions we do or do not take in the light of the changing situation. Just because a particular action has low probability of success does not mean we should not take it if the alternatives are morally repugnant; what a low probability tells us is that we should be prepared for failure, and consider the options in advance before we take action. We can never know that the achievement of a better world is impossible; rather, we are certain that it is possible. The responsibility of trying to achieve that better world, though we can have no guarantee of success, is our inescapable duty.

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