One of the interesting ideas that the chart yields is the obviously 124
increasing tempo of cultural and sociological evolution. In fact, it seems that cultural and sociological evolution takes place at logarithmic tempo for each cultural era [and] is approximately one-tenth as long as the one preceding it. This acceleration is no artifact for according to Simpson this is the usual mode of all evolutionary processes including cultural and sociological evolution.

> Evolution is a cumulative process and in it, as usual in such processes there is an effect of acceleration. Early stages were aeon-long and slow beyond imagination. They built a basis on which, finally, more rapid evolution occurred.
>
> Simpson—*Meaning of Evolution*

Thus, the eras of religion and particularly the era of superstition, were the "early stages" of culture that "were aeon-long and slow beyond imagination" but which formed the basis upon which more rapid cultural evolution is now occurring. It is upon this interpretation of current cultural change that this writer has extrapolated cultural and sociological evolution as indicated on the chart; humanity is ready for such changes and the conditions (of the nuclear age) are present to motivate these changes. Thus, this writer is maintaining, for example, that the current resurgent nationalism is a passing phenomenon; it is an artifact of social and cultural inertia. So either these nations will heed the call for adaptation to the new conditions of the nuclear age or we and they will join the role as another of the billions of extinguished species of past ages which already includes three of four past species of man. Thus, the implication of cultural evolution says to mankind: "Unity and social progress to all mankind or death to all mankind. Humanity cannot remain inactive; it must choose between unity or death." The schematic of cultural and sociological evolution also indicates that what Whyte calls "unitary theory" might not only lay the foundation for all of science but that it could serve as the scientific basis for a world civilization that would incorporate all of humanity's peoples. The above scheme of cultural and sociological evolution does not mean that Whyte's concept closes the door to any future doctrine that might seek to supplant this "unitary theory" nor does it close the door on the possibility that Whyte and the current writer delude themselves as to the power and veridicality of the current "unitary theory." No one, no man, no theory has a right to place the onus of finality on any theory for humanity on the basis of his opinion alone. And it is, as it always has been, the responsibility and duty of pure science to attempt continuously to overthrow any theory
especially a "unifying theory" and to replace these with a better theory or 125
with a more fundamental theory. But in this regard, it is significant to note three pertinent facts. First, Whyte's foundation concept is the evolutionary resultant of fundamental thought in the basic pure sciences. Secondly, in the past four hundred years of research in pure science, no new fundamental explanatory hypothesis has emerged in fundamental thought that has stood the test of experimentation other than the two doctrines which we have traced above—the mechanistic-materialism and the field process doctrines. Thirdly, the time is fast approaching for another of Europe's and Western civilization's world-wide wars which will

be a nuclear war. This means that humanity will be forced into a choice between universal unity or universal death in the very near future.

The writer takes the position that in Whyte's unitary theory humanity has attained a passably good veridical map with which to explore the universe, to understand life and the human psychological process and to develop a healthy society. We must not leave this section without indicating some general norms and values that might be accepted in order to speed adaptation to the conditions of the nuclear age. An important rule for progress in the socio-cultural sphere can be derived from the historical development of field theory that we have traced above. We have seen that many men of pure science of many lands all working together for the good of all humanity, led to the rapid development of the various branches of science which we call physics. First, veridical concepts were derived from experimental research and the methods involved in obtaining these results and the results themselves, were made known to all. Secondly, these veridical concepts led to the theoretical systems of men like Newton, Maxwell, Einstein, and, perhaps, Whyte. The salient value of this latter theoretical activity, which is to be carefully distinguished from the verbal intellectualism of the humanities (whose concepts often lack experimental veridicality to begin with), is that these theories enabled applied scientists and pure scientists to extrapolate their subject matter far beyond that which was currently known. Both experimental and theoretical aspects of pure science, then, form the subject matter which applied science uses to develop the technology which in turn produces the goods and services that satisfy our wants. Consider the theoretical systems of Newton, Maxwell and Einstein and the great applied revolutions that *followed* the formulations of their theoretical systems. These were the mechanical, the electronic and the nuclear-power revolutions which are today culminating the coupling of mechano-electronic control (automation) to nuclear power which promises 126
to free all humanity from physical toil in our life-times. Applied progress then *depends* upon science (experimentation and theory) and is *led* by pure science and not the reverse.

An important extrapolation of the above rule of progress to the sociological sphere is a follows. Take care to perform careful research in the social and cultural sciences to begin with and then synthesize these veridical concepts into theoretical systems. Then carry out the implications of these theoretical systems even if data on a particular problem are lacking. This will be harder to do on the sociological level because of the conflict of interests between various individuals, between various groups, between various nations and because we have all four of the above cultural eras with all their norms, values and viewpoints telescoped into our present society. The writer would suggest that care should be taken to put young social scientists, selected for their competence and for their dedication to pure science and to humanity, in all roles of decision making in all branches of society. The men-of-action, the practical men—the politician, the businessman, the military leader, the labor union leader, the applied scientists, etc.—these men should be made the *advisers* to the men of pure science as regards decision making and not the reverse. This is because those men engaged in the actual doings of society generally guide their actions by trial and error and rules of the thumb. A pure scientist must base his decisions on understanding—if his decisions do not work then his theory must have been unveridical. Another good reason for putting men of pure science into roles of decision making is that experience has shown that pure scientists will not, in the long run, identify with these men of action nor with the appointees of these men but the reverse situation does not hold. The society that chances putting applied scientists or men of action into positions of decision making may well manifest a psychological state of suspended animation and an over-powering inertia in the nuclear age despite overt signs of progress and activity. This state of inactive rigidity is likely to come about no matter the amount of money spent on research and [ir]regardless of empty verbalisms which can be easily seen through. If a society wants rapid and real social, political, economic and cultural progress, it is the prediction of the writer that they will find that they must put pure scientists into positions of real decision making. Half-measures will bring half-hearted progress such that characterizes the United States of 1959.

Another important need for humanity in the nuclear age is to develop super-ordinate goals for all peoples. Cultural interchanges are only secondary measures; social scientists know that all such inter- 127
changes will not develop the positive "we" feeling that humanity needs to survive the immediate future. In fact such interchanges without super-ordinate goals are known to increase the gaps and antagonisms between peoples and not the reverse. Yet, humanity must develop this "we" feeling or perish. The norms and values that are currently applied on the level of nations—namely those that lead to negative outgroup feelings directed against the other nations (e.g. the "iron curtain" nations) and the positive ingroup feelings, the "we" feelings directed exclusively to members of one groups of nations (e.g. "the free world")—are clearly maladaptive in the nuclear age regardless of their validity or lack of it. The best solution would be to selectively eliminate the negative nationalistic feelings and expand the positive "we" feelings in nationalism to include all peoples of humanity.

To take an example of a super-ordinate goal in the inter-personal sphere which it would behoove us to develop—that of romantic adventure—we must seek to make the positive emotion of pleasure and love related to romance and sex experience work for, instead of against, a more adapted and healthier humanity and particularly, a more adapted and healthier American people. Religion, philosophy, and mechanistic science have a long history of sad failure in this sphere which partly accounts for the immense modern dissipation of psycho-sexual energy into mental disorder. By making provision for romantic adventure (to be defined and described below) and by wisely regulating this activity, the nuclear age society can channel this now dissipated energy to work for humanity instead of against humanity.

* * *

The work below will unfold as a continuous sequence using the idea of a one-way development over time as the connecting link between the various aspects of the organizational hierarchy. We shall first set various problems in the biological and physical spheres. We will then start this development with the unitary process working in the unitary field and describe how the normalizing process first evolved our galactic group. We will then proceed to the origin and evolutionary development of our Galaxy—the Milky Way—then to the origin and evolutionary development of our solar system, and then briefly to the evolution of the earth. We will then account how the normalizing process may have led to the origin and evolutionary development of biological processes: life and mind upon our planet—beginning four and one-half billion years ago. We shall then pass over to the field of neuro-physiology and psychology in an attempt to 128
understand how our nervous systems function on the basis of the unitary process. Then we shall attempt to understand how some of our sociological systems operate as a unitary process. Lastly, we will terminate this book by discussing the idea of a world civilization and a world community of nations within our life-times.

The work below is a very thrilling story and in many cases an astonishing story and in many respects a very beautiful story—especially if one keeps in mind the empirical referents to which the various concepts refer. Since free energy play so important a role in all that follows, we shall develop the concept from elementary thermodynamics almost immediately below. We will later reinterpret both the free energy and entropy concepts in terms of unitary theory.

V

THE ORIGINS AND EVOLUTIONARY DEVELOPMENT OF THE UNIVERSE, LIFE AND MIND

In this section we shall encounter some of the most remarkable adventures known to mankind. This has been called the golden age of biology. Of all the sciences making tremendous advances in the twentieth century, the field of biology (especially micro-biology) might be selected as making the greatest advances. Perhaps unitary theory itself might not have been possible had it not been for the vast amount of empirical research and theory made available by this branch of science. Ever since the time Jacques Loeb rebelled against the holistic viewpoint in the 1890's at Woods Hole,[1] biology has increasingly approached the sophistication of physics and chemistry and in recent years has emerged as a rational science.

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[[1] Centers of scientific learning such as the Marine Biological Laboratory at Woods Hole are truly capitals of the modern world. Scientists in such organizations must share their experiences with the rest of the human family much more so than they have done in the past. The laboratory at Woods Hole epitomizes the history of the major movements in biology during the past half century. "The early workers at Woods Hole devoted themselves to observing the behavior of whole organisms. To tamper with the living cell or interfere with natural processes, it was held, would produce misleading artifacts. So the investigators patiently watched marine eggs under the microscope and recorded what they saw as the eggs grew, multiplied and developed. In the 1890's a profound change began in the work of the Laboratory." The man who did the most to bring about a new era was Jacques Loeb. In rebellious exasperation he exclaimed, in effect, "The h--- with the holistic approach. The most uninteresting thing I know is the normal development of the egg!" Looking backward we now know that this was a branch of science declaring its independence from philosophy, asserting that biology must be based on scientific method and the basic sciences—physics and chemistry—and not upon philosophical doctrines that impeded the development of biology rather than facilitated it. (Psychology and certainly sociology have not yet fully declared their independence from philosophy as they must to become integral parts of a unified science.) "Loeb proceeded to explore biology at the molecular level. In the face of bitter opposition from the vitalists and others he showed that the mysterious, complicated proteins, one of the main components of protoplasm, were composed like other forms of matter, of identifiable molecules. After his death (in 1924) the laboratory—and with it, all biology—gradually shifted its chief emphasis to biochemistry." It is largely the men and women working in this great tradition of micro-biology established by Loeb who have provided the research which has led to veridical concepts, which has made synthetic and unitary theory possible, and which makes biology perhaps the most interesting of the sciences—not to mention its applications to problems of practical importance such as cancer, heart disease, medicine in general, agriculture, genetics, etc.]

By this is meant that biology has achieved veridical concepts which can 130
be interrelated to form meaningful theory that can be trusted and can be used to solve problems by the exercise of the rational processes. This vastly diversified field of biology contains so much of intrinsic interest and beauty that it almost alone could form a world culture.

The theme of the sections below is as follows. Our galactic group forms a dynamic system of astronomical sub-systems within a larger system which is our universe and to which it is dynamically related. Our galactic group or system is a complex of mutually transacting and interdependent sub-systems within which, it is postulated, there operates a huge creative-formative structuring process within which atomic nuclei are developed from quantum field structures and out of which huge aggregates of atoms are formed. These are observed as, or in the vicinity of, dust clouds which eventually form new stars. This formative process leads to the appearance of life on the planets which are created along with the stars and leads to the appearance and evolution of all living species on these planets. All of these processes are ultimately based on quantum field structures. The appearance of life on our planet, the evolutionary appearance of the four billion plant and animal species, the psycho-social development of the human family and the development of the human individual from infancy to the acme of development—the mature human personality—are all manifestations of this formative process which pervades the universe. All processes which display this continuity of process are due to an underlying increase of order, organization and complexity of quantum field structures. The normalizing process which develops patterns of structures that facilitate normalization is the causal agent directing and driving the one-way increasing complexity and hierarchical organization of: quantum, nuclear, atomic, astronomical, chemical or molecular, biological and psycho-sociological structural organizations, all in accordance with their particular environments. This creative formative process is continuous and ongoing; it is at this very moment creating new galaxies, new suns and new earths and new living species throughout the galactic groups of the universe.

The problem of the "origin of life," which has been called "one of the most intriguing problems of all time," has attracted many proponents over the past forty years. Several of these view will be presented below and then the "origin of life" from the viewpoint of unitary theory will be outlined.

A. THERMODYNAMICS 131

The laws and principles of thermodynamics, more than any other theory or laws in science, have shaped the nature of theorizing in biology. For example, three of the four views to be presented below on the "origin of life" have employed thermodynamics as their basic conceptual methodology. However, in their entropy concept, both classical and statistical thermodynamics assert that a tendency toward maximum disorganization or disorder is the natural course of events in all natural (macro-physical and atomistic) systems. In fact, it is said that this tendency is so inexorable as to form a universal law of nature; the universe, as a closed system, is said to approach an entropic death. Yet, in the branches of science studying phenomena that display the continuity of process, we observe—to the contrary—a universal and pervading tendency toward the growth of order and organization. "According to the 2^{nd} law, the general direction of (macro) physical events is toward a decrease of order and organization—in contrast to this a direction toward increasing order seems to be present in evolution."[2] (Bertalanffy) Clearly the laws of thermodynamics are only partial theories that apply only to phenomena not displaying the continuity of process. That aspect of the entropy principle which implies that the universe tends toward maximum disorder and disorganization must be an unveridical concept. In the development below, we shall reinterpret the laws and principles of thermodynamics and shall postulate that both classical and statistical thermodynamics have been based on an improper empirical referent.

[[2] To take an example from the molecular level of biology, Pringle, in a recent symposium on evolution, in discussing the possibility that energy—rich nucleic acid was the basic source of energy for synthesis and catalysis in the evolutionary

development of both the anabolistic and catalytic system says the following: "...it is not impossible that the energy for a synthetic process as well as to catalysis...be combined in a single molecular structure; this would represent the ultimate triumph of that process in biological evolution which appears to have as its 'objective' the direction of available energy into useful channels." Thus, the implication of the entropy concept and its empirical referent do not correspond on either the macro-physical level (Bertalanffy) or on the atomistic-molecular level (Pringle). Instead of a tendency toward disorder and disorganization in macro-biological and micro-biological evolution, we have instead a process whose aim appears to be the growth of order and organization via the channeling of free energy into useful channels. As we have stated above, this process is that of normalization which promotes the synthesis of a pattern of structures that facilitates normalization. The "facilitation of normalization" is equivalent to the "direction of available (free) energy into useful channels" for the normalizing process is essentially a free energy maximizing process which so channels free energy (structural asymmetry) that an increase of order and organization is obtained which serves to maximize the efficiency of free energy utilization by the organism's process.]

Given this improper empirical referent, we have the partial laws of 132
thermodynamics whose entropy concept must of necessity imply a universe that tends toward disorder and disorganization. Given the proper empirical referent, the laws of thermodynamics are seen to be aspects of unitary theory with a different concept of entropy and a universe that tends toward order and organization.3

The laws and principles of thermodynamics, despite being partial theories, nevertheless constitute some of the most powerful principles known to science and will be used extensively in this and other works. Since part of our aim is to reinterpret the laws of thermodynamics in terms of unitary theory and to offer a new conception of entropy, we will take this occasion to develop these laws and principles at some length. The development immediately below will closely follow thermodynamic texts without interruption by the writer unless otherwise indicated.

Energy has been defined very generally as "any property which can be produced from or converted into work, including, of course, work itself." The science of thermodynamics then explores the laws which govern the transformation of energy from one form to another during physical or chemical changes, and the utilization of energy for useful work.

From this point of view of classical thermodynamics, thermodynamics is an empirical science. It is based on generalizations from experience and, since man's experiences must be in the macroscopic

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[[3] Schrödinger, in his neat little book: *What is Life?*, clearly recognized the inadequacy of modern statistical thermodynamics in dealing with the orderly aspects of biological structure and he seems to have anticipated the appearance of unitary theory. In his book he applies statistical quantum theory to elucidate the nature of the then currently understood (1946) genetic structure. Toward the end of his book he makes the following statement: "But strangely enough, there is just one general conclusion to be obtained from it (the description of the genetic structure by statistical quantum theory), and that, I confess, was my only motive for writing this book. From Delbrüch's general picture of the hereditary substance it emerges that living matter, while not eluding the 'laws of physics' (statistical mechanics) as established to date, is likely to involve 'other laws of physics' hitherto unknown, which however, once they have been revealed, will form just as integral a part of the science as the former." The unitary principle claims to be this new law of quantum physics. Unitary theory, however, claims to be more than an integral part of the physical laws. Unitary theory claims to be a basic theory which incorporates the statistical and mechanical laws and from which theory these laws can be derived. To obtain a veridical conception of the unitary principle, Whyte went down in the scale of empirical referents from the randomly moving atoms and molecules (the empirical referents of quantum theory) to the unitary structured field, the basic substratum of the universe. The only law that can justifiably be called a universal law of nature is the veridical conceptual representation of the fundamental mode of operation of this field and this is the unitary principle. All other laws and principles are partial laws and theories.]

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sphere, so the laws of thermodynamics are valid only on the macroscopic 133
level. That is, the laws may or may not be valid on the molecular level, but they have never been observed to be wrong on the level of man's experience. Since thermodynamic laws are based wholly on empirical observations and are not in any way based on hypothetical views of structure or mechanism, these laws are as certain as are the empirical facts upon which they are based. As put by Eastman and Rolefson, "The postulates are few, totally non-mechanistic, and backed by wide experience. The conclusions are developed by rigid logical and mathematical processes and are consequently among the surest and most exact that may be drawn concerning chemical systems." As long as there is agreement between the implications of thermodynamic laws on the one hand and experiment on the other, these laws are justified.

A point to note is that statistical thermodynamics with its basis in atomic and quantum theory has arrived at the same thermodynamic principles as has the empirical classical method we are now discussing.[4] Statistical thermodynamics may be said to be on the microscopic (or

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[[4] We noted above that the laws of quantum physics are based on a concept of natural law of a statistical character; consequently, the thermodynamic principles derived from them also display this statistical aspect—the principles being regarded as laws that express the most probable distribution of minute particles, usually meaning atoms or molecules.

> Because we know all atoms to perform all the time a completely disorderly heat motion, which, so to speak, opposes itself to their orderly behavior and does not allow the events that happen between a small number of atoms to enroll themselves according to any recognizable laws. Only in the co-operation of an enormously large number of atoms do statistical laws begin to operate and control the behavior of these assemblies with an accuracy increasing as the number of atoms involved increases. It is in this way that the event acquire truly orderly features. All the physical

> and chemical laws that are know to play an important part in the life of organisms are of this statistical kind; any other kind of lawfulness and orderliness that one might think of is being perpetually disturbed and made inoperative by the unceasing heat motion of the atoms.
>
> Schrödinger

According to statistical thermodynamic theory, if heat is added to an isolated system at the same temperature as the surrounding environment, the "heat motion" of the molecules will be greater in the system than in the system's surroundings. The greater concentration of high molecular velocities in the system is spoken of as "organization" or "order." As the system spontaneously radiates heat to its surroundings, the concentrated molecular velocities are replaced by a random distribution of molecular velocities; this is the state of statistical equilibrium. The most probable outcome or complete randomness of molecular velocities is spoken of as "disorganization" or "disorder" or "maximum entropy." Thus, the 2nd law is expressed as the tendency for all naturally occurring systems to go toward their most probable state (the state of maximum entropy or disorder). This tendency is so inexorable that the tendency toward maximum entropy or "disorder" or "disorganization" is held to be a universal law of nature. For example,

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ultramicroscopic) level for its empirical referents are atoms and molecules. 134

The energy of a system can be divided into two main categories. One of these is that energy which is dependent upon the position of the system in an electric, gravitational, magnetic, or any other particular force field, as well as upon the motion (kinetic energy) of the system as a whole, as through space. The other category is that energy which is a characteristic property of the system itself and will be called the energy content of a system. To make clearer the differentiation between the two kinds of energy, consider the hypothetical (and artificial) system of a solution of salt in water enclosed in a cylindrical container. If this container were thrown into the air, the energy of the system would consist on the one hand of the motion through the air, the gravitational attraction, etc., of the cylinder, and, on the other hand, of the energy within the solution itself. It is this last category, which we shall call the energy content of the system, that is the domain of thermodynamics. That energy of the system which is the result of factors external to the system, such as gravitation, etc., is usually ignored by thermodynamics.

1. THE FIRST LAW—DERIVED CONCEPTS AND IMPLICATIONS

Any changes in energy content, as well as changes in other thermodynamic properties, must conform to the first and second laws of thermodynamics, the proper handling of which allows the examination of

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the universe as a whole is conceived to be a closed system within which there is supposed to be "a continual entropic process in which the organization of systems in which energetic exchanges occur is being continually degraded, complex organization broken down into simpler ones, until the whole universe approaches an 'entropy death,' all energy being irreversibly converted into heat (random motion) at a low temperature." We will note, in the quote from Schrödinger above, an example of a reification of the notion of mathematical law. A law—mechanical or statistical—is man's own creation and as such does not exist in nature beyond man's books or in his imagination. It does not "operate and control" the behavior of disorderly atoms and molecules thereby bringing order to them. We should look instead for an empirical referent (the unitary field) that controls the disorderly particles and brings order to them. For example, small aggregates such as atoms, molecules and Brownian particles might be simply demonstrating the dynamic asymmetry nature of the unitary field of which the particles are a part; heat being a form of asymmetry enhances this effect. Thus, when these particles become concentrated, new inter-atomic field phenomena appear and it is these that produce the observed order and not the operation of statistical laws. The atoms, molecules and Brownian particles might be too small to display inter-atomic or inter-molecular field forces by themselves or when they are in small groups; yet, they may be small enough to display the dynamic character of the structural field of which they are a part.]

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all transformations of energy and matter including biological reactions. 135
These two laws have been stated in many ways but the chief implication of the first law is that energy can be neither created nor destroyed (or, in other words, the total amount of energy remains constant in an isolated or closed system). I.e., for every increment of one kind of energy produced in any part of a system, an exactly equivalent increment of another kind of energy must be used up. The first law of thermodynamics can be stated mathematically:

$$\Delta E_{total} = \Delta E_{system} + \Delta E_{surroundings} = 0, \qquad (1)$$

where E in the energy content and ΔE is then the change in energy content between the initial and final states of the system. The change in the energy of a system during a change of state is, in fact, dependent only on the initial and final states and is not [at] all concerned with the manner of carrying out the change. This enables one to regard any changes of energy, of whatever form, in a system as changes in a single property "internal energy" and thus define the quantity ΔE. The importance of the first law of thermodynamics is the definition of E.

Another mathematical statement of the first law is:

$$q = \Delta E + w, \text{ or } \Delta E = q - w, \qquad (2)$$

where q is the amount of heat added to a system, w is work done as a result of this addition. Thus, energy added to a system as heat must all be used to increase the energy content of the system and/or in performing work.

During any change in the state of a system,[5] there is involved a volume change, ΔV, at a pressure P. If the change in volume is an expansion, the system must perform work PΔV against the atmosphere in which it is situated. If the volume decreases, the reverse is true and work equivalent to $P\Delta V$ is done *on* the system. This term $P\Delta V$ comprises part of w in most reactions, and in some reaction $w = P\Delta V$. It has thus been convenient to identify a new thermodynamic property combining energy content E, and the pressure volume work, PV, involved in a change

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[[5] By state of the system is meant the sum of all possible characteristics or properties of a system itself specified by defining the particular set of components involved and the number of moles of each component. The state of a system is then defined by indicating the mass, chemical composition, and form of each constituent phase, as by stating the conditions, such as T, P, and V of the system. Changes in the state of a system are fully defined by description of the phases and conditions in the initial and final states and are, therefore, completely independent of the path taken by the process which results in the change. Thus, when a change of state is said to take place under constant temperature, this means merely that the final temperature equals the initial temperature.]

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in state. This new property is called “heat content” or “enthalpy” and is 136
defined:

$$H = E + PV \qquad (3)$$

Both E and H are thermodynamic properties of the system and the changes in these quantities during any process depend only upon the initial and final states of the system and not at all upon how the process is carried out.

The heat (q) and work (w) of equation (2) are dependent upon the manner in which the change is brought about; therefore these quantities are not thermodynamic properties of the system. However, q and w are not independent of each other because, since Δ**E** is a property dependent on the state of the system only, the difference q - w must not vary with the path of the process.

To examine more fully the dependence of the work term upon the manner the process is carried out, consider the reaction:

$$Zn + CuSO_4 = ZnSo_4 + Cu \qquad (4)$$

If this reaction were allowed to take place in an open beaker, heat equivalent to the heat of reaction would be given off and no work done by the system. If, on the other hand, the reaction takes place in an electromotive cell, the reaction produces electrical work. If also, a counter-emf is applied, the work done by the system will be greater, being the greatest when counter-emf is only infinitesimally smaller than the voltage produced by the system. That is, the amount of work a system must do to effect a change is dependent upon the opposition it encounters; the more resistance to a change, the greater the work done in producing a change. The work then would be the greatest when the counter-emf is only infinitesimally smaller than that produced by the cell. Under these conditions, if the counter-emf were increased by an infinitesimal amount, it would be infinitesimally larger than the emf of the cell, and the process would be reversed, retracing all the previous stages of the process. A process which takes place under these conditions is said to be a *reversible* one. Thus the maximum work is obtained from a system when the change involved takes place reversibly.

When a reversible process takes place under constant temperature conditions (i.e., isothermally), a definite path from the initial to the final state is established. That is, there is only one reversible path the process can follow at that particular temperature. Therefore, the *maximum work* (which is that quantity of work done under reversible conditions) done is dependent only upon the initial and final states in such an isothermal reversible process. The maximum work then is a definite quantity which is a function such as E and H and takes on the attributes of a thermodynamic 137
property. This means that each system contains a certain quantity called *maximum* work content; **A**; the maximum work performed in a process is:

$$w_m = -(A_2 - A_1) = -\Delta A. \qquad (5)$$

The minus sign is by convention used when the work content of a system decreases, i.e., work is done by the system. When work is done on the system and the work content increases, it is $+\Delta A$.

Notice that the term used is maximum work *content* of a system. If the process is carried out under ideal conditions, namely reversibly and isothermally, the maximum work content is all utilized as work or $w = -\Delta A$. Under any other conditions, the work done is less than the maximum work possible with the difference between the two being the greater, the further the process deviates from ideal conditions. Above we stated that:

$$\Delta E = q - w. \qquad (2)$$

For an isothermal and reversible process this could then be modified to read:

$$\Delta E = q - w_m = q + \Delta A. \qquad (6)$$

A reversible process, however, because only infinitesimal changes are involved, would required infinite time to go to completion and, since all naturally occurring processes take place in finite time all naturally occurring processes are irreversible to some extent. This maximum work concept we have developed will be useful later in our thermodynamic development.

2. THE SECOND LAW--DERIVED CONCEPTS AND IMPLICATIONS

While the first law defines the energy of a system and puts limitations on its use, it makes no statement about the probability of a change, nor about the direction of the change when it does take place. Thus, there is nothing in the first law which would deny that water could spontaneously flow uphill as long as the energy consumed equaled the energy produced in one form or another. The second law makes it possible to predict whether or not a reaction could take place under specified conditions. It also gives some information concerning the conversion of heat into work. The second law has several formulations, two of which will be mentioned here.

Observation shows that the spontaneous flow of heat always takes place from the higher to the lower temperature; the same phenomenon can be observed throughout nature: energy flows from the higher potential to the lower. *All naturally occurring processes tend to change spontaneously in a direction which leads to equilibrium.* From this statement it follows that in order to have a process proceed from a lower
to a higher potential, work must be done on the system; i.e., energy must 138
be supplied to the system from outside. Or, if the process takes place in a closed system, there must be some permanent change in the system to effect such an unnatural process. For example, in refrigeration heat is removed from a lower to a higher temperature. But in order to carry out this process, work is done by some other part of the system such that the final condition of the system differs from the initial condition.

A second way of stating the second law is that it is not possible to convert heat into work without some other permanent change taking place in the process. For example, when, in the reversible expansion of a gas, heat is converted into work, the gas occupies a larger volume finally than it did initially.

Both of these qualitative ways of stating the second law of thermodynamics are in terms of everyday experience. According to thermodynamic theorists, since there are no assumptions made, no theories or postulates called upon in the statement of these laws, the laws are completely empirical. All applications must likewise be based on empirical data. The result is that any conclusions are then as good as the facts with which the application was made, for the thermodynamic principles themselves use no assumptions.

With a brief digression from our thermodynamic development, it might be pointed out that the second law and particularly its implications are of the utmost importance in biological processes. The implications derived from the second law make it possible to predict whether or not any given reaction can take place, be it catalyzed or not. The principles which follow make it possible, not only to predict when a change can take place and what the magnitude of the tendency to change is, but also what external conditions will affect the amount of energy involved in such a change.

It must also be remembered that, since human observation and experience is based on macroscopic systems, the second law of thermodynamics is applicable only to macroscopic systems, i.e., systems containing large numbers of molecules. As an example consider a balloon filled with gas and resting on a completely level table top. In order for that balloon to move spontaneously (excluding any possibility of external factors) every molecule within the balloon must simultaneously achieve the same direction. In a system containing large numbers of molecules such an event is extremely improbable. If it were possible, however, to deal with a system containing only five molecules, it is conceivable that all five might achieve the same direction in the same instant and thus 139
convert the random molecular motion into the mechanical work of moving the balloon.

The essence of the second law, then, is that heat is never converted completely into work without some permanent change in the system. Under isothermal conditions no heat can be converted into work without some compensating change in the system, and even under non-isothermal conditions, only a part of the heat can be recovered as work. The amount of work actually obtained from a particular process depends upon the temperature difference involved during the process, and also on how the process is conducted. Even under the most ideal working conditions, some energy remains unavailable for work.[6] These considerations have dealt with heat processes but similar considerations can be applied to other systems also.

We have already defined the maximum work content of a system as A; this is the available energy of a system at any given temperature. The unavailable energy which we mentioned above is then defined in terms of entropy, S, which represents the energy per degree of absolute temperature which cannot be recovered as work. The total amount of unavailable energy in a system is TS, where T is the absolute temperature and S is the unavailable energy, or entropy, per degree of temperature. The energy of a system is thus composed of two portions:

$$E = A + TS \tag{7}$$

The change in energy between the initial (subscript 1) and the final (subscript 2) state is then given by:

$$\begin{aligned} \Delta E = E_2 - \Delta E_1 &= (A_2 + TS_2) - (A_1 + TS_1) \\ &= (A_2 - A_1) + (TS_2 - TS_1) \\ &= \Delta A + T\Delta S. \end{aligned} \tag{8}$$

Comparing equation (8) with equation (5),

$$\Delta E = q + \Delta A, \tag{5}$$

[[6] Carnot’s work cycle has shown that the maximum work which can be derived from a heat engine under ideal conditions (complete reversibility) is:

$$w_m = q \frac{T_2 - T_1}{T_2}$$

Note that w_m, the maximum work obtainable, would equal q only when T_1 equals zero, and since T_1 is always greater than zero, w_m is always less than q. Note also that in order for a heat engine to produce any work at all there must be come temperature difference; i.e., the process must be conducted from a higher to a lower temperature. In isothermal conditions, such as is the case in biological processes, $T_2 - T_1$ is zero. But in biological processes we are not dealing with heat engines. The same conclusions hold for other systems also, and even the most efficient system possible is not 100% efficient. That is, there is always some energy unavailable for work.]

where q is the heat absorbed reversibly, results in a fundamental 140
relationship:

$$\Delta S = \frac{q_{rev.}}{T.} \tag{9}$$

From this relationship we can see that if q is positive, i.e., heat is absorbed during a process, ΔS is positive and the unavailable energy of the system increases. When heat is evolved, q is negative, and the entropy of the system decreases.

Since the entropy is a thermodynamic property of a system and depends only on the initial and final states of the system, equation (9) gives the entropy change for both reversible and irreversible changes. That is, ΔS of a process is a definite quantity regardless of whether that process is carried out reversibly or not. However, the quantity q depends on the manner in which the process is carried out. Therefore in calculating ΔS from this relationship, $q_{rev.}$ must be first calculated and this value used instead of the actual, observed q in an irreversible process.

Above it was mentioned that any process which takes place in finite time, as do natural processes, must be irreversible. Natural processes, as mentioned above, proceed from a higher to a lower potential, and heat must be absorbed with the entropy thus increasing. The second law can thus be stated in its most general form: all naturally occurring processes tend to occur with a change in entropy, and the change is always in the direction of an increase in entropy.[7]

In another brief digression from the thermodynamic development, note that equation (9) and the related discussion is important in understanding living processes. Living organisms obtain most of their energy in the form of food of one kind or another, and so absorb very little energy as heat. However, organisms give off considerable heat, then q for the organism would be negative and, thus, by equation (9), so would ΔS for the organism be negative. In previous years, it was often held that because the entropy of a living organism was less than that of its surroundings, it constituted an exception to the second law of thermodynamics. However, when the corresponding changes in entropy in the surroundings are taken into account, it is seen that there is a net increase of entropy. The processes and mechanisms by which the living process maintains the organisms in this decreased state of entropy is an

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[[7] Eddington used this statement of the second law to define what he calls "Time's Arrow." This law states, as we have just noted, that the entropy of a closed system not already in thermodynamic equilibrium, always increases with time. Thus, in a single closed system of two given entropy states, the state of greater entropy is later than the state of smaller entropy. The entropic process thus points the direction of time from past to present.]

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involved problem which has been worked out in great detail by recent 141
research in biochemistry and microbiology.[8]

According to the second law as we stated it above, any systems not in equilibrium have a tendency to reach the state of equilibrium which is the most stable of all conditions. To illustrate the various types of equilibrium we will consider a mechanical system after Guggenheim. A box on a table top can assume three different positions illustrated in the accompanying figure, where **+** indicates the center of gravity. Thus in "b" and "c" the center of gravity is lower than it would be in any infinitely near position of the box. That is, if the position of the box were altered very slightly it would tend to approach spontaneously its previous position, one of equilibrium or

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[[8] Bertalanffy has pointed out that the 2^{nd} law of both classical and statistical thermodynamics applies only to closed systems which exchange energy, but not matter, with the outside world. But he also points out that all living systems constantly interchange energy and structural components with their surroundings. Classical thermodynamics, moreover, deals only with reversible systems whereas living processes seldom if ever reach a state of true equilibrium except perhaps in death. All living processes are irreversible processes in non-equilibrium states. The feature in living systems of continuous flow and interchange of component materials with their environment and the feature which keeps these component materials and proportionate quantities relatively constant in the system, Bertalanffy designates as open systems and steady states, respectively. He calls for a new thermodynamics which will incorporate these features plus the fact that these steady states in open systems lead to the growth of heterogeneity and complexity.

> In closed systems the trend of events is determined by the increase of entropy, whereas irreversible processes in open systems cannot be charac-terized by entropy or another thermodynamic potential; rather the steady

> state which the system approaches is defined by the approach of minimal entropy production. From this arises the revolutionary consequences that in the transition to a steady state within an open system there may be a decrease in entropy and a spontaneous transition to a state of higher heterogeneity and complexity. This fact is of fundamental significance for the increase in complexity and order which is characteristic for organic development and evolution.
>
> Bertalanffy—*Problems of Life*

We will discuss in a section below the concept that steady states within an open system provide the conditions to sustain a creative formative structuring process within living organisms. One aspect of this formative process forms structural aggregates and the other aspect restores each aggregate to the asymmetry norm, and in cooperation the two aspects are characterized by minimal entropy production and by the formation of structural aggregates which go toward increasing the organism's heterogeneity and complexity. (The two aspects are the catabolistic-anabolistic system of living organisms or actually the highly differentiated expression of the symmetry tendencies of the structured field acting in cooperation. The steady states are external manifestations of this underlying formative process.) Thus, Bertalanffy's concepts closely approach unitary theory except for the lack of the empirical referent—the unitary field—with Whyte's innovations.]

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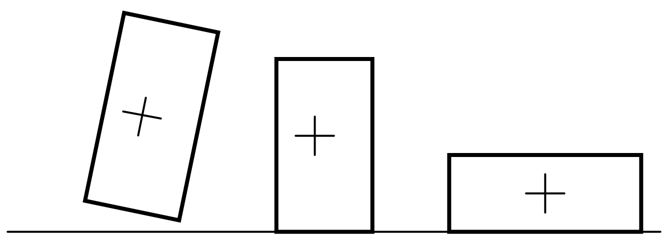

Figure 1

stability. The center of gravity of the box in position "a" is higher than it would be in any infinitely near position; thus it will move away from its original position and tend to reach either position "b" or "c." This is an unstable equilibrium; such equilibria are unknown in nature, since they require a complete absence of disturbing factors. Although positions "b" and "c" are stable compared to to "a", "c" is more stable than "b". That is, while the potential energy of position "b" is less than that of any infinitely near position, it is greater than that of "c". This position "b" is then a metastable equilibrium, while "c" is an absolute equilibrium. If the position "b" were moved more than an infinite amount, it would tend to approach that of "c". These three positions are analogous to thermodynamic equilibrium systems; no unstable equilibria are found in nature. A point to note is that the living process operates on the basis of a series of metastable equilibria.

Strictly speaking, the condition of equilibrium exists only when thermodynamic equilibrium has been reached—"when the observable properties of the system are not undergoing any change with time." Three conditions must prevail simultaneously for this to be the case: The temperature must be the same throughout the entire system (thermal equilibrium), there must be no change of composition with time (chemical equilibrium), and there must be no macroscopic movements either within the system or of the system in regard to its surroundings (mechanical equilibrium).[9]

All changes in nature, according to the thermodynamic viewpoint, take place as a result of the tendency to reach equilibrium. If such a system approaching equilibrium is harnessed in some way, it can be made 143

[9 A prerequisite for treating a specific system by thermodynamic methods is that it be in thermodynamic equilibrium. However, if chemical action in a system is so slow that it is not noticeable over a period of time, the system may be treated provided thermal and mechanical equilibria have been reached. Biological systems can and have been treated thermodynamically. This should not be confused with the treatment we are presenting which is merely a discussion of general thermodynamic principles and not application of specific equations to particular processes or parts of processes.]

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to produce work. The amount of work which is recovered from a changing system depends on the manner in which the system is harnessed. However, the *maximum work possible* in a given change of the system remains the same whether the work is utilized efficiently or not. The maximum work (which was briefly discussed above and defined in equations (5) and (6)) is greater the greater the distance from equilibrium, and thus the maximum work of a process may be used as a measure both of the distance from equilibrium and, consequently, of the tendency of the system to undergo change. This will be true regardless of how much work is actually recovered, since the maximum work is a "state of the system" property and is completely independent of the manner in which the process is conducted.

3. THE CONCEPT OF FREE ENERGY

Of the maximum work possible there is a certain amount in every change which must be utilized to perform pressure-volume work against the atmosphere, i.e., virtually every change entails some change in volume and this change in volume must be effected against (in expansion) or by (in contraction) the prevailing pressure. This pressure-volume work (henceforth to be called PV work) is useless as far as any net useful work for the system is concerned. The useful work, or net work, w′, which a system may yield at constant temperature and pressure then will be:

$$w' = w_m - P\Delta V, \qquad (10)$$

where $P\Delta V$ is the work involved against the atmosphere during a change in volume from V_1 to V_2 at constant temperature and pressure. We saw previously that the maximum total work a system is capable of doing is $-\Delta A$. Thus,

$$w' = -\Delta A - P\Delta V = -(\Delta A + P\Delta V). \qquad (11)$$

In order to treat more conveniently this quantity "net work" or available energy, we will define a new concept, that of "free energy." [10]

$$F = A + PV \qquad (12)$$

At constant pressure,

$$\Delta F = \Delta A + P\Delta V. \qquad (13)$$

Substituting equation (13) in equation (11), we have

$$w' = -\Delta F. \qquad (14)$$

This is a very significant relationship and one of the most useful not only

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[[10] Helmholtz first enunciated the term "free energy" but for him it meant that quantity now called by the followers of Lewis the maximum work function, A. The Lewis approach is used here since it seems more meaningful to call the actually available portion of the energy, the "free energy." Helmholtz used the term as opposed to bound energy, or entropy, that energy which can not be utilized for work of any kind.]

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in thermodynamics but also in physical chemistry, biochemistry and 144
biology in general. It is true, however, only under conditions of constant temperature and pressure, which conditions essentially prevail in living systems. The change of free energy is, since A and PV are both dependent only on the state of the system, also dependent only on the initial and final states of the system. The free energy change of any process is a definite quantity at any given temperature and pressure, and varies as these two variables change. Although the absolute free energy of substances can not as yet be known, the change in free energy during any process can be accurately determined. There have, in fact, been many such determinations made on biological processes.

As can be seen from equation (13), a negative free energy change accompanies work done by a system undergoing change. Since a system undergoing change (assuming no energy is being supplied *to* the system) is approaching equilibrium, a negative free energy change signifies a spontaneous reactions. A positive ΔF means a non-spontaneous reaction; i.e., energy equal to the ΔF must be supplied in order for the process in question to take place. When ΔF equals 0, there is no more tendency for change, or equilibrium has been reached.

The significance of the sign of a free energy change is that it indicates which process or reaction is thermodynamically possible. The negative ΔF means that the reaction can take place *if* conditions are favorable. It does not necessarily mean that the reaction will take place, however. For example, the free energy change for the reaction of hydrogen and oxygen to form water is −56,690 calories per mole of water. However, hydrogen and oxygen in a ratio of 2:1 even when mixed together will not react to form water until a catalyst is introduced or the temperature is raised sufficiently. The presence of the catalyst would not cause a reaction if the potentiality, indicated by the negative ΔF, to react were not there. The size of the ΔF indicates the magnitude of the potentiality to react.

We have now dealt with six major energy terms. In order to facilitate the remembering of the relationships between the various terms, a small diagram might be used. However, one should use caution not to confuse the relative magnitudes of the energy terms in the diagram. That is, this sketch is meant only as an aid in keeping in mind the mathematical relationships of the absolute terms. It does not portray relative magnitudes of the *changes* of these quantities. Thus, it might seem that ΔF must necessarily be greater than ΔA, but this is not so. ΔF will be larger than ΔA when work is done against the atmosphere by the

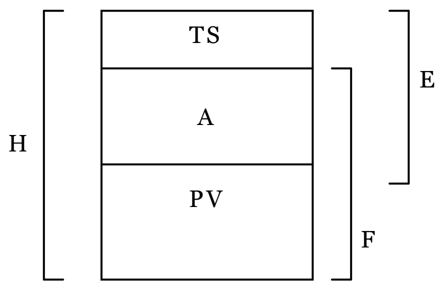

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Figure 2

system but when work is done by the atmosphere on the system ($-P\Delta V$), ΔA is larger than ΔF. Similarly ΔH is larger than ΔF when heat is absorbed from the surroundings (thus increasing $T\Delta S$). But if heat is evolved to the surroundings ($-T\Delta S$ for the system), ΔF is larger than ΔH. This can be seen from the famous Gibbs-Helmholtz equation:

$$\Delta H = \Delta F + T\Delta S \text{ or}$$
$$\Delta H - \Delta F = T\Delta S. \qquad (15)$$

This equation relates directly the changes in heat content, entropy, and free energy of any process.

To find the variation of the free energy change with temperature, equation (15) is differentiated with respect to temperature. Without repeating the derivation here, we shall merely present the final result. At constant pressure:

$$\frac{d\,(\Delta F/T)}{dT} = \frac{-\Delta H}{T^2} \qquad (16)$$

the heat of reaction, ΔH, may be considered constant over short ranges of temperature, but it is necessary to know ΔH as a function of temperature if wide temperature ranges are used. Thus we can see, assuming ΔH constant over a short rise in temperature, that such a rise in temperature causes the ΔF to increase considerably. In living organisms any changes which might occur in temperature would, according to this relationship, cause a change in the ΔF of biological processes. This in turn results in less energy available for doing metabolic and muscular work.

At constant temperature the relationship between ΔF and pressure is given by

$$\frac{dF}{dP} = V. \qquad (17)$$

Since only the volume of gases changes appreciably with pressure, 146
and that of solids and liquids remains essentially the same, the change of ΔF with change in pressure is negligible for solids and liquids.

All equations thus far discussed are based on the supposition that the particular system in question is a closed one. A closed system is one of constant mass; i.e., there is no passage of substances to and from the system. This includes passage of material from one phase to another, so a closed system is of one phase only. In this type of system, any change of a thermodynamic property must be due to a change of state in the system and not to the increase or decrease of material within the system. However, according to thermodynamic theory, the general principles and conclusions mentioned are the same for open systems as for closed ones. All biological and living systems are open systems in the sense that there is a continuous flow of materials into and out of the system, the products being modified by the action of the system. The only difference in considering open systems is that in order to apply a thermodynamic relationship to a specific process or reaction in any open system, the concept of partial molar properties, as developed by G. N. Lewis, must be introduced. The partial molar property, in brief, is merely taking into account the change in the property, G, of a system due to the addition (or removal) of one mole of substance to such a large amount of the system that its composition remains essentially the same. For out purposes, it is sufficient to note that this is the case in applying thermodynamic equations to biological systems.

B. The Origin Of Life

1. INTRODUCTION

The archaeological records indicates that hundreds of generations ago our ancestors regarded the portal by which a child enters the world as the actual giver of life. Objects such as the large Red Sea courie shell which closely simulate this "giver of life" thus came to be endowed with the same power via the concept of sympathetic magic. In time, other objects symbolizing this portal of life came to be endowed with the same powers. (That these simulated objects or symbols of the "giver of life" remained valuable is evidenced by the fact that the courie shells are still used as money or prized as personal ornaments in certain parts of Africa and the Middle East.) Men gradually forgot why they considered such objects and symbols as powerful and gradually attributed other powers and features to them.

In the cognitive works of the priesthood, down through the generations, 147
these abstracted and then reified symbolic concepts came to take on more and more elaborate conceptual forms and meanings. In this way gradually arose the notion that all living matter contained “a vital force” or a mysterious “vital principle” which idea was to confound the thoughts of many generations of men down to the present day.[11] Thus, the vitalistic theories of life preserve in the socio-cultural memory the reified concepts once referring to the mistaken notion that the portal through which the babe enters the world is the actual “giver of life.”

The historical record indicates that the philosophers of classical Greece were profoundly interested in the problem of the “origin of life” much as we are today. They, however, regarded life more or less as a substance much as we regard water, iron or mercury as substances. In other words, life was not recognized as having a historical character. So it was not surprising to have the Greeks assert that under favorable conditions living things spontaneously appeared from lifeless matter—so to speak—before one’s very eyes. This common sense view that living organisms were easily generated from decaying vegetation or from dung or from refuse or from the ocean slime seemed so obvious that there seemed to be no necessity for a more detailed study of the phenomenon. Consequently, there are hundreds of observations on record from classical times attesting to the “origin of life” via a process of spontaneous generation from the above sources. So we find in Greek thought the conception of the “spontaneous generation” of life which concept was closely associated with the idea of a “vital force” or a “vital principle” which supposedly was the factor that generated living organisms from lifeless materials. Yet, neither the hypothesis of “spontaneous generation” nor the doctrine of vitalism went unchallenged by the genius of Greece for some of her scholars came close to stating the theory of the “origin of life” as we have it today. But by 350 B.C., due to the rising power of Rome and barbaric Macedonia, the rational spirit of the Greeks began to ebb and we find around this time the vitalistic-dualistic notion of life once again gaining wide currency. In this period appeared one of the greatest of Greek philosophers—Aristotle (who himself was a Macedonian and the tutor of Alexander the Great[12])—whose

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[[11] In essence, vitalism is that doctrine which holds that life involves forces or principles other than those found in physics and chemistry even when these laws and principles are fully known.

[12] It was Alexander who, after his conquest, transferred the center of Greek learning from Greece itself to Alexandria in Egypt. Alexandria already had a long tradition as a center of

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fate it was to synthesize all of the achievements of Greek science and
whose teachings, with the reintroduction of classical knowledge in the 148
13^{th} century, became the basis of the Renaissance scientific culture. It was Aristotle who taught that living organisms are produced by the union of a passive principle “matter” with a vitalistic principle “form,” and that from this union life is spontaneously generated. This conception of the “origin of life” was to concern biology until the beginning of the twentieth

century when modern research was to extirpate the notion of vitalism from science for once and for all.

Apparently the hypothesis of the spontaneous generation of life did not suffer the same fate as did most of the rest of eclipsing Greek science for, according to Oparin, we find the idea passed on from Aristotle, to the Romans, to the neo-Platonic philosophers, to the fathers of the Christian Church and from them to the science of the Renaissance (beginning in the 13th century) which era saw the reintroduction of Greek science as a whole. With the reintroduction of classical knowledge and for several hundred years thereafter, the hypothesis of the spontaneous generation of life continued not only to prevail but was reinforced due to the close association of philosophy with science during that period. In the seventeenth century, the tide began to turn against the hypothesis of spontaneous generation in the form of Redi's experiments which demonstrated that life could not possibly have originated under the conditions and from the sources the dualistic-vitalists postulated. Yet, as the historical record indicates, time and time again the hypothesis of the spontaneous generation of life arose, only as often to have its claims challenged and its evidence demolished by scientific method. Finally, in the nineteenth century, the careful experimental work of Tyndal and Pasteur proved unequivocally that the micro-organisms which seemingly arose from the

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religion which included the concept of monotheism that stretched back for thousands of years. It was hellenistic Hebrew scholars working in this scholarly tradition that Alexander established at Alexandria. They, centuries later, combined their idea of a monotheistic-loving deity with the notion of human sacrifice to the fertility gods yielding the idea of a loving deity who sacrificed his only son to atone for the sins of humanity. This became the central concept of the New Testament. The blending of these two concepts might well have been a deliberate attempt by the highly sophisticated priesthood to capture the barbarians of Northern and Central Europe for civilization. Thus, the rational spirit of Greece—its philosophy and science—surrendered to religion. The Mediterannean peoples were ready for rationalism and science but force, fear, and superstition, in the form of the invading barbarians of the North and symbolized by Alexander the Great, was long to delay their advent—until what is called the Renaissance in the post-Middle Ages. Yet, even in our day, once again with the onset of fear and force we find a retreat to the irrationalism of the past. But unlike the Greeks, we have a choice—the future or the past; the Greeks had virtually none.]

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decomposition of dead material actually were bacterial saprophytes which 149
are always present in the atmosphere.[13]

But the hypothesis of spontaneous generation and especially the vitalistic tradition was not yet ready to yield to scientific knowledge. The dualistic vitalists, deprived of their empirical referents under local conditions, interpreted Pasteur's unequivocal experiments as signifying that life, like matter, was eternal and that science was wrong even to pose the problem of its origin in the first place. (This was an interpretation not placed on his experimental results by Pasteur himself but was due to the vitalistic tradition whose aim it was to show that life was basically different from matter and, hence, its origin should be of not concern to science. This, as we have already noted, is the very tradition rejected by Loeb who proved that living proteins were composed of identifiable proteins.) The proponents of the "eternity of life" hypothesis, pressed for an explanation of the origin of life, proceeded to postulate that life came from another planet via the medium of transporting meteorites or from cosmic dust floating in interstellar space. But thorough analysis of meteorites failed to reveal any sign of life and, in fact, yielded no sign of any kind of biochemical residue. This hypothesis was later abandoned with the discovery that cosmic rays for any structural organizations as large as a living organism and floating on dust particles in interstellar space would have been destroyed by the super-powered cosmic ray particles. The hypothesis of spontaneous generation and the dualistic-vitalistic tradition, deprived of its refuge in outer space, now took another turn; it was postulated that life arose spontaneously in some remote geological era. (By this time scientific research had indicated that life was based on a protein system but statistical calculations indicated that the spontaneous origin of a protein—all at once stroke—was a fantastically improbably event.) Assuming the spontaneous origin of a protein in some far off geological era, the vitalists took the statistical improbability of its spontaneous origin to assert that a deity or some other extra-physical (vitalistic) factor must have been present to cause the synthesis of the first aboriginal protein. (With the coming of the statistical view to science, there have been many theories of spontaneous generation ostensibly without a vitalistic bias, but these theories have almost invariably evoked some thermodynamically improbable event to

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[[13] In the 14th century came the last challenge to man's dominance on this planet in the form of a deadly plague bacteria that destroyed from one-fourth to three-fourths of the entire European population. It was this great pure scientist, Louis Pasteur, who, in the course of the above studies, linked bacteria to the plague and permitted man to control this menace to his health and existence.]

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account for the appearance of the first protein. On closer inspection, these theories reveal themselves to be but another aspect of the dualistic tradition that aims to conceive of life as apart from the rest of the universe instead of an integral part of it. But putting the understanding of the origin of life beyond the realm of scientific knowledge, the vitalist seemingly assumes he achieves his goal. What he really does is to perpetuate ignorance and error in a time when far better knowledge is available.) A book of this nature appeared as late as 1947 in Lecomte du Nouy's *Human Destiny* which was widely lauded by non-scientific readers; it was regarded by scientists in general as employing 19th century concepts and, aside from a few feeble protests, was largely ignored by the scientific community.

The history of the problem of the "origin of life" is a prime example of the differentiation of concepts by scientific method and the establishment of progressively more veridical concepts as knowledge and understanding slowly accumulate. Science started out with the Aristotelian concept of the origin of life but with the refinement of techniques of observation and more important, with the detailed knowledge of the complicated structure and organization of even the simplest of living organisms, science has brought about the selective elimination of both the hypothesis of spontaneous generation and the doctrine of vitalism and has led to the views we shall shortly outline.

2. THE MODERN CONCEPTUALIZATION OF THE PROBLEM

> It was pointed out that many authors assumed the possibility of a spontaneous generation of life on Earth at some remote epoch in the existence of our planet. They generally attributed this to the influence of external conditions prevailing on the Earth's surface at the time, which were totally different from the physical conditions of the present time. The peculiar environmental conditions were held responsible for the spontaneous generation of life and were thus regarded as its immediate cause.
>
> Oparin—*The Origin of Life*

In 1918, the Soviet biochemist Oparin published his now classic book *Origin of Life* in which he used the above (then current) theories of spontaneous generation of life as a point of departure. Oparin pointed out that there was no geological evidence to indicate that the conditions in the geological eras postulated by the above theorists were radically different from those of the present. Many of these theories were placed in the pre-Cambrian period, half a billion years ago, in which the fossil record first appears. Modern paleontology, however, has uncovered evidence which indicates that life existed on this planet for at least a 151
billion years; moreover, to the informed biologist and biochemist, even the simplest organisms of this far-off period had a complexity of structure and organization that must have removed them by hundreds of millions or perhaps billions of years from any beginnings of life. Oparin, thus proceeding to reject the doctrine of spontaneous generation of life in its various modern forms and by synthesizing data and theory from astronomy, astro-physics, geo-chemistry, and geo-physics, paleontology, biochemistry and from various fields of biology itself, puts forth the hypothesis that the appearance of life on this planet was preceded by, and a resultant of, a gradual and long evolution of carbon and nitrogen complexity that can be traced back to its inception on the hottest and, hence, the youngest stars of our galaxy. Thus, prior to Oparin's book, the origin of life was conceived to be due to an event of very short duration but Oparin's hypothesis envisions the origin of life itself to have taken place over an incredibly long span of time requiring hundreds of millions and perhaps billions of years—a process of evolutionary development in which the dynamic features of life slowly and gradually appeared. (We can, for a moment, stop and contrast the panoramas offered as to the concept of the origin of life by scientific method on the one hand, and common sense and dualistic vitalism and religion on the other hand. With science the concept of the origin of life marches with the origin of the stars and the origin of the earth and over vast eons of time—indicating that life is a grand, unique and marvelous phenomenon. With common sense and dualistic-vitalism we march with the immediate present, with reified concepts, and a concept of the origin of life whose empirical referents were, at various times, decaying vegetation, ocean slime and even the dung pile. With religion we march with St. Augustine's proclamation that the origin of life was a creative miracle

ascribable to the deity “Jahweh” whose creation of the universe was calculated to have taken place on Sunday, October 23, in the year 4004 B.C.) The modern viewpoint of science is that there is a bridge rather than a gulf between the non-living and the living realms. “The biologist, unlike the layman, knows no lines of demarcation separating plant life from animal life, nor for that matter living from non-living material, because such differentiations are purely conceptual and do not correspond to reality.”[14]

[[14] It should be carefully understood that scientists in stating that biology must be based on physics and chemistry merely mean that these sciences must furnish the basic explanatory and investigative principles, laws and empirical referents to understand the phenomenon of life and its dynamic characteristics. Scientists, however, do not attempt to resolve the phenomenon of life completely into physical and chemical factors

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In the course of dealing with the problem of the origin of life, a 152
modern theory must account for the origin of the sub-systems (in the course of an evolutionary process of increasing complexity) which manifest the dynamic characteristics of life such as: irritability, motility, reproduction, catabolism and anabolism and features peculiar to living organisms such as the fact that living systems universally synthesize only one instead of both pairs of otherwise identical enantiomorphs or mirror image proteins. In providing the answers to how these dynamic and peculiar properties arose and achieved their organization, in the course of a long evolutionary process, we answer both the “problem of the origin of life” and “what is life” for the sub-systems “originated” or gradually appeared and differentiated in the course of this evolutionary process and life itself is the dynamic organization of these differentiated sub-systems; if this dynamic organization is destroyed, life is destroyed. Most modern theorists, therefore, postulate conceptual schemes synthesizing available data and theory to suggest how these sub-systems and their organization could have appeared and have undergone gradual differentiation in the course of an evolutionary process which first led to the appearance of certain fundamental particles usually conceived to be proteins or nucleoproteins and out of whose intrinsic properties these sub-systems first appeared. Before we briefly discuss four of these views, including the writer’s, we will outline the cosmological aspects of Oparin-Haldane-Bernal-Urey’s theory of the evolutionary increase of carbon complexity, brought up to date by recent research as well as the writer knows it.

3. MICRO EVOLUTION ON THE STARS AND EARTH

According to the theory of the expanding universe (after Gamow), a primordial mass exploded approximately five billion years ago[15] filling space with uniformly hot and dense gas which slowly cooled and congregated

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for this would neglect the creative nature of the process that creates each new level of the hierarchy. On each new level of organization, aggregates with new properties appear which properties and the phenomena they display, would disappear if the organization they were dependent upon were destroyed. Life is a part of the rest of the universe but at the same time, it is the product of a creative process that operates in that universe.

[15] Using the regular pulsation periods of certain stars called Cepheid variables, astronomers are able to calculate their absolute brightness. By comparing this calculated absolute brightness with the apparent (observed) brightness of the same star which brightness varies with the star's distance from us, the astronomer is able to determine the distance of the star or of the galaxy wherein the observed variable star is embedded. Then, utilizing the observation that all galaxies have on the average the same size and the same intrinsic luminosity, the astronomer can estimate the distances of remote galaxies (wherein variable stars can not be resolved) by comparing their mean brightness with that

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into huge dust clouds and out of which eventually differentiated galactic 153
systems such as our galactic group, galaxies such as our Milky Way, and stars and planets such as our sun with its family of planets. According to this theory, all the mass now in the galaxies of the universe was tightly packed together at the "creation" and in a short critical period after the maximum compression of this primordial mass (or, in other words, when this began to expand), the temperature dropped to a billion degrees which permitted the formation of atomic nuclei and the formation of the elements found in the periodic table of chemistry. All elements are postulated to have been created in this short critical period with their relative abundance remaining essentially constant throughout the subsequent five billion years of expansion of the universe.[16]

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of nearby galaxies whose distances can be calculated using the above methods. Then by assuming that all galaxies originated at one central point and by determining their current recession velocities, the astronomer is able to calculate the age of the universe.

In calculating the age of the earth, geologists use the half-life property of various radioactive elements whose nuclei "decay" at fixed rates to form isotopes of the same element (or other elements such as in the decay sequence from uranium to lead) which rates are not influenced by any external factor. By determining the relative proportions of the aboriginal radioactive substances and its decayed residues, and knowing its rate of decay, the geophysicist can determine how long the two elements existed together in a particular specimen of rock. The most recent estimate of the age of the universe and of the earth arrived at by using these above methods is 5.5 billions years and 4.5 billion years respectively.

[16] In 1929, Hubble noted a correlation between the spectrum shift in the spectographically analyzed light coming from various galaxies and the distances of the galaxies from the earth. He noted that if the galaxies are put in progressive order of their distance from the earth there is a systematic shift in the spectrum light bands coming from these galaxies toward the low energy or infra-red end of the electromagnetic spectrum. By analogy to the Doppler effect and because of the fact that the motion of the sun and other near stars is known to alter the wavelengths of light they transmit, most theorists have assumed that the displacement of the spectrum band from distant galaxies indicates motion. This phenomenon of the spectrum band shift has come to be called the red shift and is interpreted by postulating that the galaxies are receding from each other at recession velocities directly proportional to their distances from one another. From these related ideas originated the theory of the expanding universe. For example, if one picks a fixed region in space (after Gamow), say our galaxy, and divides the distance to another galaxy by their respective recession velocity, one always arrives at approximately the same figure no matter which pair of galaxies one chooses. This seems to indicate that all galaxies have been receding from one central point.

The interpretation of the red shift and consequently the theory of the expanding universe and the idea that the universe was “created” in one fell swoop in a cataclysmic explosion has not gone without challenge as the following quote from Gray indicates:

> There is no question of the reality of the red shift...But what does the red shift mean?...It is conceivable that light may simply lose energy in the

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The dust clouds destined to become stars began to rotate and 154
condense under the force of their own gravity. The accompanying contraction resulting from the condensing process resulted in tremendous temperatures in the interior of the stars (between 15 to 30 million degrees C.)-—temperatures which strip atoms of their orbital electrons and

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> the course of travelling millions of years through space. If it did, all its wavelengths would systematically lengthen and all of its spectral lines would shift toward the red or low energy end of the spectrum, even though the source of light was standing still or moving at random. It is a question, therefore, whether the red shift means that the universe is expanding or merely that light energy has grown tired.

Another way of stating Gray’s last sentence is that it is a question whether the universe is expanding or whether we are observing an inter-galactic environment wherein galactic systems are fairly evenly distributed, whose galaxies do not have appreciable recession velocities and from which we receive light which has lost energy in proportion to their distance from us.

It seems to the writer that the expanding universe hypothesis depends upon the basic nature of the photon. Until a few years ago the photon theory of light held that each photon is a localized bundle of electromagnetic energy which under all circumstances travels at the invariant speed of 186,282 m. p. s. and the amount of energy carried by each photon is proportional to its frequency. The significant point of this theory is that it assumes the photon to be an “element”; that is, it assumes no internal changes go on within the photon say, for our purposes, from the time it leaves an atom in some remote galaxy until it reaches our planet. This is the “homogeneous photon” hypothesis. Unitary theory, on the other hand, conceives of the photon to be composed of a concentration of asymmetrical quantum or sub-nuclear size electromagnetic field structures. It might be recalled that unitary theory postulates that the structures of a quantum structured field can pass through a wide asymmetry to symmetry gradient. For the electromagnetic field this range would extend on the one end from cosmic rays through a vast gradient to the long radio waves on the other end and with the visible electromagnetic spectrum falling in between. At particular points in this asymmetry to symmetry gradient, a concentration of these quantum field structures would yield a "particle" such as the photon. These particles would display the following characteristics: The point occupied by the quantum structures (of which the particle or photon is composed) in the asymmetry to symmetry range or gradient of the field, provides the photon with its asymmetry or energy level. The quantum structures being immediately related to the quantum field would share the field’s vibratory nature (which motion is a part of it asymmetrical character); this provides the photon with its frequency rate and since the asymmetry level is identical to the energy level, the frequency of the photon would be directly proportional to its energy level. The unitary tendency of the quantum structures within the photon would tend to cause them to couple with one another and form fewer but larger quantum structural aggregates; the chain of quantum structural aggregates would be the wavelength of the particle. Thus, accepting the speed of the electromagnetic field as invariant and even without postulating a field-like type of space, unitary theory would expect that the unitary tendency would manifest itself in photons travelling for vast eons of time and over vast expanses of space to manifest: a lower energy level, a lower frequency and a longer wavelength. The red shift would be interpreted as demonstrating that the electromagnetic quantum structures, in shifting from visible light to the next step down in the field gradient, display the unitary tendency of the quantum structural field. The red shift is actually displaying the arrow of time characteristic of a universe in process rather than displaying a feature of an expending universe.]

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which are necessary for the initiation of the thermonuclear cyclic chain 155
reactions among carbon, nitrogen, hydrogen and helium nuclei which result in the release of energy which in turn sustains the cyclic chain reactions and keeps the star radiating as a sun. The thermonuclear reactions are actually two in number—worked out by Bethe—called the “carbon-nitrogen” cycle and “proton-proton” cycle. Essentially, in both processes, four hydrogen nuclei or atoms are fused to form a helium nucleus, the loss in mass of the fused hydrogen nuclei being converted into heat and electromagnetic radiation according to Einstein’s formula: $E=mc^2$. This hydrogen (actually an isotope of ordinary hydrogen called deuterium used in man-made explosions), we should note, is the same kind we have in water and air. Scientists have learned to release the nuclear energy in the form of a destructive explosion and in the not too distant future will learn to release the energy for constructive purposes.

Utilizing the Harvard classification of stars, Oparin pointed out that in the hottest stars, ultra-violet, with surface temperatures of approximately 50,000°C., all the elements present are in their ionized state. In the interesting rare O-type stars with surface temperatures of 25,000°C., the element carbon, as well as hydrogen and nitrogen, is present although largely in the ionized state. In the bluish-white or B-type stars (many of which are present in the spiral arms of our galaxy), with temperatures from 20,000° to 15,000°C., the un-ionized carbon appears. In the A-type or white stars, with surface temperatures of 12,000°C., carbon is present mostly as the element but traces of hydrocarbon (CH) are found. Our own sun belongs to the G-type or yellow stars, with surface temperatures of 8,000°C., on which are found di-carbon molecules (C^2), hydrocarbons, and cyanogen (CN). In still cooler stars, M and N types with surface temperatures of 4,000°C., and 2,000°C., carbon and nitrogen compounds are found. (Note the increasing atomic and molecular complexity of carbon and nitrogen with the descending order of temperature.)

By synthesizing geo-physical and geo-chemical knowledge, it is possible to trace how this micro-evolution of carbon and nitrogen complexity continued on earth—again as a function of decreasing temperature.