MISC. PAPERS, PUBLICATIONS AND LECTURES II

ASTRONOMY AND ESCHATOLOGY

By ALBERT G. WILSON

What the astronomer finds when he studies the cosmic disasters which could end the existence of mankind

AFTER PASSING SEVERAL centures in a state of neglect, the ancient art of prophesying is again becoming quite fashionable. This is easily verified by going into any book store and looking over the drove of books currently appearing on such subjects as human destiny, the next million years, the end of the world, etc., etc. The men behind these books, the modern Jeremiahs and Daniels, do not get their source material from handwriting on walls, but from the data science has accumulated concerning the evolutionary processes of stars, rocks, and living organisms. And unlike their ancient predecessors, modern prophets generally avoid forecasting the time and place at which a specific event will occur; they prefer to confine their prophesying to the delineation of rough bounds within which future events must lie.

But in spite of this dilution, prophecy is still as popular as ever. For example, an informal sampling of the thousands who every year visit Palomar to view the world's largest telescope reveals that most of these people look on Palomar as a sort of 20th century Delphi, and are primarily interested in those phases of astronomy which are relevant to the old questions of the purpose, significance, and destiny of man in the universe.

Traditionally such questions as these have been the monopoly of theologians, who have gone into these matters in great detail, even giving a name to the subject—eschatology, the study of the ultimate destiny of man and the world. But with the great progress which science has made during the past few decades in disentangling evolutionary processes, it was inevitable that scientists should invade this field.

Though science has accumulated enough facts to enable certain types of long-range predictions to be made, the picture is still extremely fragmentary and fraught with uncertainties. The largest uncertainties in the predictions do not arise from the incompleteness of science's picture of nature and its evolutionary processes, but from the fact that intelligent life, through its increasing control over nature, can alter the course of future development to conform with its own purposes. If man's control of his environment were complete, and if his goals were well established and intelligently pursued, then a prophet could simply say that the future is circumscribed by these goals and he would be close to being right.

But this is not the case. The present situation is somewhat between that of the past, in which the laws of organic and inorganic evolution alone determined the course of events, and the case described above in which an intelligent organism possessing complete control of itself and its environment determines the future.

This uncertainty factor imposed upon evolutionary development by the impact of intelligence is negligible in those areas of the natural order which lie beyond the control of men. In such areas science may predict the future from natural laws with confidence.

The extraterrestrial universe stands as a region wherein man's influence will in all likelihood forever remain of minute importance. When the limited extent of man's domain is compared to the background of the vast distances of space, it is quite evident that the cosmic stage is almost completely unaffected by what man does on this planet. Even if he should choose to blow the earth to bits, the effects would be of no cosmic consequence. The cosmic order remains indifferent to the aspirations and efforts of man. And though man may eventually completely subdue nature on this planet, his ultimate destiny on earth is circumscribed by the earth's destiny in the cosmic order. And the earth's destiny, in turn, is circumscribed by the evolutionary processes of the universe.

The role of astronomy

It is then the role of astronomy, in science's prophecy of the future for man, to ascertain the earth's probable future as determined by the action of cosmic forces. Specifically, astronomy must seek to discover what the prospects are for the earth's continuing as a suitable abode for life, and study those events which could end the existence of mankind.

It is difficult to imagine life being obliterated by purely terrestrial forces. Cataclysmic earthquakes or meteorological changes which would terminate all human life could occur only as a result of a change in our cosmic environment.

What, then, are the cosmic events whose occurrence would either directly by their own action, or indirectly through the triggering of terrestrial forces, effect a termination of the delicate conditions necessary for life? Two types of such cosmic disasters are conceivable: first, a collision or a close encounter between the earth and another celestial body which could disrupt the earth, or cause gigantic earthquakes, tides, and/or loss of the earth's atmosphere, or perhaps even cause the earth to assume a new orbit which would alter its mean temperature; second, a change in the intensity or nature of radiation received by the earth from the sun, as for example would occur if the sun's luminosity or temperature were to change.

This array of "Sunday Supplement" material has been carefully considered by astronomers and it is now possible to make some evaluations and predictions.

First, the likelihood of collisions and encounters: Every day the earth's mass is increased by several thousand tons through its collisions with meteoritic material. For the most part, this accreted material consists of fine dust or of small grains which, striking the earth's atmosphere with velocities of the order of 30 miles per second, are immediately consumed by friction. Larger particles, weighing up to about 200 pounds, may strike the earth with frequencies of perhaps five or six each day. But this material poses no threat to human life, although a meteorite about the size of a fist struck a garage in Illinois a few years ago and, passing through the top of a car, came to rest in the car seat.

But larger masses frequently strike the earth. Twice during the present century two large meteorite falls have occurred, both fortunately in relatively uninhabited regions. In 1908 a group of large meteorites, estimated as having a mass of a few hundred tons, struck in the Tunguska River region in Siberia. The resulting hot air blast devasted an area of some 3000 square miles. And again in 1947 a fall of comparable size occurred in eastern Siberia. It has been estimated that meteorite falls of this size occur once every 50 to 100 years.

But what is the chance of the earth's colliding with a really large body? Within the past few years about a dozen new asteroids have been found whose orbits cross that of the earth. In October of 1937 one of these objects passed at a distance only three times that of the moon, a near miss on the celestial scale. If the number of these asteroids whose orbits bring them close to the earth is no greater than the number observed up to the present time, E. J. Opik (of the Armagh Observatory in North Ireland) then estimates that a direct hit would occur about once every 30 million years. If, as is more likely, there exist several hundred such asteroids, the estimate is every two million years.

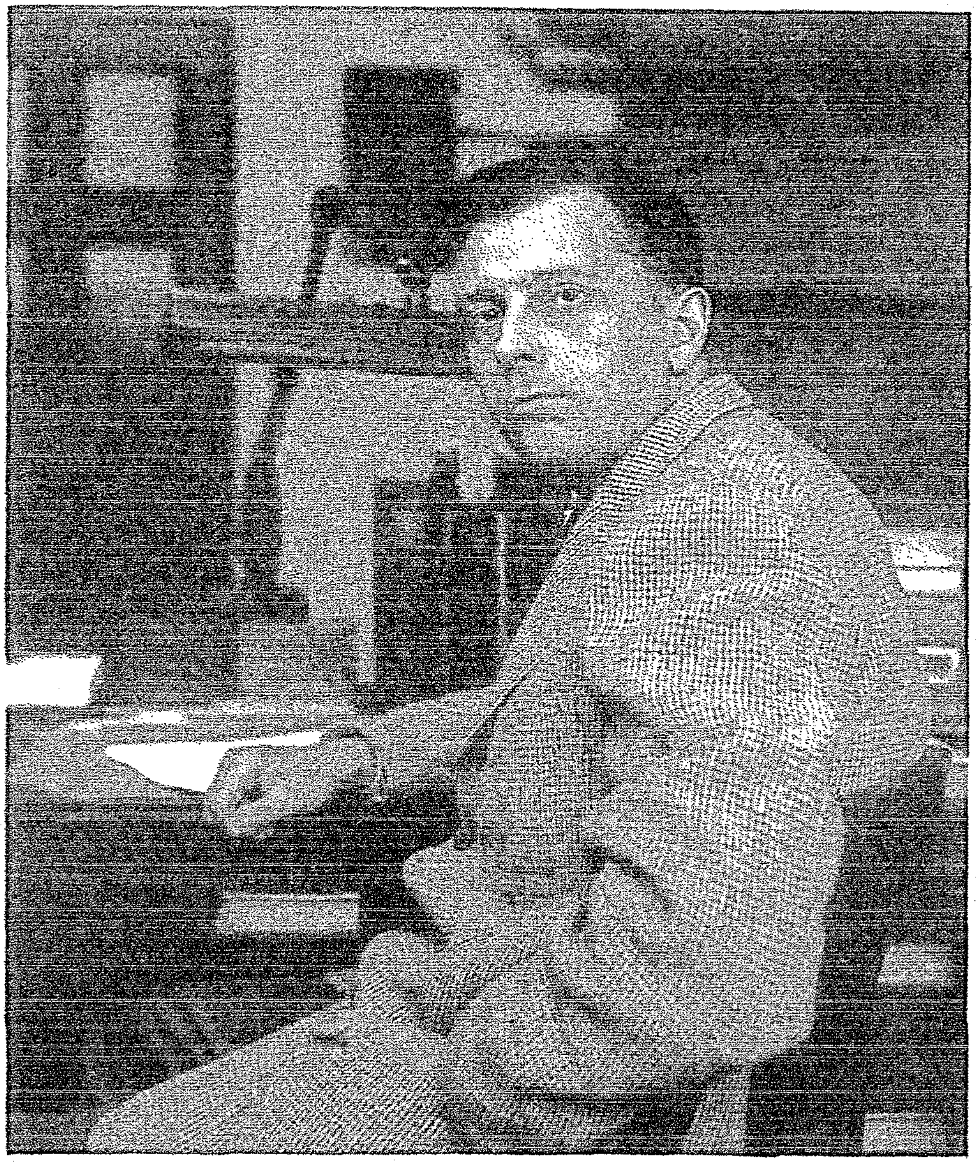
But even a collision with one of these asteroids whose mass is comparable to that of a mountain would not be a total disaster. One recently discovered at Palomar is the smallest yet observed, having an estimated diameter of only a quarter of a mile. A collision with such a body would create a crater perhaps 25 miles across and devastate an area about the size of Texas. This is about the worst that could happen. The orbits of all objects significantly larger are known, and none come near the earth.

Strangers from outer space

This survey takes care of visitors from within the solar system, but what of strangers from interstellar space?

A subject very popular with writers of science fiction is the destruction of the solar system by an encounter with a passing star. This idea used to be popular with astronomers too, not for the destruction of the solar system, but for its creation. A once highly regarded theory would have the planets formed from pieces of the sun torn out by the tidal action of a passing star. But when the probability of such encounters was computed it was found that even among the hundreds of billions of stars in the galaxy, only one or two encounters would have occurred in the 3,000,000,000 years believed to be the galaxy's age.

A remaining possibility in this field of Sunday Supplement disasters is the disintegration of the moon, resulting



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in huge pieces raining down from the sky, leaving the earth dead and pock-marked like its late satellite. Actually this event could happen. Sir George Darwin and Harold Jeffreys have worked out the effects of tidal friction on the stability of the earth-moon system. If the loss of energy through tidal friction continues at the present rate, the month and the mean lunar distance will increase. The maximum will occur when the earth's sidereal day and the month are equal to 47 of our present days. After this time the effect of tidal friction will be to shorten the month and bring the moon closer. When the moon comes within a distance of about 2.4 times the earth's radius it will be torn apart by gravitational attraction, parts falling to the earth and parts going into the formation of rings like Saturn's. If this theory is correct, the date at which the disaster will occur is January first, 100,000,000,000 A. D.

The second type of cosmic event which could affect the existence of life on earth is a change in the sun's integral properties, such as its size, luminosity, or temperature. It is estimated that the atomic furnaces in the sun's interior have been operating for roughly three billion years, helping to maintain the earth's surface at a nearly constant temperature. How much longer the sun's thermo-nuclear reactions will continue to operate and what will happen when the fuel supply is exhausted are problems studied by a branch of theoretical astronomy called "stellar interiors."

The present theories of the structure of the sun do not pretend to be definitive and revisions are constantly being made. However, some zero order ideas concerning the sun's future can be derived from these present models.

One idea is to represent the sun by a model consisting of two zones: a core, whose temperature is sufficiently high to enable thermo-nuclear energy generation processes, such as the carbon cycle, to be operative; and a cooler surrounding envelope in which no energy generation occurs. Initially, a star is composed almost entirely of hydrogen. Within the core the hydrogen is being converted into helium, accompanied by convective currents which keep the substances thoroughly mixed. The envelope, cooler and less disturbed, remains hydrogen rich. As long as there exists an adequate supply of hydrogen in the convective core, there is little change in the star's integral properties. Eventually, however, the hydrogen in the convective core becomes exhausted and within the core there no longer exists nuclear energy production. The central core becomes an extremely hot isothermal core, and at the interface between the core and the hydrogen rich envelope, nuclear energy generation occurs in a thin shell. The isothermal core grows in mass and radius as the thermo-nuclear shell eats its way out through the hydrogen envelope. Chandrasekhar and Schönberg have shown that this process cannot continue until the shell traverses the entire envelope, but must terminate when the isothermal core acquires a mass about 12 percent that of the entire star. During the time of growth of the isothermal core, the star increases somewhat in luminosity, but remains constant in temperature. Schwarzschild and Sandage have developed an evolutionary sequence which comes into operation after the 12 percent limit has been reached. According to their theory, after the isothermal core reaches the critical mass it begins to contract, and through contraction gravitational energy is released. During this phase the total luminosity of the star remains nearly constant, but the envelope becomes greatly extended. Later, when the contracting helium core reaches a much higher temperature a thermo-nuclear reaction in which helium nuclei form carbon becomes operative. Then the star becomes more luminous. After this stage, the star may collapse and become what is known as a white dwarf star. These are stars whose matter is in a degenerative form. The nuclei of the atoms, devoid of their electronic shells, are pressed together, giving densities of the order of tons per cubic inch.

Theories and observational data

These are theories. But some very remarkable agreements have obtained between the consequences of these theories and the observational data. The rate at which a star consumes its hydrogen depends on its mass. The most massive stars burn their fuel at the highest rates and are therefore the most luminous. It follows that massive stars reach the Chandrasekhar-Schönberg limit earlier than less massive ones and start out earlier on an evolutionary track such as that proposed by Schwarzschild and Sandage. In a large aggregate of stars, such as a globular cluster, containing stars of all masses, there should be some which are still consuming the hydrogen in their cores and some which have reached the post-12 percent evolutionary stages. Sandage, at Mount Wilson and Palomar, has studied the luminosities and temperatures of several hundred stars in the globular cluster M3, and finds that all the stars heavier than 1.2 solar masses have taken off on an evolutionary track resembling that predicted by the theory.

If the universe is in the neighborhood of 3,000,000,000 years old, as is derived from several independent observations, and stars down to 1.2 solar masses have consumed the hydrogen available to them, how much time remains before stars of mass 1.0 reach this critical evolutionary stage? Assuming that our sun is of the same age as the stars in M3 and is subject to the same interior processes, then it should continue to radiate more or less as in the past for another four or five billion years.

We may now relax. Based on what has been observed of the cosmic order, it appears that man will not be exterminated by nature before he can perfect the means of doing the job for himself.

Our prophecy may well end here, but it is usual for the prophet to tell first what the future will be, and then tell how this future can be avoided by following his advice. In the present discussion, the future described can be avoided by simply constructing a different sort of stellar model.

Further, according to the best traditions of prophecy, the predictions must be supplemented by exhortations and admonitions. Whereas the predictions themselves are usually well received, the sermons which prophets insist on giving with their forecasts have always made them unpopular. (First-rate prophets have never measured their success by the success of their predictions, but by how unpopular they can become.) Therefore, both in order not to disappoint anyone and to help crystallize reader opinion, I shall conclude with some brief admonitions and exhortations.

A difficult problem of choice

Mankind today is in the position of the child who has spent his life thus far under rigid parental guidance, but now coming of age, suddenly acquires freedom and means. The laws of evolution which developed intelligence on this planet are now at the disposal of that intelligence. The knowledge of the processes of nature and the ability to utilize these processes for his own ends have come to man at the same time. But like the child with newly acquired freedom and means, man is faced with a difficult problem of choice: What shall he do with his control of nature? What ends shall he seek? What destiny should he wish?

Perhaps no better advice can be given than that the child should continue to pursue those ideals and principles laid down by its parents, at least until it acquires sufficient maturity to evaluate all the courses open to it. Man can set no better goal for himself than to emulate the goal of nature: To develop a species with the maximum possible survival potential. In the past, survival potential has depended on adaptability to environment; in the future it will also depend on control of environment. So man must use the understanding and control which his science affords him to increase further his control and to establish those conditions which enhance the long-range survival of his own or derivative species.

The astronomer can only assure man that cosmic forces give him a green light for whatever he plans. To others he gives the task which is the most important of all—to derive from the above general goals and principles the specific rules and patterns for action.

Theory of Structures

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TRAFFIC DENSITY AND SYNAPSE DENSITY

It is suspected that there exists a bound to the ratio of the traffic density in the neighborhood of a synapse to the mean spatial density of the synapses themselves. Such a bound appears as the possible explanation of Zipf's Law and the Scott Effect, relating the brightest star in a galaxy to the number of members of the galaxy.

We shall assume a spherical aggregate of N spherical synapses, each of mass M and radius A. The radius of the aggregate will be taken as R. The mean spatial density of synapses will be

$$(1) \quad \bar{\rho} = \frac{3NM}{4\pi R^3}$$

There is assumed to exist a flow of traffic into or out of each synapse. This traffic may take the form of mass particles, energy packets, information packets, or field effects. For example, if the synapse is a city, the traffic may be aircraft, motor vehicles, or telephone messages. If the synapse is a star, the traffic may be material particles (protons, electrons.....), photons, neutrinos, or gravitons. If the synapse is neural, the traffic may be nerve impulses. This traffic is channeled by the nature of the nexus which connects the various synapses. For a city, the nexuses may be the highways, the rail lines, or the air routes leading into the city. In the nervous system the nexuses are the nerves themselves. For a star, the nexus is the field space surrounding the star. This may be ordinary Euclidean space with the nexus permitting a 4π solid angle or it may have more restrictive geometric and topological properties.

I. 4π Nexus

Let us assume that the energy packets may be represented by equivalent masses m. The flux F of these packets will be proportional to the number n crossing a surface of radius r in time T. If v is the velocity of the packets at the surface r, then the energy flux per unit time per unit area will be,

$$(2) \quad F = \frac{n(mv^2)}{4\pi r^2 T}, \quad [F] = \left[\frac{M}{R^3}\right]$$

From Equations (1) and (2) the ratio γ of the traffic density F to the synapse density ρ is

$$(3) \quad \gamma = \frac{F}{\rho} = \frac{n}{3N}\,\frac{m}{M}\,\frac{R^3}{r^2}\,\frac{v^2}{T} \quad \text{with } [\gamma] = \left[\frac{L^3}{T^3}\right]$$

i.e., the dimensionality of the density ratios is that of a velocity cubed. This dimensionality is bounded in relativistic physics by the quantity c. We therefore assume (4) $\gamma \leq c^3$.

Example:

The traffic is the radiation leaving a star. In this case the energy packet mv^2 becomes $h\nu$. Substituting in (3)

$$\gamma = \frac{nh\nu R^3}{3NMr^2T}$$

But the bolometric luminosity of a star, $L = nh\nu/T$, i.e., the total energy per unit time (take T = 1 sec.), hence

$$\gamma = \frac{L}{3NM}\frac{R^3}{r^2}$$

But r is arbitrary so long as $r \geq A$. We may, therefore, take r as equal to A.

For a star $\frac{GM}{c\ A} < 1/2$. Thus setting r = A, we obtain

$$\frac{2}{3}\frac{GL}{c^2N}\left(\frac{R^3}{A}\right) < \gamma < c^3$$

or

$$(5) \quad L < \frac{3}{2} N \left(\frac{A}{R}\right)^3 \frac{c^5}{G}$$

The expression (5) says that the energy emitted per unit time is less than a constant times the ratio of the volume occupied by the synapses when close packed to the volume actually occupied.

The maximum value of the bound is when the synapses <u>are</u> close packed. In this case we get the maximum luminosity, $\hat{L}$,

$$(6) \quad \hat{L} < \frac{3}{2}\frac{c^5}{G}$$

The right member of expression (5) can be evaluated. Assume the following values:

$\log N = 11.6$

$\log A = 10.84$

$\log R = 21.8$

$\log c = 10.48$

$\log G = -7.16$

Giving $\log L < 38.46$ ergs/sec.

Using the relation,

$$M_{bol} = M_{bol\,\odot} - 2.5 \log (L/L_\odot)$$

with $\log L_\odot = 33.59$ and $M_{bol\,\odot} = 4.72$

(3.90×10^{33} erg/sec) Allen p. 161

$$M_{bol} = -7.45$$

The maximum absolute magnitude of galactic novae is

$M_{pg} \sim -7.5$ (Allen p. 214)

(using $\log L_\odot = 33.59$ and $M_B = 5.41$)

$$M_B = -6.76$$

Hence the bound given by the assumption (4) is in excellent agreement with the maximum value of absolute nagnitude observed in the galaxy. (Super giant stars have $M_{pg} = -6.8$.) Supernovae will be discussed separately.

It is of interest to evaluate the maximum possible luminosity of a radiating object under the assumption (4). This may be done in equation (6). Using the same values as before, we obtain

$$\log \hat{L} < 59.74 \text{ ergs/sec}$$

This is essentially the power value for quasars, according to the cosmic distance hypothesis (Hoyle and Fowler). We thus have as a consistent interpretation of equation (6), that whenever a set of stars are close packed (or one star not a member of any aggregate), that the luminosity can be a maximum and has the value $10^{59.74}$ ergs/sec. This does not permit the mass of the quasar to be derived, but it suggests that quasars may possess a wide range of masses all having essentially the same luminosities. It is accordingly their <u>lifetimes</u> that vary with mass not their luminosities.

Equation (6) may alternately be derived by setting $r = R$, the radius of a galaxy, and using

$$\frac{GNM}{c^2R} < 1/2$$

which gives (6). This would lead to the conclusion that quasars are ~ galactic mass.

Let us evaluate L in equation (5) under the same conditions of N, R, etc., but assume that A, the stellar radius is that of a giant star instead of a main sequence star, i.e., log A ~ $10^{13.2}$ cm

	$R_{\odot}$	cm
ζ Aur	190	$10^{13.12}$cm
32 Cyg	353	$10^{13.37}$cm

From equation (5) we get

$$L < 10^{45.5} \text{ ergs/sec}$$

or

$$M_{bol} \sim -24 \text{ or } -25$$

This corresponds approximately to the luminosities of supernovae. (The values of N and R sould be selected for other galaxies.) It thus appears that supernovae correspond to giant stars and novae to main sequence stars under assumption (4).

Equation (5) shows that for a fixed type of star (A fixed), that the maximum luminosity depends on the density of the galaxy in which it is located, such that the greater the density the brighter the maximum. However, since $2GM \sim c^2R$, the mass increases with R not with R^3. Hence for a given type star, i.e., A, M fixed, $\frac{N}{R^3} \sim \frac{1}{R^2}$. Hence the bigger the galaxies the less luminious their giants. This is consistent with the maximum population II stars being fainter than the population I stars and the elliptical galaxies being more massive than spirals.

GRAVITATIONAL CORRECTIONS TO REDSHIFTS

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GRAVITATIONAL CORRECTIONS TO REDSHIFTS

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For the Robertson-Walker line element, the well known relation between intervals of cosmic time, dt, at the source of a light signal (subscript s) and at the observer (subscript o) in terms of the value of the scale factor R(t) at times of emission t_s and observation t_o, is

$$(1)\quad \frac{dt_o}{R(_o)} = \frac{dt_s}{R(t_s)}$$

(see for example, Tolman [1] p. 391). In accordance with the Schwarzschild line element, the relation between the proper time interval $d\tau$ and the cosmic time interval dt is

$$(2)\quad d\tau = \sqrt{1 - \phi}\, dt$$

where $\phi = GM/c^2r$ is the dimensionless gravitational potential at distance r from mass m (Tolman, loc. cit., p. 212). The ratio of the proper times at the source and observer accordingly is given by

$$(3)\quad \frac{d\tau_o}{d\tau_s} = \frac{\sqrt{1 - 2\phi_o}\; R(t_o)}{\sqrt{1 - 2\phi_s}\; R(t_s)}$$

From the constancy of the ratio $d\tau/\lambda$, the total redshift, $1 + z^* = \lambda_o/\lambda_s$ observed by an observer with potential ϕ_o, at epoch to a ϕ_o of a signal originating from an atom with a potential ϕ_s at epoch t_s will be

$$(4) \quad 1 + z^* = \frac{1 - 2\phi_o}{1 - 2\phi_s} (1 + z_h)$$

where z_h is the "Hubble" redshift or that portion of the redshift attributable to the cosmic expansion.

The ratio of the redshifts of light signals from two sources a and b when seen by the same observer will be

$$(5) \quad \frac{1 + z_a^*}{1 + z_b^*} = \frac{1 - 2\phi_b}{1 - 2\phi_a}^{1/2} \frac{R(t_b)}{R(t_a)} \quad .$$

If the signals are emitted at the same epoch, $t_b = t_a$, then their redshifts will be equal if and only if their local potentials are equal. It follows that if the object belongs to a class of objects, such as normal galaxies, for which ϕ_a is of the order of 10^{-5}, then its Hubble distance, $\Delta = (t_o - t_a)c$, may be approximated from its redshift z_a^* by the usual Hubble relation, $\Delta_h = cz_a^*/H_o$, for which H_o has been calibrated.

If the emitter belongs to a class of objects whose potentials ϕ_b may <u>not</u> be neglected, then, since the luminosity - total redshift relation still obtains, Eq. (5) requires only a distance correction

$$(6) \quad \Delta_c = \frac{c}{H_o} (1 + z_b) (1 - \sqrt{1 - 2\phi_b})$$

to be subtracted from the corresponding distance derived from the usual (low ϕ) Hubble calibration, to give the correct distance.

The potential ϕ_b of an object in terms of its observed redshift z_b and the redshift z_a of an object at the same distance but with negligible potential, is therefore

$$(7) \quad \phi_b - \phi_a = \frac{1}{2} \left[1 - \left(\frac{1 + z_a}{1 + z_b} \right)^2 \right] .$$

If the largest quasar redshifts have cosmic components the same as the largest non-quasar redshift, we independently calculate ϕ_b for quasars to be

$z_a = 0.47$ for 3c295

$z_b = 2.18$ for 3G9

$\delta t = 1.71$

$$\phi_b = \frac{1}{2} \left[1 - \frac{1}{\left(1 + \frac{1.71}{1.47}\right)^2} \right] = 0.393$$

Eq. (4) gives the law of composition for redshifts under the assumption that all contributions other than the gravitational and cosmological can be neglected. If there are significant peculiar motions, a doppler effect will give a non-negligible contribution and should be included in the law of redshift composition. A straight forward calculation based on the results reported by Edelen [2], in conjunction with the above considerations, gives

$$(8) \quad 1+z = \left(\frac{1-u_o/c}{1-u_s/c}\right)\left(\frac{1-v_s^2/c^2}{1-v_o^2/c^2}\right)^{1/2}\left(\frac{1-2\phi_o}{1-2\phi_s}\right)^{1/2}(1+z_h),$$

where the v's denote the peculiar velocities and the u's denote the corresponding line-of-sight components.

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[2] Edelen, D. G. B., "A Cosmological Kinematics with Peculiar Motions," Arch. Rational Mech. Anal. 25, 159-177 (1967).

A. G. Wilson, 11/5/68

FORMS OF HIERARCHY

A type of hierarchy very frequently encountered is the modular hierarchy - the hierarchy whose levels are identified with stable semi-autonomous modules that 1) are composed of lower level sub-modules, and that 2) are assembled into higher level super-modules. Familiar examples are molecules composed of atoms and assembled into crystals, words composed of letters assembled into sentences, platoons composed of squads assembled into companies.

The ubiquity of modular hierarchies and the commonality of their structure intriques us to inquire as to whether they differ only in the specific media in which they are cast or whether there exist several distinct types of modular hierarchies distinguishable through the details of their form and the causes of their origin. It is possible that the resemblance of specific modular hierarchies to one another is only superficial even though it is sufficient to produce a pattern that attracts our attention and causes us to establish a class we name modular hierarchies. Some patterns sufficiently regular to attract our attention may arise from chance - which means that the occurrences of the elements in the pattern are attributable to many different causes. It is only when a high percentage of the members in a class owe their presence to a very small number of causes that the class becomes epistemologically meaningful to us. Otherwise it leads to no economies of representation or relationship and any analogues perceived are likely to be misleading and superficial.

The effort of investigating modular hierarchies finds justification, therefore, on the premise that the large number of specific hierarchies that we encounter will be explainable by a small number of underlying principles. (This premise itself also is a modular hierarchy.) Since the immediate explanation of any specific modular hierarchy is to be given in terms of the known physical, chemical, biological, psychological, or social laws appropriate to the substantive ingredients of the hierarchy, the premise that the large number of different specific hierarchies are explicable in terms of a few basic principles implies the existence of a meta-law underlying or defining the forms of the laws of physics, psychology, sociology, etc.

The concept of meta-law is as old as Plato, but it has not been fruitful or a popular concept in the 20th century. In a pragmatic culture the pursuit is too high risk for most tastes. None-the-less from time to time papers appear concerning for example the properties of the fundamental constants of nature and hint at relations between the microcosmos and the macrocosmos. Some of the best physicists have looked at this question - Schroedinger, Dirac, Eddington, Chandrasekhar, and most recently Gamow. Perhaps these gentlemen display their pragmatism by limiting their search for meta-concepts to infrequent incursions separated by years of solid more immediate research. I raise this only to remind us that in confronting the problem of hierarchy, in seeking relational concepts between the laws of various disciplines, we are possibly quixotically assaulting what may turn out to be a windmill of superficial analogy, or we may possibly obtain some new glimpses of the heights and depths that surround us.

In order to classify the types of modular hierarchies, we may first inquire as to whether the size, the complexity, the limit of the module at any level is determined 1) by the properties of its sub-components, 2) by its environment, or 3) by a combination of both contents and context. And to these possibilities we must add a fourth, that the levels and modules in a hierarchical structure are determined by a meta-relational or transcendental structure that determines the ontological possibilities. In such a meta-structure, the levels in the basic hierarchy themselves become the modules on a single level of the meta-hierarchy, their hierarchical representation in the material world becomes a second level of the meta-hierarchy.

As an example we may think of the energy levels in an atom as an ordinary hierarchy (but not a modular hierarchy). A meta-hierarchy would have the levels of spectral lines, energy levels, and the abstract rule - such as the Balmer sequence that defines the levels.

We may object that this is not a real hierarchy but rather a representational hierarchy. But the essential point is that the levels are not determined by the sub-levels, or the super levels, or both in combination, but by a set of eigen values. We shall need names for these concepts.

Rough Draft
A. G. Wilson
11/13/68

HIERARCHICAL STRUCTURE IN THE COSMOS

Cosmologists have attempted to explain the structure of the universe and the structure in the universe by models which smooth out the distribution matter and ignore the information that is contained in the detailed structure. There are several reasons for ignoring this information. One of these reasons is that most modern views of the world in purisism, positivism, behavorism, reflect the position formalized by John Locke in 1690 in his essay on human understanding. Locke's viewpoint consisted of three general propositions: 1) what is small is more fundamental than what is large; 2) what is earlier in development is more basic than what comes later; and 3), what is objective and visible is more important than what is not. These statements seem natural or self-evident to most of us who have been brought up in a scientific culture. They constitute the nucleus of what is now called reductionism; that is, the large and the complex is built up from the small and the elemental, and the properties of the large are explicable in terms of the smaller parts of which the large is composed. This view has met with little to contradict it and married to our expertise and analytical decomposition, it has proven highly successful in accounting for much of what we have observed in the physical world.

But there are some things missing and there are many contradictions. Germane to this problem of the parts and the wholes and their structure on levels and in hierarchies is the nature of the relationship between levels; and the relationship between levels brings us to the question of communication within levels and between levels.

There are many features of the visible sample of the universe that suggests the existence of a high order of regularity spanning forty orders of magnitude in size and over eighty orders of magnitude in mass. This micro to cosmic regularity is undoubtedly of central significance to the origin and nature of the universe, yet the information contained in these regular features is for various reasons ignored by most cosmologists.

Existing physical theories are hard put to explain the origin of the observed structure, the hierarchy of cosmic bodies - qualitatively, much less quantitatively. Success to date has been limited, although many highly admirable attempts have been made.

It is my thesis that we must search for a new approach to the problem of the origin of cosmic structure and that what we learn of the general properties of hierarchical structure from specific examples of various hierarchies may lead us to that new approach. With this as the ultimate objective, I would like to begin by examining some fundamental aspects of hierarchical structure.

ASTRONOMY AND ESCHATOLOGY

By ALBERT G. WILSON

What the astronomer finds when he studies the cosmic disasters which could end the existence of mankind

After passing several centuries in a state of neglect, the ancient art of prophesying is again becoming quite fashionable. This is easily verified by going into any book store and looking over the drove of books currently appearing on such subjects as human destiny, the next million years, the end of the world, etc., etc. The men behind these books, the modern Jeremiahs and Daniels, do not get their source material from handwriting on walls, but from the data science has accumulated concerning the evolutionary processes of stars, rocks, and living organisms. And unlike their ancient predecessors, modern prophets generally avoid forecasting the time and place at which a specific event will occur; they prefer to confine their prophesying to the delineation of rough bounds within which future events must lie.

But in spite of this dilution, prophecy is still as popular as ever. For example, an informal sampling of the thousands who every year visit Palomar to view the world's largest telescope reveals that most of these people look on Palomar as a sort of 20th century Delphi, and are primarily interested in those phases of astronomy which are relevant to the old questions of the purpose, significance, and destiny of man in the universe.

Traditionally such questions as these have been the monopoly of theologians, who have gone into these matters in great detail, even giving a name to the subject—eschatology, the study of the ultimate destiny of man and the world. But with the great progress which science has made during the past few decades in disentangling evolutionary processes, it was inevitable that scientists should invade this field.

Though science has accumulated enough facts to enable certain types of long-range predictions to be made, the picture is still extremely fragmentary and fraught with uncertainties. The largest uncertainties in the predictions do not arise from the incompleteness of science's picture of nature and its evolutionary processes, but from the fact that intelligent life, through its increasing control over nature, can alter the course of future development to conform with its own purposes. If man's control of his environment were complete, and if his goals were well established and intelligently pursued, then a prophet could simply say that the future is circumscribed by these goals and he would be close to being right.

But this is not the case. The present situation is somewhat between that of the past, in which the laws of organic and inorganic evolution alone determined the course of events, and the case described above in which an intelligent organism possessing complete control of itself and its environment determines the future.

This uncertainty factor imposed upon evolutionary development by the impact of intelligence is negligible in those areas of the natural order which lie beyond the control of men. In such areas science may predict the future from natural laws with confidence.

The extraterrestrial universe stands as a region wherein man's influence will in all likelihood forever remain of minute importance. When the limited extent of man's domain is compared to the background of the vast distances of space, it is quite evident that the cosmic stage is almost completely unaffected by what man does on this planet. Even if he should choose to blow the earth to bits, the effects would be of no cosmic consequence. The cosmic order remains indifferent to the aspirations and efforts of man. And though man may eventually completely subdue nature on this planet, his ultimate destiny on earth is circumscribed by the earth's destiny in the cosmic order. And the earth's destiny, in turn, is circumscribed by the evolutionary processes of the universe.

The role of astronomy

It is then the role of astronomy, in science's prophecy of the future for man, to ascertain the earth's probable future as determined by the action of cosmic forces. Specifically, astronomy must seek to discover what the prospects are for the earth's continuing as a suitable abode for life, and study those events which could end the existence of mankind.

It is difficult to imagine life being obliterated by purely terrestrial forces. Cataclysmic earthquakes or meteorological changes which would terminate all human life could occur only as a result of a change in our cosmic environment.

What, then, are the cosmic events whose occurrence would either directly by their own action, or indirectly through the triggering of terrestrial forces, effect a termination of the delicate conditions necessary for life? Two types of such cosmic disasters are conceivable: first, a collision or a close encounter between the earth and another celestial body which could disrupt the earth, or cause gigantic earthquakes, tides, and/or loss of the earth's atmosphere, or perhaps even cause the earth to assume a new orbit which would alter its mean temperature; second, a change in the intensity or nature of radiation received by the earth from the sun, as for example would occur if the sun's luminosity or temperature were to change.

This array of "Sunday Supplement" material has been carefully considered by astronomers and it is now possible to make some evaluations and predictions.

First, the likelihood of collisions and encounters: Every day the earth's mass is increased by several thousand tons through its collisions with meteoritic material. For the most part, this accreted material consists of fine dust or of small grains which, striking the earth's atmosphere with velocities of the order of 30 miles per second, are immediately consumed by friction. Larger particles, weighing up to about 200 pounds, may strike the earth with frequencies of perhaps five or six each day. But this material poses no threat to human life, although a meteorite about the size of a fist struck a garage in Illinois a few years ago and, passing through the top of a car, came to rest in the car seat.

But larger masses frequently strike the earth. Twice during the present century two large meteorite falls have occurred, both fortunately in relatively uninhabited regions. In 1908 a group of large meteorites, estimated as having a mass of a few hundred tons, struck in the Tunguska River region in Siberia. The resulting hot air blast devasted an area of some 3000 square miles. And again in 1947 a fall of comparable size occurred in eastern Siberia. It has been estimated that meteorite falls of this size occur once every 50 to 100 years.

But what is the chance of the earth's colliding with a really large body? Within the past few years about a dozen new asteroids have been found whose orbits cross that of the earth. In October of 1937 one of these objects passed at a distance only three times that of the moon, a near miss on the celestial scale. If the number of these asteroids whose orbits bring them close to the earth is no greater than the number observed up to the present time, E. J. Opik (of the Armagh Observatory in North Ireland) then estimates that a direct hit would occur about once every 30 million years. If, as is more likely, there exist several hundred such asteroids, the estimate is every two million years.

But even a collision with one of these asteroids whose mass is comparable to that of a mountain would not be a total disaster. One recently discovered at Palomar is the smallest yet observed, having an estimated diameter of only a quarter of a mile. A collision with such a body would create a crater perhaps 25 miles across and devastate an area about the size of Texas. This is about the worst that could happen. The orbits of all objects significantly larger are known, and none come near the earth.

Strangers from outer space

This survey takes care of visitors from within the solar system, but what of strangers from interstellar space?

A subject very popular with writers of science fiction is the destruction of the solar system by an encounter with a passing star. This idea used to be popular with astronomers too, not for the destruction of the solar system, but for its creation. A once highly regarded theory would have the planets formed from pieces of the sun torn out by the tidal action of a passing star. But when the probability of such encounters was computed it was found that even among the hundreds of billions of stars in the galaxy, only one or two encounters would have occurred in the 3,000,000,000 years believed to be the galaxy's age.

A remaining possibility in this field of Sunday Supplement disasters is the disintegration of the moon, resulting

Dr. Albert G. Wilson, Staff Member, Mount Wilson and Palomar Observatories.

in huge pieces raining down from the sky, leaving the earth dead and pock-marked like its late satellite. Actually this event could happen. Sir George Darwin and Harold Jeffreys have worked out the effects of tidal friction on the stability of the earth-moon system. If the loss of energy through tidal friction continues at the present rate, the month and the mean lunar distance will increase. The maximum will occur when the earth's sidereal day and the month are equal to 47 of our present days. After this time the effect of tidal friction will be to shorten the month and bring the moon closer. When the moon comes within a distance of about 2.4 times the earth's radius it will be torn apart by gravitational attraction, parts falling to the earth and parts going into the formation of rings like Saturn's. If this theory is correct, the date at which the disaster will occur is January first, 100,000,000,000 A. D.

The second type of cosmic event which could affect the existence of life on earth is a change in the sun's integral properties, such as its size, luminosity, or temperature. It is estimated that the atomic furnaces in the sun's interior have been operating for roughly three billion years, helping to maintain the earth's surface at a nearly constant temperature. How much longer the sun's thermo-nuclear reactions will continue to operate and what will happen when the fuel supply is exhausted are problems studied by a branch of theoretical astronomy called "stellar interiors."

The present theories of the structure of the sun do not pretend to be definitive and revisions are constantly being made. However, some zero order ideas concerning the sun's future can be derived from these present models.

One idea is to represent the sun by a model consisting of two zones: a core, whose temperature is sufficiently high to enable thermo-nuclear energy generation processes, such as the carbon cycle, to be operative; and a cooler surrounding envelope in which no energy generation occurs. Initially, a star is composed almost entirely of hydrogen. Within the core the hydrogen is being converted into helium, accompanied by convective currents which keep the substances thoroughly mixed. The envelope, cooler and less disturbed, remains hydrogen rich. As long as there exists an adequate supply of hydrogen in the convective core, there is little change in the star's integral properties. Eventually, however, the hydrogen in the convective core becomes exhausted and within the core there no longer exists nuclear energy production. The central core becomes an extremely hot isothermal core, and at the interface between the core and the hydrogen rich envelope, nuclear energy generation occurs in a thin shell. The isothermal core grows in mass and radius as the thermo-nuclear shell eats its way out through the hydrogen envelope. Chandrasekhar and Schönberg have shown that this process cannot continue until the shell traverses the entire envelope, but must terminate when the isothermal core acquires a mass about 12 percent that of the entire star. During the time of growth of the isothermal core, the star increases somewhat in luminosity, but remains constant in temperature. Schwarzschild and Sandage have developed an evolutionary sequence which comes into operation after the 12 percent limit has been reached. According to their theory, after the isothermal core reaches the critical mass it begins to contract, and through contraction gravitational energy is released. During this phase the total luminosity of the star remains nearly constant, but the envelope becomes greatly extended. Later, when the contracting helium core reaches a much higher temperature a thermo-nuclear reaction in which helium nuclei form carbon becomes operative. Then the star becomes more luminous. After this stage, the star may collapse and become what is known as a white dwarf star. These are stars whose matter is in a degenerative form. The nuclei of the atoms, devoid of their electronic shells, are pressed together, giving densities of the order of tons per cubic inch.

Theories and observational data

These are theories. But some very remarkable agreements have obtained between the consequences of these theories and the observational data. The rate at which a star consumes its hydrogen depends on its mass. The most massive stars burn their fuel at the highest rates and are therefore the most luminous. It follows that massive stars reach the Chandrasekhar-Schönberg limit earlier than less massive ones and start out earlier on an evolutionary track such as that proposed by Schwarzschild and Sandage. In a large aggregate of stars, such as a globular cluster, containing stars of all masses, there should be some which are still consuming the hydrogen in their cores and some which have reached the post-12 percent evolutionary stages. Sandage, at Mount Wilson and Palomar, has studied the luminosities and temperatures of several hundred stars in the globular cluster M3, and finds that all the stars heavier than 1.2 solar masses have taken off on an evolutionary track resembling that predicted by the theory.

If the universe is in the neighborhood of 3,000,000,000 years old, as is derived from several independent observations, and stars down to 1.2 solar masses have consumed the hydrogen available to them, how much time remains before stars of mass 1.0 reach this critical evolutionary stage? Assuming that our sun is of the same age as the stars in M3 and is subject to the same interior processes, then it should continue to radiate more or less as in the past for another four or five billion years.

We may now relax. Based on what has been observed of the cosmic order, it appears that man will not be exterminated by nature before he can perfect the means of doing the job for himself.

Our prophecy may well end here, but it is usual for the prophet to tell first what the future will be, and then tell how this future can be avoided by following his advice. In the present discussion, the future described can be avoided by simply constructing a different sort of stellar model.

Further, according to the best traditions of prophecy, the predictions must be supplemented by exhortations and admonitions. Whereas the predictions themselves are usually well received, the sermons which prophets insist on giving with their forecasts have always made them unpopular. (First-rate prophets have never measured their success by the success of their predictions, but by how unpopular they can become.) Therefore, both in order not to disappoint anyone and to help crystallize reader opinion, I shall conclude with some brief admonitions and exhortations.

A difficult problem of choice

Mankind today is in the position of the child who has spent his life thus far under rigid parental guidance, but now coming of age, suddenly acquires freedom and means. The laws of evolution which developed intelligence on this planet are now at the disposal of that intelligence. The knowledge of the processes of nature and the ability to utilize these processes for his own ends have come to man at the same time. But like the child with newly acquired freedom and means, man is faced with a difficult problem of choice: What shall he do with his control of nature? What ends shall he seek? What destiny should he wish?

Perhaps no better advice can be given than that the child should continue to pursue those ideals and principles laid down by its parents, at least until it acquires sufficient maturity to evaluate all the courses open to it. Man can set no better goal for himself than to emulate the goal of nature: To develop a species with the maximum possible survival potential. In the past, survival potential has depended on adaptability to environment; in the future it will also depend on control of environment. So man must use the understanding and control which his science affords him to increase further his control and to establish those conditions which enhance the long-range survival of his own or derivative species.

The astronomer can only assure man that cosmic forces give him a green light for whatever he plans. To others he gives the task which is the most important of all—to derive from the above general goals and principles the specific rules and patterns for action.

Table 1. COMT ACTIVITY IN THE VARIOUS ORGANS EXAMINED

	C.p.m. in ethyl acetate extract	Specific activity (mμmoles/mg protein/h)
Liver (supernatant fraction)	7,505	50·6
Skeletal muscle (rat)	955	1·33
Skeletal muscle (mouse)	545	0·82
Boiled rat skeletal muscle	5	—
Lung	1,265	1·65
Heart	885	1·34

After incubation, 10 μl. of the mixture was transferred from each tube to 0·5 ml. of 0·13 molar borate buffer, *p*H 10. After extraction by 5 ml. ethyl acetate and centrifugation, 2 ml. of the upper phase was used to determine the radioactivity in a liquid scintillation counter ('Tricarb', type 314 *X*). The 2 ml. are mixed with 10 ml. of scintillating fluid (4 g PPO, 0·1 g POPOP, toluene q.s.p. 1,000, 400 ml. ethanol).

The results of the various determinations are given in Table 1.

Under the conditions used here, ethyl acetate extracted half the methoxyadrenaline present in the sample. In the control preparations, ethyl acetate extracts contained little radioactivity. The small radioactive fraction obtained in controls can be explained by the untransformed *S*-adenosyl methionine and by degradation products. This radioactivity does not interfere significantly in determinations (0·3 per cent).

To test whether the enzyme transformation actually occurred, 100 μl. was spotted after each incubation on Whatman No. 3 *MM* paper with 3 μg methoxyadrenaline as carrier. The sample was chromatographed in an ascending system of butanol, glacial acetic acid and water (80 : 20 : 20). The bands were then dried and their radioactivity analysed (Packard chromatogram scanner). An important radioactive peak was found in all chromatograms of incubation residues from supernatant organ fractions (Fig. 1 *A*; rat muscle). The R_F of the radioactive zone corresponds with that of methoxyadrenaline. In chromatograms effected with controls, however, no radioactivity appeared in this zone (Fig. 1 *B*). A peak of radioactivity of intermediate R_F can also be seen on all chromatograms. It has been ascribed to methionine

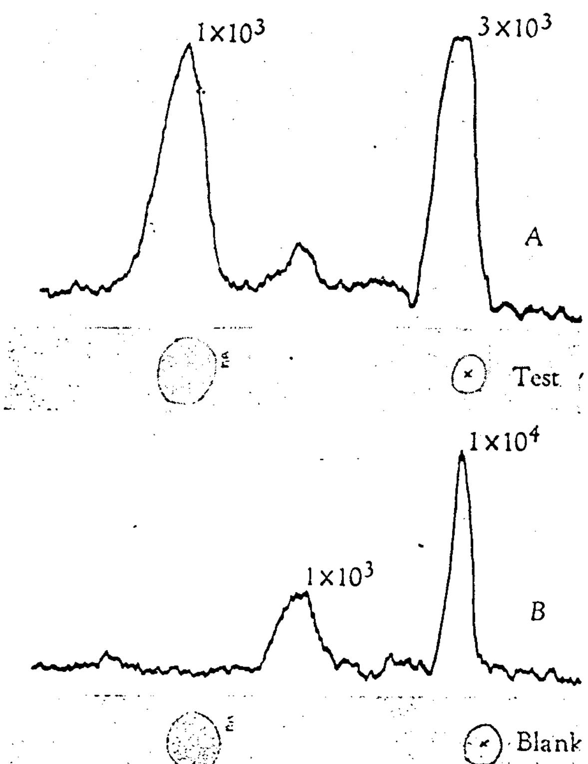

Fig. 1.

resulting from a slight degradation of *S*-adenosylmethionine at 37° C.

We were careful to ensure that the activity found was not caused by contamination from the blood. No COMT was found in rat serum. The activity of COMT in muscles was not modified by partial inhibition, but we were unable to show any inhibitory effect of muscle preparations on the enzyme extracted from rat liver.

These results show that skeletal muscles in rats and mice contain a considerable quantity of COMT. The results are indirectly confirmed by the results of Tomita *et al.*[2], who found COMT activity in rabbit skeletal muscle. A similar enzyme, but with a more limited specificity, GEP-*o*-methyltransferase (GEP, guanidoethyl phosphate) has been found in an Annelid (*Ophelia neglecta* Schneider) and localized only in muscle tissue[3].

We have also attempted to demonstrate MAO activity. This enzyme, too, is present in skeletal muscle tissue. A determination using the method of Weissbach *et al.*[4] showed a mean value of 7·7 mμmoles cynuramine transformed per mg protein per hour. The origin of the COMT and MAO in skeletal muscle, and the eventual action of these enzymes in muscular function, remains to be explained.

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GENERAL

Dimensionless Physical Constants in Terms of Mathematical Constants

IT is of interest to note that a simple logarithmic expression involving π may be used to obtain the values of two basic dimensionless physical constants within the experimental uncertainty. The Sommerfeld fine structure constant, $\alpha_0 = 2\pi e^2/hc$, and the ratio of Coulomb to gravitational forces $S = e^2/Gm_pm_e$, where m_p, m_e are the masses of the proton and the electron, respectively, are given by $\alpha = 1/(2+w)$ and $S = 2^w/2\pi^2$.

When $w = \pi^4 \ln 4$, the numerical value of $(2+w)$ to nine significant figures is 137·037664. The present measured values[1] for α^{-1} are

137·0388 + 0·0006	Triebwasser, Dayhoff, Lamb
137·0370	Robiscoe
137·0352	Hyperfine splitting in hydrogen
137·0388 ± 0·0013	Hyperfine splitting in muonium
137·0381 ± 0·0032	Electron magnetic moment anomaly
137·0361	Hughes

The numerical value of $\log_{10}(2^w/2\pi^2)$ is 39·355058. The present indicated empirical value of $\log_{10} S$ lies between the three standard deviations of the mean, that is, between 39·357 and 39·355, the largest part of the uncertainty being in the value of G. The three standard deviations of the mean of S are 2·27 (01) × 10^{39} and 2·25 (46) × 10^{39}, whereas $2^w/2\pi^2 = 2{\cdot}264947 \times 10^{39}$.

From these two relations a third numerical relation

$$G = \frac{8\pi^2}{2^{1/\alpha}} \cdot \frac{e^2}{m_pm_e}$$

may be derived. This equation, giving G in terms of other fundamental physical constants, is independent of w.

Although one may be reminded of relationships derived by the late Sir Arthur Eddington, the quantity w used here has no known physical basis and the approximations are quite possibly fortuitous.

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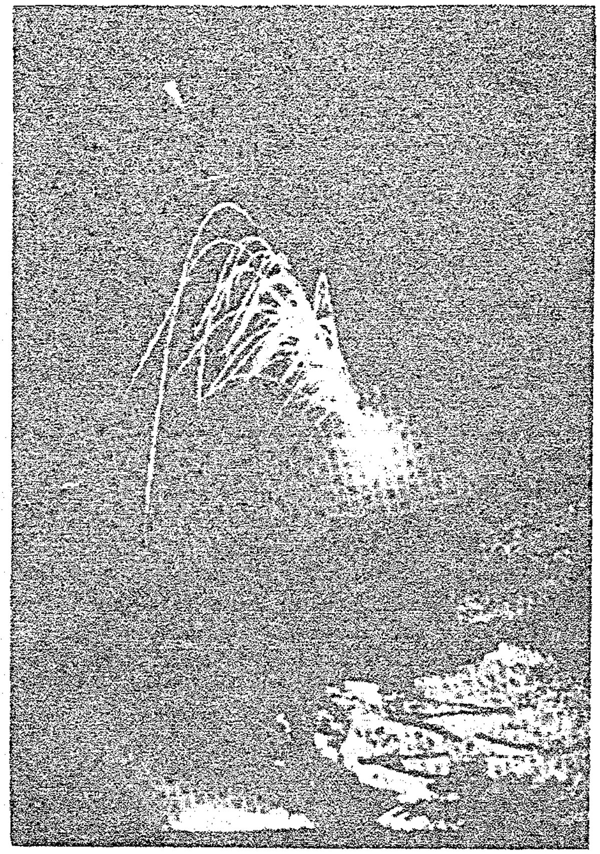
THE ANNIVERSARY OF A HISTORIC FAILURE

by Albert G. Wilson



A test of artificial meteors—December 16, 1946.

The pages of *Engineering and Science* magazine provide a historical record of many of the achievements and successes of Caltech researchers—alumni and staff. The dead ends and failures rarely appear in print. Fortunately for publication costs, few people want their failures recorded. However, now and then certain types of failures become historic and deserve a place in the record.

The 17th of December this year marks the 20th anniversary of such a historic failure—the first attempt to launch particles into space with escape velocity. A team of Caltech men headed by Fritz Zwicky, professor of astronomy, in cooperation with Army Ordnance, the Johns Hopkins Applied Physics Laboratory, the Harvard College Observatory, and the New Mexico School of Mines, put together a project in White Sands, New Mexico, combining the hardware components available in 1946 in a way which, theoretically, would launch a few pellets in orbit about the earth or throw them off into interplanetary space. Two marginal devices and one valid motivation made the attempt worthwhile. The devices were the V-2 rocket and the Monroe rifle grenade or "shaped charge." The motivation was to generate a shower of artificial meteors in order to calibrate the luminous efficiency of natural meteors.

The possibility of throwing something up that would not come down again fired the imagination. Although there had been 16 postwar V-2 rocket firings, this was to be first night firing of a V-2 in the United States. In those days the launching of a V-2, with or without an instrument on board, was as much news as the launching of a Gemini today. Dr. Zwicky, who designed the experiment, placed the event in historical context: "We first throw a little something into the skies, then a little more, then a shipload of instruments—then ourselves."

A V-2 rocket was equipped with six 150-gram penolite shaped charges with 30-gram steel inserts. These were set to fire at times after launching that would eject the slugs of molten steel at heights of approximately 50, 65, and 75 kilometers. At these heights the ejection velocities of from 10 to 15 km/sec would place the slugs either in orbit or on

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escape trajectory. The ultimate fate of a slug would depend on its mass and velocity. Most would be meteors, but some might not be consumed.

To determine the destinies of the meteors, a battery of K4 aerial cameras equipped with rotating shutters was scattered over the White Sands Proving Range. One of these was equipped with a transparent objective grating to obtain spectra of the V-2 exhaust jet and the luminous artificial meteors launched. The sites were selected to acquire optimal triangulation data. In addition the Caltech eight-inch Schmidt camera was removed from its usual house at Palomar and set up a few miles south of the launch site to photograph the flight of the V-2 rocket and of the particles ejected from the shaped charges. Astronomers at nearby observatories with wide angle telescopes also focused in on the firing.

As this 17th postwar V-2 left the pad at $22^h\ 12^m\ 49^s$ mountain standard time, expectations were high. There was a feeling that history was being made. There was also the anxiety that has become as much part of every launching as the countdown. (The 16th rocket, fired a few days earlier, had tilted on lift-off and travelled 131 miles horizontally.) Lifting slowly, No. 17 filled the whole range with sound and, falling upward, held true to its course—5° tilt north. The shutters clicked and telescopes tracked—then burnout. But the rocket could still be followed by the red glow from its exhaust vanes. The time came and passed for the three pairs of charge detonations. Nothing was seen. The rocket mounted to a new record of 114 miles, then returned to earth.

Films were hastily developed in hope of seeing on the emulsion what could not be seen in the sky. But there were no trails. Tests of the charges made on previous evenings had been in every way successful. Had the charges fired, but been undetected? Subsequent investigations have not solved the mystery of just what did happen.

Just as man's first attempts at flight in the atmosphere failed, the first attempt to reach space with a chance of succeeding also failed. It is significant, however, that whereas the span between the first attempts to fly and the first successful flight is measured in centuries, the span between the first attempt to achieve orbital velocity and the successful orbiting of Sputnik was only one decade. Those who participated directly and indirectly in this experiment, though failing to launch the space age on the night of December 17, 1946, have to their credit an important contribution leading to later triumphs. Zwicky's idea was ultimately vindicated, when success crowned the *second* experimental firing of shaped charges from a rocket on October 16, 1957—twelve days after Sputnik.

Clumping of Cluster Redshifts

The nebular (B) spectrograph with the 100-inch telescope has been used by Dr. A. G. Wilson of the Douglas Aircraft Company to observe the redshifts of bright galaxies in nearby clusters. The purpose of the program is to study the spatial distribution of clusters and to investigate suspected regularities in redshift distributions. The nearby clusters so far observed appear not to be randomly distributed. Mean redshifts of clusters beyond the local Virgo–Ursa Major complex and closer than $z = \delta\lambda/\lambda = 0.09$ appear to possess an unexplained regularity that is closely represented by the one-parameter expression

$$\log_{10} z = -\frac{5}{3} + \frac{n}{4}\log_{10} 2 \qquad n = -1, 0, 1, 2, \ldots, 9$$

For most of the clusters in this range, the relative error, $\delta z/z$, of this formula is less than 1%. More distant clusters appear to be nonuniformly distributed, their redshifts showing a nonstatistical banded distribution. Comparison with Schmidt's redshifts of radio sources shows the existence of a similar banded distribution for the radio sources. Wilson suggests that these distributions may be indicative of the clustering of both clusters and radio sources on a larger scale than that of any currently recognized aggregate of matter.

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CHAPTER 2

MORPHOLOGY AND MODULARITY

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The morphological approach is not only a methodology for solving problems, it is an attitude toward problems. It is an attitude that demands that no problem be considered in isolation of all relevant contexts. It is an attitude that would try to take off our customary blinders before looking at the problem. It tries to obtain an unfiltered view by comparing views through as many different filters as possible. It looks for all possible solutions by also looking at many of the impossible ones. It attempts fresh views of the problem by looking at similar problems. In short, the morphological approach uses whatever methodologies are available to arrive at the most complete and unbiased representation of the structure of the problem and its solutions as is possible.

This attitude will be recognized as basic not only to the morphological method but to some of the other methodologies described in this symposium. In order that ground previously covered not be repeated, this paper will restrict discussion to examples of two important methodological procedures not hitherto considered. The first of these is an exercise toward the development of useful non-mathematical modeling. The second is an example of

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hypothesis generation through morphological analogy.

I. NON-QUANTIFIED MODELS

One of the extensions of problem solving capability needed for many important problems today is the development of methodologies for handling problems not easily quantified.

It frequently happens that many of the parameters that we know have relevance to a problem are not readily amenable to measurement or quantification. There is a tendency to concentrate on those parameters for which numerical values are obtainable and to neglect those parameters which are not measurable even though their relative weight in the problem may be high. To offset this tendency a methodology is required by which we are somehow able to incorporate the effects of those parameters which cannot be quantifiably represented. Examples are esthetic, ethical and moral values, psychological factors, and unquantifiable requirements of the future.

When standard numerical methodologies fail, or when non-quantifiable factors must be taken into account, a relevance type morphological procedure proposed by Alexander and Manheim may be applicable. The idea is based on the predicationthat any form or structure may be thought of as resulting from the interaction of a set of abstract forces or tendencies. These are general, not merely physical, forces. They may be quantifiable or unquantifiable, with no restriction on their variety. The totality of these forces generates a solution that reflects the contribution of each. The problem is to find a representation of the forces that allows them to be combined. Said in another way the problem is posed in an abstract space in which the representative elements are the generalized forces. The aggregate of such elements defines a form. If the aggregate is complete and in balance, the form becomes a stable object or solution.

A concrete example of this approach attempted by Alexander and Manheim may be found in the MIT report entitled, "The Use of Diagrams in Highway Route Location." Alexander and Manheim's problem was to locate the route for a freeway covering a 20 mile stretch in Massachusetts starting at Springfield and ending somewhere near North-hampton. They first morphologically derived all of the individual abstract forces whose interaction would determine the path which the freeway should take. Shown on Table 1 of the freeway design parameters, is the goal or objective of the study, which was a freeway to meet major current traffic desires. In this case the aggregate solution was restricted to be a new freeway, rather than a morphological examination of all possible solutions to meet current traffic requirements. This new freeway had to be considered in the context of its interaction with existing freeway systems and in support of the competition with other transportation systems. Future transportation systems as visualized also had to be given representation. However, the largest number of constituent forces fall into two classes; those which determine the internal structure and behavior of the freeway, and those reflecting the interaction of the freeway with the environment. Table 2 of freeway design parameters shows the decomposition of the internal and environmental parameters into their different values. Under internal parameters, are first the construction parameters including earthwork costs, bridge costs, pavement and subgrade costs, and construction interference. Secondly, there are economic factors: land costs, public financial losses, user costs, obsolescence; and thirdly, operational factors: travel time, local accessability, safety, maintenance, and self-induced congestion.

The environmental parameters may be divided into physical, economic and esthetic. The physical environment includes questions of drainage patterns and catchment areas, effects of weather, air pollution. The economic environmental factors include the effect of the freeway on regional and local land development, public and private losses, such as the obliteration of historical, commercial, or other structures due to the routing of the freeway. Finally, esthetic con-

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siderations such as eyesores and noise must be considered.

Certainly not all of these parameters are easily measured, nor is it even possible to assign numerical values to some of them. Alexander and Manheim developed a method by which each factor would be reflected in the overall selection of the freeway route. They employed a modification of the method Zwicky has termed composite analytical photography. Each of the modular forces listed on the charts by itself favors a particular location for the highway. For example, consider earth work costs. The requirement to minimize earth work favors the location of the freeway in areas where the land is relatively flat. A transparent map is made in which the flat portions are rendered dark and the hilly portions light, the degree of hilliness and flatness can be represented by a corresponding density or opacity on the map.

Thus the tendency or force to locate the freeway in accordance with the minimization of earth work costs is to put the path in regions of maximum density on the map. Similarly for each of the other forces. If a separate transparent map of each of the forces which contributes to the location of the freeway is made so that the dark area favors location and the light area rejects location; if the forces are then combined through the process of composite photography, the resulting density on the photograph made from superimposing all the individual photographs would give the location that all the forces in combination tend to favor. The darkest strip would mark the best route.

By using this method, those parameters or forces which cannot be quantified can be weighted either through the density used on their representative maps or through the way in which the maps are superimposed. A subset of three or four parameters given equal weight and densities can be combined to produce a composite density which might then be reduced in order to adjust the joint weight of the set before combining with the maps of other parameters or sets. The structuring of the combinations thus provides the ability to weight the various factors.

II. MORPHOLOGICAL ANALOGY

a) Artifical and Natural Systems

An interesting emergent property of recent times is that the source of new concepts and basic scientific knowledge is not only the natural order but also the structures and organizations created by man. The collection of concepts which are called "cybernetics" were derived jointly from the study of animal nervous systems and man-made control systems. The idea of information came from the study of special communication networks but merged with the concept of entropy. Today the important basic concepts underlying structure and organization are being brought to light by the designer of complex systems as well as by the observer of the natural order. In the sense of discovery vis-a-vis application the historic distinction between science and technology is thus tending to disappear.

As a result of the abstract parallelisms between natural and artifical systems we are able to create objects for study which provide us with the equivalent of new views of the natural order with temporal and spatial resolving powers hitherto unavailable. For example, the freeway provides us with a new type of fluid, called traffic, whose properties can be made useful to us in developing more comprehensive theories of fluid dynamics, extending to new realms the laws of fluids as observed in nature. The growing sample of such structures and organizations which have been made available for study as a result of our own creations provides still another positive feedback contributing to the accelerated development of science and technology. In effect we are creating another powerful epistemological methodology simply through constructing and studying systems that occupy some of the gaps in the natural order. (Even the reasons for the natural gaps may be learned in time if our creations prove unstable.)

b) Hierarchical Modular Structures

One possible source of information on systems of complex structures is in the analysis of how complexity and bigness are treated in the natural order. We observe throughout nature that the large and complex is constructed in a <u>hierarchical modular</u> manner from the small and simple. Direct confrontation of the large and small is avoided, a hierarchical linkage is always interposed. Bigness is avoided in the sense that the ratio between the size of any structure and the modules out of which it is built is functionally bounded. If there are demands for a structure to continue to grow in size or complexity, then a new level in the hierarchy and a new module are introduced so that aggregate to module ratios may remain bounded.

Formally, by a hierarchical modular structure we shall mean an aggregate or organization of modules that are in turn hierarchical modular structures. Such a structure may be closed in the sense that there is ultimately a lowest level whose modules are not decomposable. Examples of hierarchical modular structures are ubiquitous: in the macrocosmos, there is the grouping of stars into galaxies, galaxies into clusters, etc.; in the microcosmos, the grouping of atoms into molecules, molecules into crystals, etc.; in the mesocosmos, there are the organizations and structures of man, armies, hospitals and hierarchical coding models.

What can we learn through comparing the properties of these hierarchical modular structures, artificial and natural, that will be useful in deriving a syntax to structure and increasingly complex systems of today's world, or that will be useful in understanding the limitations of our own organizations and structures? As an example of the method of morphological comparison we propose to look at two hierarchical systems--one social, one physical.

Martin Ernst's paper in this volume on city planning from the operations research point of view discusses the modular parameters basic to urban structure and evolution. The paper elaborates on one model, affording techniques through which planners and city officials could control the direction of changes in an urban complex. Ernst's approach might be called a reductionist approach, decomposing the city into components and sub-components, and looking at the "portfolio of possibilities." This is an important part of the analysis of any complex problem. However, the morphologist wants to add something. There may exist some parameters which place limits on the portfolio of possibilities but which are not evident in the reductionist approach. I would like to look at the city in this alternate manner. For this purpose the important properties of hierarchical modular structures to abstract are the bounds or limits to which the modules and the aggregates may be subject.

There are indications that our cities may be approaching some kind of critical limits. What kind of limits might these be, and how may we avoid difficulties without having to test to destruction to see where the failure occurs? To do this, let us compile sufficient modular forces to close the form we call a city, and see what the limitations on that form might be.

First, human beings as modules are subject to aggregating forces as are other so-called social creatures. These forces tend to draw people into physically compact aggregates. Historically, humans aggregated into towns and walled cities for trade and physical security. Today natural gregariousness is still very much a force bringing men together for physical, economic, and emotional security and growth.

Next, there are density limits governing how closely people may satisfactorily live together. These limits depend on the amount of freedom of movement and privacy we require. The higher densities in prisons and concentration camps are possible because of the restriction of movement and loss of privacy. Without knowing the value of the density limit, we can definitely assert that such a limit exists. (If you want an absolute limit, you may take the value of one person per 1.83 sq. ft., provided by Surajah Dowlah's experiment in close packing of humans in Calcutta in 1756.) However, we must bear in mind that in the modern city for purposes of density limits, the real inhabitants are motor vehicles, not people. The maximum density is determined by the minimum space needed for maneuvering, parking, and servicing automobiles.

A second limit exists in city life. This is the limit on the time required to be in movement to transact the city's business, or the bound on the maximum fraction of the day that the average commuter can tolerate spending in commuting. Doxiadis' studies show in cities of the past, the maximum distance from their centers was ten minutes by walking. We have certainly moved a long way from this value toward the commuting time limit. Three hours, or one-eighth of the day is not uncommon although the average is still considerably less than one hour per day. Both the city and the human modules which come together to make it are governed by the characteristic time period of 24 hours. This is an "absolute" value that is not at our disposal appreciably to modify. It is more basic than the day-night cycle imposed by the earth's rotation since this period is also set by the biological clock in each inhabitant. Even though adjustments in basic commuting problems can be made by some people, such as going to work on Monday, living near their work, and returning home on Friday for the week end, such practices can not alter the basic 24-hour period set by the needs of the city and its population. With present work and sleep requirements commuting time must be no greater than 1/3 of 24 hours.

These limits may readily be combined symbolically to define a closed entity. Let $\hat{\sigma}$ be the density bound and $\hat{\tau}$ the commuting time bound. (The latter may be expressed in terms of the natural period of the city $T = 24^h$ by $\hat{\tau} \leq \zeta T$ where $\zeta < 1$.) For a simplified model of a two dimensional city, $N = a\bar{\sigma}R^2$ where $\underline{R}$ is the maximum length path through the city and $\underline{a}$ is a shape factor. A limiting velocity which depends on the state of the art will be designated by $\underline{c}$. The realizable commuting velocity will be less than c.

Since $R \leq c\bar{\tau} \leq c\hat{\tau}$ and $\bar{\sigma} < \hat{\sigma}$, where barred quantities are mean values, we have $N = a\bar{\sigma}R^2 < ac^2\bar{\sigma}\bar{\tau}^2 < ac^2\hat{\sigma}\,\hat{\tau}^2 \leq ac^2\hat{\sigma}\zeta^2T^2$. In a three dimensional model we may introduce the mean height, $\bar{h}$, of the city and use three dimensional densities, $\bar{\rho}$ and $\hat{\rho}$, giving

$$N < a'c^2\bar{h}\,\hat{\rho}\,\hat{\tau}^2$$

If we designate the absolute limit $\hat{\rho}\,\hat{\tau}^2$ by $1/H$, then

$$\frac{HN}{c^2\bar{h}} < a' \qquad (1)$$

These particular limits combined with an aggregating force may indeed have some significance with regard to cities, for it is interesting that a similar relation obtains in cosmic aggregates.

In 1907 before the development of modern cosmological theories and before the establishment of the existence of white nebulae as external galaxies, the Swedish mathematician C. V. L. Charlier showed that in a universe containing an infinite number of stars the sum of gravitational forces acting at every point would still be finite provided the universe were structured in a hierarchical modular manner. Quite independently of possible relevance to cosmology, Charlier's inequalities showed in general that a hierarchical modular structure could be used to bound density and inverse square type forces.

Under assumptions of uniform density and spherical symmetry, Schwarzschild showed that the field equations of general relativity predicted the existence of a bound on the gravitational potential

$$\frac{GM}{c^2R} \leq \frac{1}{2} \qquad (2)$$

where M is the mass and R the radius of the gravitating sphere. Under the assumption of uniform density this limit demands the existence of hierarchical modular structure. If the equation is written in the form

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where $\bar{\rho}$ is the density and B is a fixed bound (we assume that G and c are constants), we see that for a given density--as for example, mean stellar density--the maximum possible radius of a star is determined. Such an inequality not only defines a limit to stellar size but forbids close packing of stars in space. Stars can be organized together into a larger aggregate only if a lower value of $\bar{\rho}$ obtains. If $\bar{\rho}$ assumes the mean value of galactic density the argument may be repeated. The maximum size of a galaxy is determined by the same bound but with a lower value of $\bar{\rho}$. The repeated application of a potential bound, like in the Schwarzschild inequality, can account for the levels in the hierarchical modular structure observed in the universe. However, the inequality does not explain the particular set of $\bar{\rho}$'s which are observed in the universe nor does it indicate at what level the hierarchical modular structure may terminate. Potential bounds like the Schwarzschild limit may also be interpreted as bounding the maximum velocity a module may possess in a coordinate system at rest with respect to the aggregate. With this last interpretation, we see from Figure 1 that cosmic bodies are either "density limited" or "velocity limited." The "slope 3" line represents the limiting density of matter in a non-degenerate form. Solid cosmic bodies lie on or to the right of this line. (On the logarithmic scales used in the diagram, the planetary bodies appear to have essentially the same densities.) The "slope 1" line represents the observed location of the velocity limited bodies, i.e., the star, galaxy, cluster, and derived super cluster having the largest potentials or escape velocities. (This is an observed potential bound and differs in numerical value from the theoretical Schwarzschild bound. The objects falling on the observed bound, like those on the density bound, are non-degenerate.) The inequalities (1) and (2) may be put in the respective forms,

$$\bar{\rho}\tau^2 < B^* \quad \text{and} \quad \bar{\rho}R^2 < B$$

These inequalities have the same ingredients and we might expect them to have the same significance even though the values of the coupling constants are quite different.

On the basis of these similarities we might propose a theorem of the form:

Given

1. The existence of an aggregating force tending to bring modules into a condition of maximum compactness, (gravity in the case of cosmic bodies.)
2. The existence of a maximum limiting density, (the limit set by non-degenerate matter in the cosmic example.)
3. The existence of a potential bound or its equivalent, (such as the Schwarzschild Limit, in the gravitational case.)

then hierarchical modular structures provide a way for accommodating indefinite size while satisfying these intrinsic limitations. Specifically we are led to inequalities of the $\overline{\rho} R^2 < B$ or $\rho \tau^2 < B^*$ type. If we assume we may apply such a theorem to a city, then from $\overline{\sigma} R^2 \leq a c^2 \hat{\sigma} \hat{\tau}^2$, we see that for a given density, the size depends on a bound set by the effective velocity of travel and the maximum acceptable commuting time. The bound may be satisfied as N increases by increasing c, or alternatively the solution may be found in hierarchical structure.

If a polynucleated city develops on hierarchical lines, it will be stable so long as each nucleus and the complex of all the nuclei (with an overall lower density) satisfy the inequality, $\sigma R^2 < B$. However, the nuclei will not close pack, which means that if subsequent urban development fills in the areas between the nuclei bringing the mean density up to the level obtaining within a nucleus, the complex will surpass the limit. This sort of "filling in" process is occurring in the "megapolis" areas of the Eastern United States and Southern California. If these derived inequalities are valid, we will not escape with impunity the destruction of our open spaces or the low density background between present cities.

Since no physical restrictions governing the distribution of density in the city exist as in the cosmic case, there are other possible solutions. It can be shown that the bound may be satisfied by selecting a density distribution $\sigma(r) \sim r^{-(\gamma+1)}$ where $\gamma > 1$. In this case, the city may grow and still satisfy the bound if it is built in a ring shape. Several suggestions of this sort have been made including a city which is nothing but a series of linear structures several stories high with freeways on top.

Additional limit theorems on the structure of cities may be derived. However, these require more sophisticated models and exceed the parallelisms in the hierarchical modular analogy given. Since our purpose here is not to develop a general theory of urban structure, but to illustrate the method of morphological parallelism, this one analogy will suffice. The method of morphological analogy does <u>not</u> per se generate valid theories. It produces hypotheses and ideas on which models may be constructed. These must then be tested by the usual canons of scientific verification.

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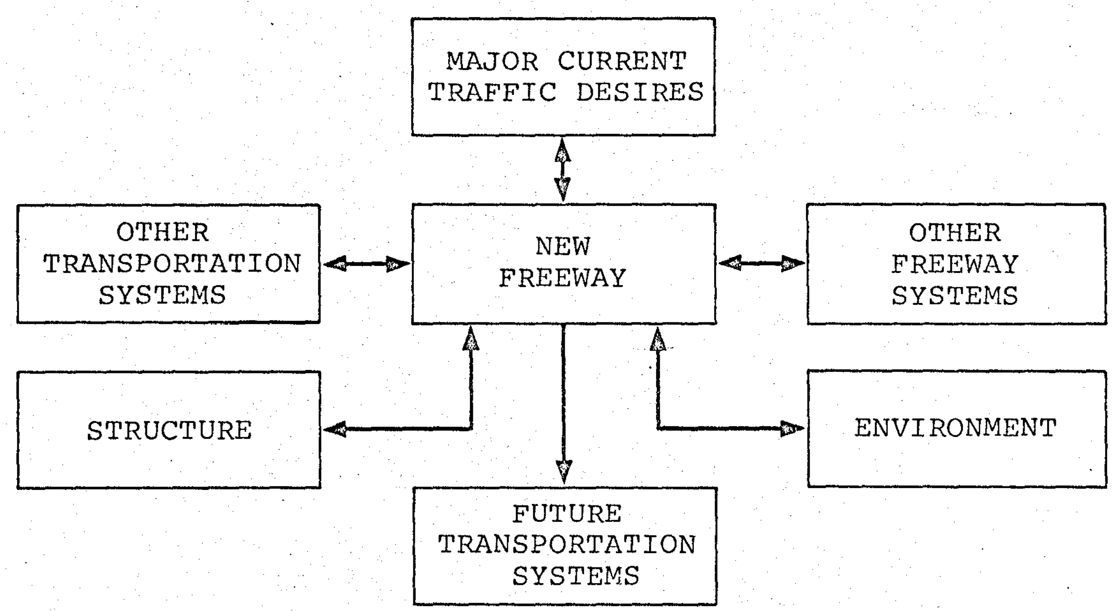
FREEWAY DESIGN PARAMETERS
I



FREEWAY DESIGN PARAMETERS
II

Internal

Constructional
- Earthwork costs
- Bridge costs
- Pavement and subgrade costs
- Construction interference

Economic
- Land costs
- Public financial losses
- User costs
- Obsolescence

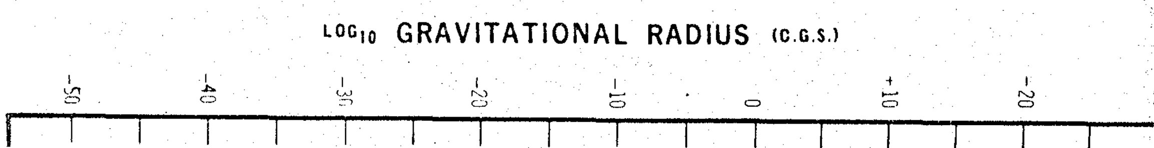
Operational
- Travel time
- Local accessibility and integrity
- Safety
- Maintenance and services
- Self induced congestion

Environmental

Physical
- Catchment areas
- Drainage patterns
- Weather effects
- Air pollution

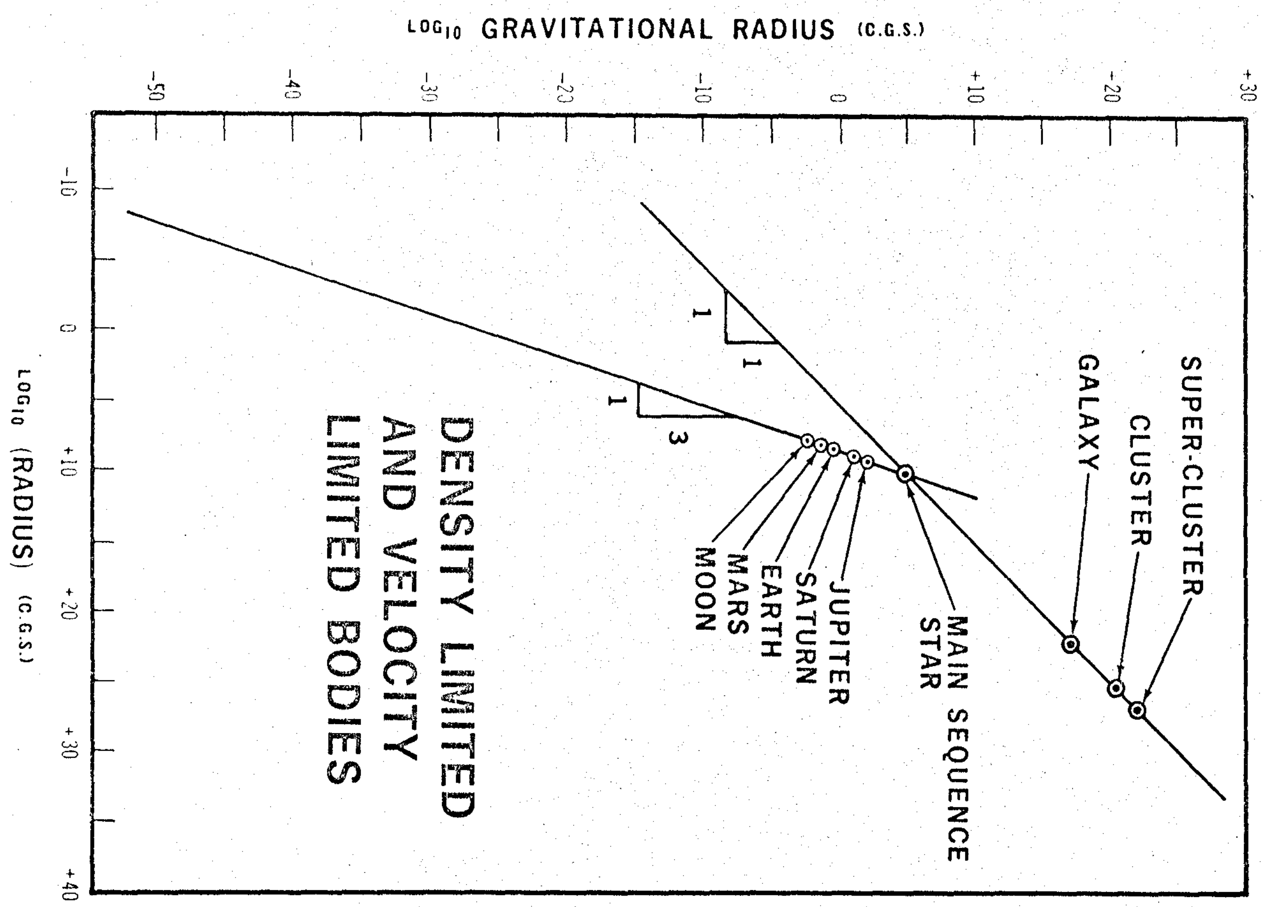
Economic
- Regional land development
- Local land development
- Non-recompensable public and private loss

Esthetic
- Eyesores
- Noise



Travel time
Local accessibility and integrity
Safety
Maintenance and services
Self induced congestion

Eyesores
Noise



FROM "NEW METHODS OF THOUGHT AND PROCEDURE"
SYMPOSIUM ON METODOLOGIES C.CT. 1967

EPILOGUE

METHODOLOGY--A DISCIPLINE

A primary purpose of this conference has been to consider whether the various methodologies employed in solving problems when taken together constitute in themselves a useful scientific and technological discipline. The descriptions of the several approaches to problems that have been presented here--Operations Research, Systems Engineering, Morphological Analysis, etc.--have made visible some common principles which have been independently developed for structuring, analyzing, and solving complex problems of many types. Though using different names and terminologies, the identities and overlaps contained in these approaches, taken with the fact of their independent discovery in many diverse contexts, strongly suggest the developability of a useful discipline that we may call "methodology." Although the presentations during this conference have only partially defined the subject area of methodology, they have demonstrated that it would now be meaningful to take steps toward systematic definition and organization of the concepts so far developed and establish a formal discipline.

Specific problem areas from hospitals to codes to jet engines have been treated at this conference. However, in all the variety of problems discussed, almost nothing has been said concerning how to select which problems to solve. It seems most important that any discipline of methodologies for problem solving be concerned not only with the definition and solution of specific problems but also with the totality of that growing complex consisting of the set of problems competing for our attention. The discipline of methodology should investigate criteria by which to assign priorities, the appropriate levels of resources--funds and talent--to be thrown against a problem, the nature of the interrelatedness of problems, the consequences of solutions to problems and the anticipation of derivative problems.

Neglecting an overview of the interrelated complex of problems has given rise to some serious unbalances in our culture. Dr. Ramo, in his introduction, pointed out a few of these unbalances. In 90 minutes we can travel around the earth in Gemini while in 90 minutes in our cities we sometimes can travel only a few blocks. We can provide pure breathable air 100 miles above the earth for our astronauts, but not within a hundred surface miles of our major cities. We have developed remote sensing equipment that can tell us everything going on inside a space capsule, but have not equipped the physician with comparable equipment for monitoring what is going on inside his patient. There is no need to enumerate our disparate and desperate social unbalances. We might now add that a conference on methodologies for solving problems without consideration of how to choose which problems to solve in itself constitutes an unbalance.

In addition to unbalances, there are other shortcomings inherent in our present approach to the growth and application of scientific and technological knowledge. For example, early this year, the world's largest oil tanker of 120,000 tons was wrecked off the east coast of England, releasing thousands of tons of crude oil which floated ashore and polluted hundreds of miles of shore line. This developed into a tragedy that assumed national proportions in England. It is estimated that extensive portions of beach will be polluted for decades, perhaps even permanently; and since the feedback on the ecology of major environmental alterations of this sort are some-

times delayed, the full extent of the damage created by the pollution probably will not be evident for some years. As expected, there was widespread comment on this disaster. However, criticism did not focus on the navigational situation which was the immediate cause of the wreck, nor on the structural feasibility of large tankers (they are quite feasible--there is a tanker of 300,000 tons currently under construction and one of 500,000 tons on the drawing boards) rather comment focussed on the defects in a technology that could blindly and blandly create the set up for this sort of disaster. This isolated example made some of the blind spots of technology visible to many for the first time. One of our own cabinet officers commented, "The environmental backlash we confront today cannot be eliminated just by applying more of the same science and technology that put us in our present predicament."

There is growing feeling in some quarters that the time has come to ring the bell on applying technology without responsibility to the environment or to the future; on synthesizing complexity without regard for social and human consequences; on continuously injecting change into society without direction or evaluation. We must now face the great responsibilities of what we choose or do not choose to do with our technological capabilities. We have reached the precarious level of technological development in which we have the power significantly to alter our environment without having either the power totally to control the means by which we effect the alterations, or an understanding adequate to predict the properties of the environmental states we bring about. Not only must the proposed discipline of methodology be able to derive knowledge concerning the limits to the controllability and predictability of specific applications of technology but also be able to derive the summary consequences resulting from the piecewise solutions of the various portions of the total problem complex.

Some of the methodologies reviewed at this conference pointed to the importance of the elimination of prejudice as basic to the problem solving process. Prejudices are often habits of thought that we unconsciously carry to new situations in which they are no longer applicable. An example of such a habit of thought that affects our application of technology is the making of decisions primarily on the basis of feasibility. One of the severe deficiencies in the present use of technology is the failure to note that at some level of the state of the art the answers to the two questions: how big can we build a tanker, and how big should we build a tanker, begin to diverge. For decades technology has been primarily concerned with finding ways to do things hitherto impossible. The emphasis has been on pushing back the limitations of nature and ignorance in order to make more products and activities feasibile and broaden our spectrum of choice. In an increasing number of technological areas we have recently moved from the regime of finding a way to the regime of choosing the best way. The task is no longer to remove natural limitations but to set up limitations of our own, to define the constraints and restraints which are prerequisite to sensible choice. In a regime of limited capability, choice is usually properly made for the limit of feasibility--build a plow that will cut as many furrows simultaneously as possible. However, the habit of thinking developed in this regime tends to carry over into the second regime; the difficult problems of choice being ignored and option being made simply for the limit of feasibility. For example, in typical past wars the level of tolerance to destruction and ability to recover was higher than the level of any enemy's capabilities to destroy. However, in the past two decades, this inequality has been reversed. It is now possible to destroy beyond any nation's tolerance to absorb. We have entered the regime of choice. There is the necessity for limited and restrained actions, but some spokesmen still adhere to first regime thinking.

Although this phenomena of regime change seems tautological to many, and is well understood by many business and government leaders, the oil on the beaches bears witness that one of our urgent problems is to spread more broadly the awareness of the regime change and replace feasibility thinking with some of the new methodological tools that are now available for making difficult decisions.

We had best rapidly acquire the techniques essential for decisions in a choice regime. The new developments in biology, for example, are leading us to a capability level where we may shortly be able to determine the sex of our offspring, extend our life spans indefinitely, and even create new varieties of organisms. Clearly the responsibilities of choice imposed by such developments are likely to be as demanding as any ever faced by man. The temptation to be guided purely by feasibility, say in producing selective viruses, could put an end to the human experiment.

In a choice regime, it becomes necessary to formulate every problem, not only in terms of the internal capability parameters, but also in terms of the contextual parameters, considering environmental effects and interrelationships and possible synergistic developments. Our failure to do this reveals another prejudice--the prejudice to settle for the reductionist factors and ignore the holistic ones. This is a pattern of thought which derives partially from the past successes of reductionism, especially in physics, and partially from the unwarranted association of holistic effects with supernaturalism.

Besides facing up to these and other prejudices such as fadism, the proposed discipline of methodology must derive techniques for treating the increasing complexity of our problems and systems, complexity leading to such occurrences as regional power blackouts or postal service breakdowns. Oftimes feedback signals from complex systems cannot be interpreted promptly. The signals may be delayed or lost in other effects. Pollution is an example of a problem area whose feedback signals have been unheeded until the environmental backlash has reached proportions whose correction will require major technological and social surgery. Development of techniques for prompt interpretation of feedback signals is an urgent problem area of the discipline of methodology.

Other new problem situations are on the horizon. The trend toward longer development times and shorter life times for new systems with the impossibility of paying off development costs before obsolescence may place us in the same situation as an organism whose life span drops below its gestation period.

There are many other aspects of the subject of how to select, define, and solve problems which will concern the methodologist. If the future comes to be dominated by unknown and uncontrolled parameters arising from the interaction of the random application of technology to specific problems in agriculture, medicine, manufacture, space, defense, etc., then planning becomes illusory and the course that our civilization will take is that of a car without a driver. It will be useless to construct one of our usual "good guy--bad guy" explanations for the situation. There is no villain, only complexity, and it is not too early to bring out best research talents to grips with it.

Albert Wilson

Because lunar sinuous rills look "deceptively like terrestrial meanders" and run "parallel to the regional slope," Schumm and Simons have cast aside our "ingenious mechanism" and have devised the pseudo-alternative that "parts of some of the channels" are the "coalescence of chain-crater systems." However, it is our opinion that the differences between lunar sinuous rills and coalesced chain craters are fundamental. If we consider only the examples cited by these authors, Rima Prinz I and II, the sinuous channel in Schroeter's Valley, Rima Marius, and Rima Plato II, it is obvious that their basic morphological characteristics (continuous and uniform meandering channels, mature meanders, goosenecks, distributary channels, and flood plains) cannot be imitated by coalesced chain craters. As can be seen in some straight rills, such as Hyginus, coalesced chain craters do not resemble sinuous rills nor should they be confused with them. Coalescence of craters produces depressions with irregular floors and opposing walls that are mirror images of each other, that is, like (), rather than the observed smooth floors and matching walls, that is, like ((, of the lunar sinuous rills.

Using the lunar astronautical charts, Schumm and Simons state that sinuous rills do not follow the local gradient and that Rima Marius and the rill at the end of Schroeter's Valley both cross ridges. However, the Lunar Orbiter photographs have shown that these charts are so inaccurate that they cannot be used as a basis for the study of sinuous rills. Even such large features as the Cobra's Head of Schroeter's Valley are grossly distorted on the charts. From a survey (*1*) of Lunar Orbiter IV photographs of about 130 sinuous rills, we find that, wherever it is possible to determine a gradient, the rills meander from higher to lower elevations. Lunar Astronautical Chart 39 shows a "ridge" crossing Rima Marius, whereas Lunar Orbiter IV photograph H150 reveals that this "ridge" is in fact two ridges offset by 10 km, which do not cross the rill but terminate on either side of it. Similarly the Schroeter's Valley rill does not cross any "ridges" but meanders between isolated hills (Lunar Orbiter IV photograph H157).

Despite the erroneous examples cited by Schumm and Simons, there is no reason to doubt that a channel eroded by surface water could not be subsequently uplifted. A possible example of this might be Rima Prinz II. Since its channel is deeper on the plains to either side of the ridge, the rill must either have been uplifted subsequent to its formation, or must have passed through a gap in the ridge depressed below the level of the surrounding plain.

Schumm and Simons' contention that the course of Rima Prinz I is "unusual" fails to recognize the fact that the course of this rill and of neighboring ones is partially controlled by a rather conspicuous regional fracture pattern, as are the courses of terrestrial rivers. Their statement that there has been no major mass movement on the walls of Schroeter's Valley is contradicted by the fact that "only half of the channel is visible." The only places where Rima Plato II appears discontinuous are those where the channel has been obliterated by obvious impact craters.

The very distinctive morphology of the lunar sinuous rills, particularly the mature meanders, goosenecks, distributary channels, flood plains, and other features similar to those of terrestrial rivers, requires that they be features of surface water erosion.

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Hierarchical Structures

The portion of the summary of the Conference on Hierarchical Structures describing the "cosmic diagram" (*1*) contains the same error in Fig. 1, the caption, and the text.

In Fig. 1, the limit parallel to the Schwarzschild limit marked $m = Sr$ should be marked $m/r = Sm_p/a_0$. In the caption, the limit $m/r = S = 10^{39.4}$ should read, $m/r = Sm_p/a_0 = 10^{23.8}$ g/cm. In the text (p. 1229, right-hand column, line 17), the phrase "or at $m = Sr$" should be similarly changed.

The maximum observed gravitational potential for stars, galaxies, and clusters of galaxies appear to have closely the same value in the neighborhood of $10^{23.5}$ g/cm. In dimensionless terms—expressing mass in units of baryon mass m_p, and lengths in units of the Bohr radius a_0—the observed potential limit takes the value $ma_0/m_pr = 10^{39}$ or fS where f is a number of the order of unity. From the definitions, $S = e^2/Gm_pm_e$ and $a_0 = e^2/\alpha^2c^2m_e$, it follows that for the observed limit $Gm/c^2r = f\alpha^2$ compared to $GM/c^2r = ½$ for the Schwarzschild limit. The fine structure constant thus emerges from astronomical measurements, under the assumption that all dimensionless physical numbers of the order of 10^{39} are the same (*2*).

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1 April 1969

Granitic Rock: Properties in situ

Simmons and Nur (*1*) have reported that laboratory measurements of sound velocity and electrical resistivity of granitic rocks yielded results that were inconsistent with certain measurements *in situ*. One possibility they offered to explain this inconsistency is that the rock *in situ* lacks the small, open cracks evident in the laboratory specimen. They conclude that "the absence of small, open cracks that close due to lithostatic pressure with depth in the earth's crust holds serious implications for geophysics." I do not wish to treat here the important question of whether cracks are present in rock *in situ* but simply to suggest that the conclusions reached by Simmons and Nur may be based on doubtful evidence. My principal objections to their comparison of measurements *in situ* and in the laboratory are as follows:

1) The lithology of the Matoy well is extremely complex (*2*), with wide variations in composition, grain size, and texture. It seems highly questionable to compare a measurement made *in situ* over a wide suite of rocks with laboratory measurements for a single rock or rock type. Although half the cuttings examined by Ham *et al.* (*2*) were described as diorite or diabase rather than granite, the velocity of these cuttings *in situ* was compared with the velocity of granites.

2) I have studied in detail the electrical log for the Phillips No. 1 Matoy well. It is very difficult to obtain the

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Hierarchical Structure in the Cosmos

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The primary focus of cosmological thought in the present century has been on interpreting the observations of the sample of the universe available to our telescopes in terms of a set of models based on various theories of gravitation, especially the General Theory of Relativity. The problem of the structure *of* the universe is customarily divorced from the problem of the structure *in* the universe. Theoretical cosmologists usually choose to explain the structure and behavior – past and future – of the universe with models that smooth out the distribution of matter in the universe, replacing the observed structured distribution of matter with a uniform homogeneous perfect fluid whose density varies in time, but not in space. However, the structure contained *in* the universe becomes difficult to relate to models constructed around smoothing postulates. This has resulted in separate theoretical approaches to the origin of the various structures in the universe. While most of these approaches have met with some success, they are inadequately related to one another and to cosmological theories.

The arbitrary separation of the structure and behavior of the universe from the structure and behavior of its contents may be expedient from the point of view of mathematical simplification, but it cannot be accepted as more than an exploratory strategy. The observational tests for discriminating between various cosmological models are difficult and marginal. Since several smoothed models are candidates for best fit to the observations, it is unfortunate that the large amount of information contained in the sub-structures of the universe cannot be used in testing these models. But until models that relate the properties of the sub-structures to the properties of the whole are employed, much information of potential cosmological value in sub-structure astronomical observations is not cosmologically useful.

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So long as the cosmological problem has been approached through smoothing out the sub-structures, it is not surprising that little attention has been paid to the regularities that exist among the sub-structures. There are many features of the visible sample of the universe that suggest that the regularities in sub-structures which range over 40 orders of magnitude in size and 80 orders of magnitude in mass, are of central significance to the order and operation of the universe. The fact that these regularities may not be readily explainable in terms of existing physical theories, should not deter their examination. The object of this paper is to present an overview of the known structural regularities that link the properties of physical bodies across a hierarchy of levels from the atomic to the cosmic.

MODULAR HIERARCHIES

Because of the confusion created by the many uses of the term "hierarchy" some amplification concerning the sense in which hierarchy is used in astronomy and cosmology is needed. Astronomical usage, in general, employs "hierarchy" to mean a *set of related levels* where the levels may be distinguished by a size or mass parameter. Examples from the past include the hierarchy of spheres associated in ancient cosmographies with the various heavenly bodies beginning with the moon and continuing to the sphere of fixed stars, and the hierarchy of epicycles used by Ptolemy to account for observed planetary motions. Modern concepts of hierarchy in the cosmos began with the speculations of Lambert (1761) who extrapolated to higher order systems the analogy between a satellite system such as that of Jupiter and its moons and the solar system of the sun and its planets. Lambert speculated on a hierarchy consisting of a distant center about which the sun orbited as a satellite and an even more distant center about which the first center orbited, and on to more and more distant centers comprising larger and larger systems. To explain Olbers' and Seeliger's Paradox, Charlier (1908, 1922) posited a universe built up of a hierarchy of "galaxies." The first order galaxies were the familiar ones composed of stars, second order galaxies were aggregates of first order galaxies, third order of second order, and so on. Shapley (1930) pointed to the set of levels into which all matter appears to be organized extending from the sub-atomic particles to the "metagalaxies." Shapley's organization, like Charlier's, constructed the material bodies on any level from the bodies on the level next below. A hierarchy of this type which is of fundamental importance in astronomy we designate a *modular hierarchy*.

The central idea in a modular hierarchy is the *module* which is a structure or a system that may be regarded both as a *whole*, decomposible into sub-modules identified with a lower level, and as a *part* combinable into super-modules identified with a higher level. In astronomy, even though the modules on any level are not identical, the levels may be readily distinguished on the basis of the nature of the principal sub-modules out of which entities are directly composed. Thus, for organization in a modular hierarchy, open and globular star clusters and galaxies would be assigned the same level, all being aggregates of stars. Stars, planets, and moons, all built from atoms, would share the next lower level, while clusters of galaxies would be assigned the next level above. There are several other ways than that of a modular hierarchy for organizing cosmic bodies into levels. Some of these will be discussed later.

The term "module" being used here in this general sense need not be precisely defined, however, we may ascribe two fundamental properties to modules. First, a module possesses some sort of closure or partial closure (Wilson 1969). This closure may be topological, temporal, or defined by some operational rule as in group theory. Second, modules possess a degree of semi-autonomy with respect to other modules and to their context. These two properties appear to be common in all modular hierarchies.

In considering the origin of a modular hierarchy we may inquire at any level as to whether the size, the complexity, and the limits to the module are determined (1) totally by the properties of its sub-structures, (2) by its environment, or (3) by a combination of both module contents and context. And to these logical possibilities we must add a fourth: that the levels and modules in a hierarchical structure are determined by some principle or process that operates independently of all levels of the hierarchy. In this fourth case the *levels* of the modular hierarchy themselves become the *modules* on a single level of a meta-hierarchy. The various levels in the meta-hierarchy are an observable level, an energy or force level and a meta-relational level. As an example, we may think of the lines in the spectrum of an atom as an ordinary hierarchy (but not a modular hierarchy). The levels of the meta-hierarchy would be the spectral lines, the energy levels, and the mathematical law – such as the Balmer formula – that defines the sequence. It may be objected that this is but a representational hierarchy. But the essential point is that the levels are neither determined by the sub-levels nor the super levels, but by a set of eigen values that act as a causal meta-relation.

COSMIC-ATOMIC NUMERICAL RELATIONS

Let us now return to our specific example of a modular hierarchy: the levels of cosmic structure. Instead of assuming a two level model of the cosmos – the level of a homogeneous perfect fluid and the level of the universe as a whole – we shall attempt a multi-level view retaining the atomic, stellar, galactic, galaxy cluster and universe levels. Further, in view of the lacunae in our knowledge of physical processes governing "vertical" relations between levels, it is appropriate to work from observation toward theory. In doing this the steps we must take are somewhat analogous to those taken by Kepler and his successors in the investigation of planetary orbits. From the arithmetic ratios of various powers of the sizes and periods of planetary orbits, Kepler discovered his kinematical relations and from these later came Newton's formulation of the physical laws governing planetary motions. Thus while our ultimate goal is the formulation of the physical laws and processes governing the relations between the levels in the cosmic hierarchy, our

immediate goal is much more modest. It is simply to display whatever quantitative regularities may exist between the fundamental measurements made on bodies at each cosmic level.

The properties of the arithmetic relations between fundamental atomic and cosmic constants is not new ground. It has received the attention of many leading physicists and astronomers. Eddington (1923, 1931a,b); Haas (1930a,b, 1932, 1938a,b,c); Stewart (1931); Dirac (1937, 1938); Chandrasekhar (1937); Jordan (1937, 1947); Schrödinger (1938); Kothari (1938); Bondi (1952); Pegg (1968); Gamow (1968); and Alpher (1968) all have developed the subject.

The central theme in the numerical approach to atomic-cosmic relations has been to identify quantitative equivalences between various dimensionless combinations of fundamental constants and whenever possible give them physical interpretations. The epistemological weakness in this approach is the shadow of chance coincidence that cannot be removed by any of the common tests of statistical significance. Confidence in the validity of the numerically indicated relations can only follow from successful predictions or the development of a consistent theoretical construct linked to well established physics.

The basic ingredients in the relational approach are the micro-constants, e, m_e, m_p, and h (the charge and mass of the electron, the mass of the proton, and Planck's constant) the meso-constants, c and G (the velocity of light and the gravitational coupling constant), and the macroparameters H and ρ_u (the Hubble parameter and the mean density of the universe). Recently determined valves of these constants are given in Table I. From these fundamental quantities several important dimensionless ratios may be formed. The values of the dimensionless quantities $\mu = m_p/m_e$ (= 1836.12); $\alpha = 2\pi e^2/hc$ (= 1/137.0378); and $S = e^2/Gm_p m_e$ (= $10^{39.356}$) may

Table I

Values of Fundamental Physical and Cosmic Constants

Constant	Value (c.g.s.)	$\log_{10}$ (value)	Reference
e	4.80298×10^{-10}	−9.318489	1
m_e	9.10908×10^{-28}	−27.040526	1
m_p	1.67252×10^{-24}	−23.776629	1
h	6.62559×10^{-27}	−26.178776	1
c	2.997925×10^{10}	10.476821	1
G	6.670×10^{-8}	−7.176	1
H^{-1}	13×10^{9} years	17.613 seconds	2
ρ_u	10^{-28}	−28	3
a_o	5.29167×10^{-9}	−8.276407	1
r_e	2.81777×10^{-13}	−12.550095	1
α^{-1}	137.0388	2.136844	1
S	2.265×10^{38}	39.356	
μ	1836.12	3.263901	

From top: charge on electron, mass of electron, mass of proton, Planck's constant, velocity of light, Newton's gravitational constant, inverse Hubble parameter, mean density of visible matter in universe, Bohr radius, radius of electron, inverse fine structure constant, ratio of Coulomb to gravitational forces, ratio of proton to electron mass.

1. Cohen and DuMond (1965), 2. Sandage (1968) and 3. Allen (1963) p. 261.

be established in the laboratory. These are respectively, the ratio of proton to electron mass, the Sommerfeld fine structure constant, and the ratio of Coulomb to gravitational forces.[1]

When the two macro-parameters H and ρ_u are introduced, three additional dimensionless quantities may be formed. The first of these is the "scale parameter" of the universe (the product of the velocity of light, c, and the Hubble time H^{-1}), divided by the electron radius, c/Hr_e. The second is the "mass of the universe" expressed in units of baryon mass (where the scale parameter is taken as the radius of the universe), $\rho_u c^3/H^3 m_p$. The third is the dimensionless gravitational potential of the universe $GM_u/c^2 R_u = G\rho_u/H^2$. Using 75 km/sec/mpc as the present value of the Hubble parameter (Sandage 1968), and $10^{-28} g/cm^3$ for the mean density of matter in the universe (Allen 1963), we obtain:

$$c/Hr_e = 10^{40.64} \doteq 2\pi^2 S$$

$$G\rho_u/H^2 = 10^{0.05} \doteq 1.$$

$$\rho_u c^3/H^3 m_p = 10^{79} \doteq 2S^2$$

It is thus seen that to within small factors (whose exact value cannot be determined with the present precisions of ρ_u and H), the dimensionless cosmic quantities representing the potential, size, and mass of the universe are closely equal to S^ν, where ν = 0, 1, and 2 respectively. The significant matter here is not the fact that the values differ from integral powers of S by factors

1 It has been recognized that S and α appear to be logarithmically related. As an example of an arithmetic equivalence presently lacking theoretical confirmation, we have $8\pi^2 S = 2^{1/\alpha}$ to within experimental uncertainties. If this equivalence is not a coincidence, it has several important implications. Bahcall and Schmidt (1967) have shown on the basis of 0 III emission pairs in the spectra of several radio galaxies with redshifts up to $\delta\lambda/\lambda = 0.2$ that α appears to have been constant for at least 2×10^9 years. The above equivalence, if non-coincidental, would imply that S has also been constant over this period. Hence if G has been changing with time, e^2 and/or m_p and m_e have also been changing, and if e^2 has been changing, so also has h and/or c. The gravitational constant may, indeed, be expressed in terms of other basic constants by the relation, $G = 8\pi^2 e^2/m_p m_e 2^{1/\alpha}$ (Wilson 1966).

as large as 2 or $2\pi^2$, but the fact that laboratory and observatory measurements of quite diverse phenomena when expressed in dimensionless form appear to approximate so closely some small power of the ratio of electric to gravitational forces. It is also interesting to note that the gravitational potential of the universe is near the Schwarzschild Limit, the theoretical maximum value for potential. These *quantitative* equivalences indicate that there probably exist basic causal *qualitative* relations between the structure of the universe and the properties of the atom and its nucleus (the question of the direction of causality being open).

So far the two levels represented by the atom and the universe as a whole have been shown to be derivable from integral powers of the basic dimensionless ratio S. Numerical relations of a similar type involving fractional powers of S were pointed out by Chandrasekhar (1937) to be related to other cosmic levels. Chandrasekhar formed the dimensional combination

$$M_\nu = \left(\frac{hc}{G}\right)^\nu m_p^{\,1-2\nu} \qquad (1)$$

having the dimensions of mass. He pointed out the case $\nu = 3/2$ occurring in the theory of stellar interiors, leads to $M_{3/2} = 5.76 \times 10^{34}$ grams, the observed order of stellar masses. This is also the upper limit to the mass of completely degenerate configurations.

But the Chandrasekhar relation (1) also gives the observed order of mass for other cosmic levels in addition to the stellar level although this is not justifiable theoretically. If values of ν of the form $(2 - 1/n)$ where n is an even integer 2, 4, 6, 8, . . . are selected, then the Chandrasekhar relation predicts a sequence of masses given in Table II that corresponds to those observed for the stellar, galactic, cluster, second order cluster, ...levels of cosmic bodies.[2]

Table II. Masses for Levels of Cosmic Bodies from the Chandrasekhar Relation

Level	n	ν	$\log_{10} M_\nu$ (grams)	$\log_{10} M_\nu$ (dimensionless)
stellar	2	3/2	34.766	58.543
galactic	4	7/4	44.523	68.299
cluster	6	11/6	47.775	71.552
2° cluster	8	15/8	49.401	73.178
3° cluster	10	19/10	50.377	74.153
.....	...	.....	.....	.....
Universe	∞	2	54.280	78.056

Using well known relations between fundamental constants, equation (1) may be rewritten in the form:

$$M_\nu = \left(\frac{2\pi m_e}{\alpha m_p} S\right)^\nu m_p = A^\nu S^\nu m_p \qquad (2)$$

where $A = 0.4689$. Hence the masses of the bodies on various cosmic levels defined by $\nu = 1\frac{1}{2}, 1\frac{3}{4}, 1\frac{5}{6}, 1\frac{7}{8}, \ldots, 2$, are seen to be nearly equal to these respective powers of S times the proton mass.

2. If equation (1) is valid for all ν of this sequence, then clusters of higher orders could exist until the ratio of consecutive cluster masses becomes less than two. The first pair for which this happens is $\nu = 31/16$ and $\nu = 35/18$, i.e., 6° and 7° clusters. Observationally, although 3° order clustering has been suspected (Wilson 1967), not even the existence of 2° order clustering has been satisfactorily established. While *even* values of n give masses in good agreement with cosmic levels, the *odd* values do not appear to correspond to any long lived objects. Nonetheless, if there exist two species of body, with masses $10^8 \odot$ and $10^{13} \odot$, such bodies would correspond to $n = 3$ and 5 respectively.

There are additional relations between the measurements of cosmic physics and microphysics. The largest gravitational potentials that have been observed for each of four species of cosmic bodies (stars, galaxies, clusters and 2° order clusters) are given in Table III. The potentials for each species are derived in physically distinct ways. For stars, from eclipsing binary observations; for galaxies, from rotational dynamics; for clusters, from the virial theorem; and for second order clusters, from angular diameters, distances and galaxy counts. It is interesting and somewhat surprising that the maximum in each case is nearly the same, a quantity of the order of 10^{23} grams/cm. If, instead of c.g.s. units, masses are expressed in baryon mass units and radii in Bohr radius units, the dimensionless ratio, $M/R \div m_p/a_o$, is in each case closely equal to 10^{39}. Thus, the upper bound for the gravitational potential of these species of cosmic bodies seems to be σS where σ is a factor of the order of unity not determinable from the present precision of the observational data.

Table III. Maximum Values of Potentials

System	$\log_{10}[M/R]$ (c.g.s.)	$\log_{10}[M/R]$ (dimensionless)
Stars	23.27	38.8
Galaxies	23.6	39.1
Clusters	23.5	39.0
Second-Order Clusters	23.2	38.7

From $M/R \leqslant \sigma S m_p/a_o$, substituting e^2/Gm_pm_e for S and $e^2/m_e\alpha^2c^2$ for a_o, we obtain

$$\frac{GM}{c^2R} \leqslant \sigma\alpha^2$$

In other words, the dimensionless gravitational potential for these four species of cosmic bodies is bounded, not by the Schwarzschild limit, but by a bound α^2 times smaller. We thus see that not only the dimensionless microphysical quantity, S, but also the fine structure constant, α, emerges from cosmic measurement. (Another occurrence of α^2 in cosmic measurements derives from cluster redshifts (Wilson 1964).)

These results may be displayed graphically. Figure 1 is a small scale representation showing quantitative mass and size relations between atomic and cosmic bodies. The axes are logarithmic.

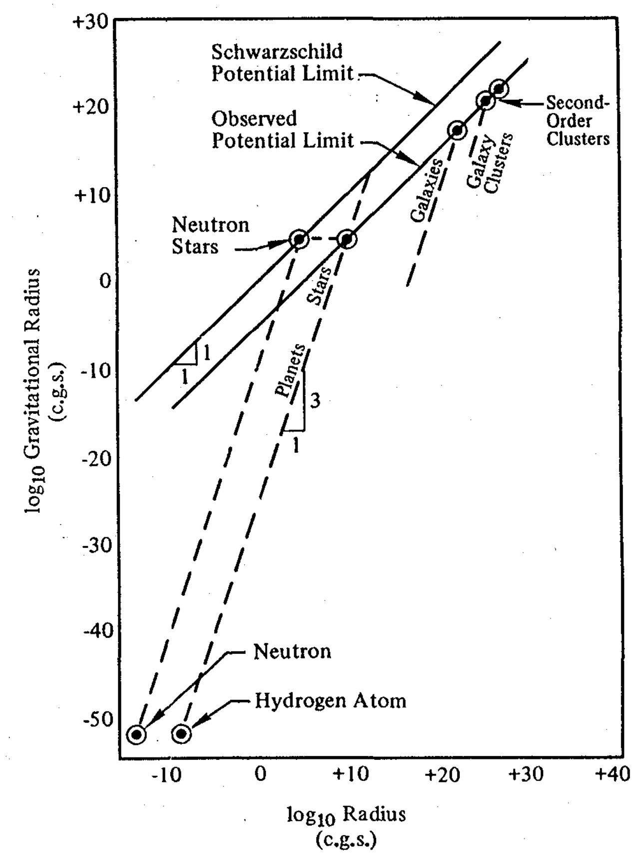

Figure 1 Mass and Size Relations Between Atomic and Cosmic Bodies

The abscissa represents the physical radius; the ordinate, the gravitational radius (GM/c^2). The upper 45 degree line is the Schwarzschild potential limit,

$$\frac{GM}{c^2R} = \frac{1}{2},$$

the theoretical boundary separating the excluded region (upper left) from the allowable region for self-gravitating bodies. Such bodies as neutron stars, and presumably the universe itself lie on this limit. The lower 45 degree line is the observed or modular potential limit,

$$\frac{GM}{c^2R} = \alpha^2,$$

marking the locations of the various cosmic bodies having the maximum observed potentials. All other stars, galaxies, clusters, etc., lie below this limit. The relation of the nucleus of the atom and the atom to the degenerate neutron star and the normal star is shown by the dotted lines of constant density (slope 3). Thus a neutron star has the largest mass with nuclear density allowed by the Schwarzschild limit. A normal main sequence star is seen to be limited to the same mass but is non-degenerate, lying on the line representing "atomic density." Thus, given the properties of the atom and the Schwarzschild limit, it is possible to derive the observed maximum mass for a star, but as with the Chandrasekhar relation, it is difficult to account for the locations on the diagram of the bodies of lower density (clusters, galaxies, etc.) and the fact that they are also bounded by the α^2 potential limit.

The parallel lines of equal density (slope 3) through the atom, planets and normal stars, the star clusters and galaxies, the clusters, etc., represent the levels of a modular hierarchy as previously described. These levels are thus definable by a discrete density parameter. Further, in consequence of the universal relation for gravitating systems, $\tau \propto \rho^{-1/2}$, relating a characteristic time to the density, the levels in the cosmic

modular hierarchy are also definable in terms of a discrete *time* or *frequency* parameter. We shall return to this concept later.

MASS BOUNDS

In order to display the cosmic or upper portion of Figure 1 with more detail and to make comparisons with observations, the logarithms of observed masses (M) and potentials (M/R) of planets, stars, globular star clusters, galaxies, and clusters of galaxies have been plotted in Figure 2. The masses and potentials (Allen 1963) include maximum and minimum observed values and other representative values selected to show the domains occupied by the respective cosmic species.

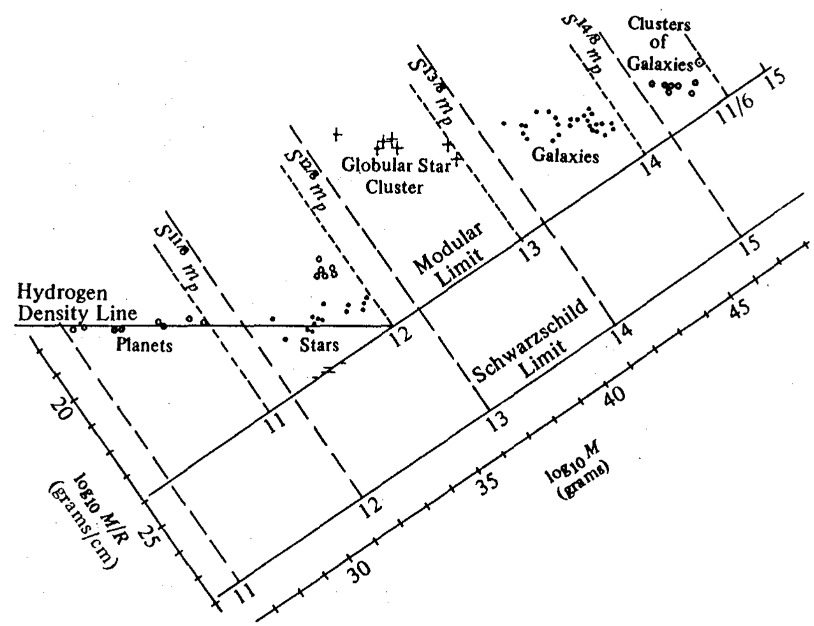

Figure 2 Mass Bounds of Cosmic Bodies

However, because of observational bias toward brightest and largest objects, the minimum observed values are not as representative of actual minimum values as the maximum observed values are of actual maximum values. Figure 2 is related to Figure 1 by an affine transformation (Figure 1 has not only been dialated, but has also been subjected to shear, reflection and rotation transformations). In Figure 2, the lines of constant density are shown horizontally so as to display the levels into which cosmic bodies fall when viewed as a modular hierarchy.

The supergiant stars lying above the mean stellar density level are shown as open circles, while the white dwarfs lying below the level near the modular potential limit are shown as dashes. The Schwarzschild Limit, $M/R = c^2/2G$ and the modular (or observed) limit, $M/R = Sm_p/a_o$ have a slope of 2/3 with respect to the horizontal equi-density lines. The short-dashed and long-dashed lines perpendicular to the Schwarzschild and modular limits are lines of constant mass. The set of short-dashed lines, extending only to the modular limit represent the sequence of masses $M_\nu = S^\nu m_p$, showing values of ν = 11/8, 12/8, 13/8, 14/8, and 11/6. The set of long-dashed mass lines, extending to the Schwarzschild Limit are located so as to pass through a sequence of points on the Schwarzschild Limit that have the same gravitational energy as the intersections of the $S^\nu m_p$ mass lines with modular limit. The pairs of intersections marked 14, 13, 12, . . .lie on lines of constant gravitational energy, $GM^2/R = S^\nu m_p(\alpha c)^2$. For identification, corresponding upper and lower bound intersections with the modular and the Schwarzschild Limits are marked with the *numerators* of the exponent ν. That is, 14 on the Schwarzschild Limit marks the lower bound of galaxies and corresponds to the upper bound $S^{14/8}m_p$ intersection with the modular limit.

The values of mass given by the Chandrasekhar relation (1) in Table II are the correct order of magnitude for the masses of

stars, galaxies, and clusters. In Figure 2 it can be seen from the set of short-dashed lines of constant mass that the sequence of masses $S^\nu m_p$ are close in value to least upper bounds of the masses of planets, stars, globular star clusters, galaxies, and clusters of galaxies. Numerical comparisons of maxima are given in Table IV. In addition, the set of long-dashed lines are seen to be lower bounds, while probably not greatest lower bounds nonetheless close to the actual observed minimum values of the masses of the respective species of cosmic bodies. Numerical comparisons of minima are also given in Table IV where the lower bounds are the upper bounds diminished by $10^{3.9}m_p$. It can be shown that this value of maximum-minimum mass differential may be derived from "ν sequences" of maximum

Table IV. Observed and Calculated Mass Limits

Mass Limit	Planets	Stars	Globular Clusters	Galaxies	Galaxy Clusters
MAXIMUM					
	Jupiter	VV Cephei A	M22	M31	Local Super Cluster
Observed	30.279	35.225	40.14	44.8	48.3
Model	30.338	35.258	40.176	45.096	48.376
$S^\nu m_p$	$\nu = 11/8$	$\nu = 12/8$	$\nu = 13/8$	$\nu = 14/8$	$\nu = 11/6$
MINIMUM					
	Mercury	R CMa B	M5	NGC6822	
Observed	26.509	32.340	37.3	41.9	
Model	26.4	31.4	36.3	41.2	

All masses are given in $\log_{10}$ (grams). Upper bounds are given by $S^\nu m_p$, lower bounds by $S^\nu 10^{-3.9} m_p$.

masses and gravitational energies, with the minimum mass being the least allowed by the Schwarzschild Limit for a given gravitational energy.

THE COSMIC DIAGRAM

The good agreement between the observed values for the masses and sizes of various species of cosmic bodies and the values given by sequences involving simple expressions containing fundamental physical constants indicates the probable validity of the gross features of the sequences. However, systematic errors and incompleteness in the observational data and the uncertainties intrinsic in establishing observationally least upper bounds and greatest lower bounds render it impossible, in the absence of a rigorous physical theory, to predict the exact form of the expressions and the values of the small factors (such as the 2π's, etc.) that should be included. We might, as an analogy, think of our discerning Kepler's Third Law in the form: periods squared are proportional to orbital diameters cubed without knowing the important constant of proportionality, $G(M_1 + M_2)$.

In the spirit of focusing on the major patterns that emerge from the present body of observations that are not likely to be seriously altered by refinements in observation, or even by discovery of new bodies, we represent the gross features of the structure in the universe in Figure 3. In this stylized representation, the cosmos is mapped on a rectangle whose length is the logarithm of the mass, $S^\nu m_p$, and whose hieght is the logarithm of the extension, $S^\eta a_o$. The masses and radii of various sub-components are related to values of ν and η. The hydrogen atom, mass m_p, and radius a_o, is located at the origin at H with $\nu = 0$, $\eta = 0$. The mass and radius of the universe are represented by the values $\nu = 2$, $\eta = 1$ at U. The modular and Schwarzschild potential limits are the upper and lower 45° lines respectively. The remaining observed bodies in the universe lie roughly within the three hatched bands, whose slope is that of constant density terminating at the modular limit. The bodies

on the lowest and longest band have density of the order of one g/cm^3 and include asteroids, satellites, planets, and stars. This band terminates on the modular limit at $\nu = 3/2, \eta = 1/2$. With little mass overlap of the first sequence, the next sequence of bodies (star clusters and galaxies) begins near $\nu = 3/2$ and falls along an equi-density band reaching the modular limit at $\nu = 7/4$, $\eta = 3/4$. Above this point the observational uncertainties do not permit a definitive picture. It is not clear whether there exist two (or more) sequences of clusters of galaxies or only one.

A cluster sequence terminating at $\nu = 11/6, \eta = 5/6$ together with a second sequence of higher order clusters terminating at $\nu = 15/8$, $\eta = 7/8$ (as shown in Figure 1 and Figure 2) may fit observations better than the single sequence extending to $\nu = 15/8$, $\eta = 7/8$ shown in Figure 3. The resolution of this structure as well as whether still higher levels of clustering exist must be decided on the basis of future observations.

From the point of view of hierarchies, the levels occupied by cosmic bodies may be described either as *modular levels* (in the sense defined earlier), or as levels defined by a density

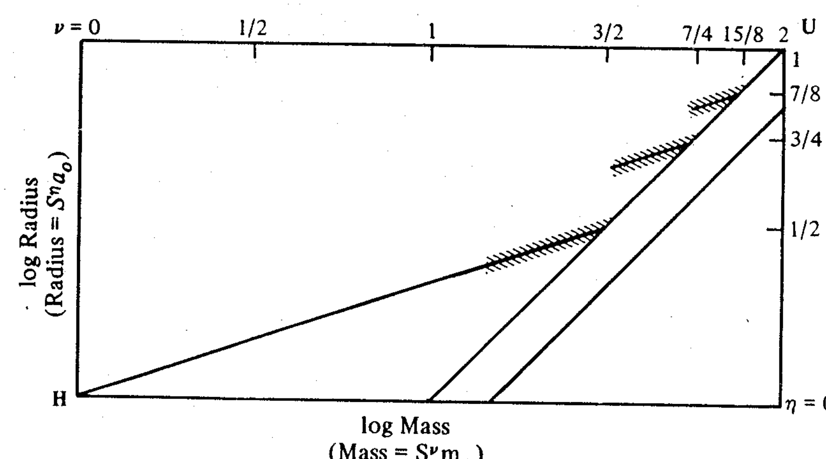

Figure 3 Cosmic Diagram

parameter, or its equivalent frequency parameter. In addition the structure may be "sliced" differently and the cosmic bodies may be allotted to distinct levels defined by a mass parameter. These levels are broad but on the scale of Figure 2 appear to be distinct.

INTERPRETATIONS

An intrinsic difficulty in relating empirical results (such as those displayed in Figures 2 and 3) to current physical theories is that numbers of the magnitude of S are not contained in any classical equations of physics. This difficulty has been expounded by Dirac (1938), Jordan (1947) and others. Eddington (1931) made attempts to derive the fundamental dimensionless constants from first principles, not, however, with complete success in reproducing the observed values. A theoretical understanding of the various observed relations between the different levels of cosmic structure – atoms, stars, galaxies, . . .the universe – is thus likely to come only after new theories of such concepts as time, degeneracy, and informational content of structure are available. At the present stage only some *speculative* suggestions can be made.

For example, the existence of *two* potential limits, the Schwarzschild and the modular, implying that the same extension ratio (the α^2 ratio of atomic to nuclear dimensions) holds between non-degenerate and collapsed configurations at stellar, galactic and cluster levels, suggests that through a generalization of the concept of degeneracy, the theorectical validity of equation (1) for all levels might be established. One might speculate that configurations at every level possess a collapsed or close packed state, and an extended state α^{-2} times larger. An alternate approach may be that the reflection of the α^2 ratio into higher levels of cosmic-structure is a cosmogonic vestige from a universe in a highly collapsed state. But whatever the cause of the modular limit, it must be regarded as an important observational feature to be accounted for by cosmological theories.

A second speculative suggestion is that in the sequence of powers of S that map observed mass configurations, we are encountering a resonance phenomenon. However, the fundamental and the overtones are exponentially related instead of being related in the manner of Pythagorean harmonics. This suggests kinship to the logarithmic time derived by Milne (1935) in his kinematic relativity. If we take as the basic gravitational frequency, the inverse Schuster period, $f_o = (Gm_p)^{1/2}/2\pi a_o^{3/2}$, then the overtones are given by

$$f_\nu = \frac{(GS^\nu m_p)^{1/2}}{2\pi(S^{\nu-1}a_o)^{3/2}} = f_o S^{3/2-\nu} \qquad (3)$$

where $\nu = 3/2, 7/4, 15/8, \ldots.$

Numerically, $f_{3/2} = f_o$, the frequency associated with the hydrogen-stellar line of Figure 3, corresponds to a period of about two hours; $f_{7/4}$, the galactic line corresponds to 10^6 years; $f_{15/8}$, the cluster line corresponds to 85 x 10^9 years; and f_2 corresponds to 10^{15} years. The cluster value is close to the period derived by Sandage for an oscillating universe. Viewed as a Hubble time, it corresponds to a value of H = 74.13 km/sec/mpc, in close agreement with the observed value of H = 75.3 km/sec/mpc derived from cluster distances (Sandage 1968).

If we take this equivalence between the $\nu = 15/8$ cluster gravitational time and the observed cluster Hubble time, as additional corroboration of the valid representation of the cosmic diagram, then we infer that the visible sample of the universe, the "realm of the galaxies and clusters" is not the $\nu = 2$ universe. The observations at the limits of our telescopes are describing the $\nu = 15/8$ sub-structure and not the universe. Characteristic times of the order of 10^{10} years are those associated with the cluster level sub-structure. The characteristic gravitational time of the $\nu = 2$ universe, on the other hand, is of the order of 10^{15} years. The appearance of a time of this magnitude brings to mind the controversy that waged in cosmology following the publication of James Jeans (1929) estimate of the dynamic age of the galaxy at 10^{13} years. The adherents of the "short time-scale," held the age of the universe to be but a few eons while those who subscribed to the "long time-scale," required an age of the order of 10^{13} years or greater. Since the galaxy could not be older than the universe, the issue was settled against Jeans. But if the few eons refers not to the universe but to the cluster level sub-structure, there is no *a priori* reason why the galaxy cannot be older than the cluster level sub-structure.

If the cosmic diagram suggests some form of resonance as the process of morphogenesis, then as sand collects at the nodes on a vibrating drum head, matter concentrates at nodes corresponding to the set of frequencies $S^{3/2-\nu} f_o$. This raises many physical questions. Most importantly, what is it that is pulsating or vibrating at these frequencies – some substratum, matter itself, or what? Analogies to familiar equations suggest that from the cosmic diagram, we have a set of eigen values representing mass levels, energy levels, or frequencies that are solutions to some "cosmic wave equation." Perhaps the first step toward a physical theory would be to derive such an equation.

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■

Dimension as Level

Robert Edward Williams*

In geometry, dimensionality is usually conceived as a set of independent, mutually perpendicular space coordinates $x, y, z, \ldots$. Dimension is not ordinarily considered to be a 'level' or to be associated with an 'emergent whole' of higher order that arises from lower order elements (Bunge 1960). It is the purpose of this note to point out a sense in which dimension can be considered to be a level, and give an illustration of emergence using geometrical polytopes.

Eighteenth century geometers realized (Coxeter 1963) that a certain algebraic sum of realizable geometrical entities in a polytope is either equal to zero for $n = 0, 2, 4, \ldots$,dimensions or equal to two for $n = 1, 3, 5, \ldots$,dimensions. This relation known as Euler's Law (Euler 1752) was generalized to n dimensions by Schläfli in 1852 (Coxeter 1968) and proved by Poincaré (1893). This law can be written:

$$N_0 - N_1 + N_2 - \ldots + (-1)^{n-1} N_{n-1} = 1 - (-1)^n, \qquad (1)$$

where N is the number of entities and the subscript is dimension. Specifically, N_0 is the number of vertices, N_1, the number of edges, N_2, the number of faces, N_3, the number of solids, ...

To appreciate how a new level emerges from combining entities of lower dimension, consider the case of equation (1), for a two-dimensional tessellation,

$$N_0 - N_1 + N_2 = 1. \qquad (2)$$

Combining polygons under the rule that (i) we maintain Euclidian space, (ii) we do not distort the polygons, and (iii) that every two polygons share one edge, we may build up an indefinitly large aggregate of connected polygons satisfying equation (2). If we are aggregating pentagons, for example, when we accumulate twelve (Figure 1a) and connect them so as to join *all* edges, we obtain a dodecahedron (Figure 1b).

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Closure, Entity, and Level

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The manner of decomposition of a complex organism or structure into sub-components is arbitrary. With a scalpel in the dissecting room or with the knife of pure intellect, the decomposer has freedom to isolate many alternative sub-groupings. However, unless his knife follows the "natural interfaces," severing a minimum of connections in isolating the sub-components, his decomposition may prove to be confusing, uninteresting, and messy. Whereas all decompositions possess the kind of properties that are treated in classical set theory, those decompositions conforming to natural interfaces frequently reveal additional interesting properties. What we call the "natural interfaces" are identifiable either by the occurrence of a steep decrement in the number or strength of linkages crossing them, as developed by Simon (1962) in the concept of *near decomposibility*, or through the existence of some form of *closure*. The purpose of this note is to sketch how entity and level may be related to one or more forms of closure.

The most apparent from of closure is *topological* closure—the encompassing by (one or more) closed surfaces of a spatial neighborhood that coincides with or bounds the extension of a physical object. We thus perceive balls, donuts, strings, and sheets as topologically closed. In general, topological closure bestows finitude and convexity on objects and is a property of most entities that we differentiate by visual perception.

A second type of closure, associated with a neighborhood in time that coincides with or bounds the *duration* of an entity, may be called *temporal* closure. More abstract notions of closure may be employed to distinguish non-physical entities. Thus a *group* may be defined as a set of numbers, elements, or transformations that possess closure with respect to some *operation*. For example, the integers 0, 1, 2, 3, 4 form a group closed under addition modulo 5. This type of operational closure, when the number of elements is finite, joins temporal closure in being cyclical in the sense that some parameter follows a path that periodically returns to previously assumed values. Topological closure and cyclical closure can be related through various Fourier type transformations. Spatial representations (particles) and frequency representations (waves) may thus both be subsumed under the notion of closure. In addition isolation of entities may take the form of either physical separation or "detuning."

Not only may differentiatable entities and modules be described through the use of some form of closure or cyclical parameter, but many

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notions of *level* may also be differentiated through closure. For example, levels in control hierarchies such as industrial corporations are determined by subsystems identifiable through various feed-back loops which are mappable onto a set of closed cyclical parameters. In modular hierarchies (Wilson 1967) levels and modules share a set of topological closures and when the modules are homogeneous the levels become identical to the modules.

The example of hierarchical cosmic sub-structures (Wilson 1969) shows that levels may be distinguished by a characteristic time or frequency, which is to say that each level is temporally closed. This suggests that the properties of space and time are closure properties of structures, bringing to mind the basic idea of Leibniz that space and time have no independent existence, but derive from the nature of structures. Einstein's equivalence of dynamics and geometry contained in his field equations (e.g., matter density determines spatial curvature) is also consistent with Leibniz's view and a departure from the Newtonian idea that all structure exists within an independent framework of space and time. It may then be that from the various closures and partial closures of structures and systems, we infer the descriptions we call space and time.

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Approaches to a General Theory of Structure

Lecture SIU, April 13 1966

Tape #1

There is a subtle revolution taking place today in the Weltanschauung of scientific methodology. This revolution in point of view paradoxically is not originating among the scientists themselves so much as among the artist, the architect, the engineer, and those who are aware of the complex patterns occurring in the structures of nature. This revolution may be said to be a revolt against the atomism of ~~Heracleides~~ Democritus and the reductionism of ~~Newton.~~ Aristotle? Bacon? For the past three centuries the basic approach of science has been through the descriptor of the differential equation. This has proved to be a very effective vehicle, and at the present time is the basic feature of the principal constructs of science. However, it is being increasingly recognized that the atomistic approach as is best represented through the methodology of the differential equation and continuum mechanics, has been recognized to have rather severe limitations. It is the biologist who first became aware of the deficiencies of the reductionist approach. The reductionist approach is the attempt to explain all phenomena in terms of the component sub-parts of the phenomena. This ultimately leads to breaking down the sub-phenomena themselves into more and more basic phenomena, ending hopefully with some sort of monad upon which the whole structure of knowledge can be based through certain minimal principles and theories of the organization of fundamental particles. The biologist recognized severe limitations in this atomistic or reductionistic approach from his point of view. He had to explain why certain patterns affected certain behaviors in the eye of the frog, the cat, and the rabbit. It soon became evident that a reductionist explanation was impossible. What patterns the rabbit saw, recorded and passed on to the brain which affected the behavior of the organism, could not be explained in terms of the sub-components of the rabbit's eye or nervous system. Rather it was necessary to look at the ecology of the rabbit in order to understand that his response to certain patterns and not to other patterns was determined by the structure of his enemies. George Gaylord Simpson introduced the concept of the compositionist explanation as contrasted to the reductionist explanation. The phenomena of the neurology of the rabbit's eye must find its total explanation in the patterns of structure in which the rabbit lived, as well as in the sub-components. This idea has been slow to spread to physics, astronomy, and other exact sciences. In these fields, the basic effort is still to seek the reductionist or atomistic solution to all problems. The unfortunate aspect of this is that it tends to make the researcher in physics and astronomy unaware of certain patterns of a microscopic or compositionist nature which may play an extremely important role in the operation of the cosmic order. So long as one continues to focus on the X, the Y, the Z, the T, they may fail to notice the actions at a distance, the large scale patterns, and phenomena. What I would like to present to you today is nothing more than some immediate more or less obvious consequences of looking at some data which has been obtained and well established enough to appear in standard text books and hand books, but which has never been looked at from a compositionist point of view. Instead of looking, for example, at a star and trying to understand the mechanisms which are taking place in its interior, to try to understand the details of the energy transfer from layer to layer of the star, to try to understand what is taking place with regard to the ionization and excitation of atoms in the outer layers of the star, and of the alteration of the nuclei of atoms in the deepest parts of the star, we will try to look at a star as a whole - to look at its compositionist or gestalt properties and compare the star with its environment and the context in which it finds itself. To seek relationships between a star and the galaxy, a galaxy and its environment, etc. This is the compositionist Weltanschaung in which the fundamental feature initially is not to seek explanations but rather, to observe whatsoever relationships and patterns in structure that may be evident from the data which is well established and available to all of us. I would like to start by looking at the most trenchant aspect of the structure of the cosmos. This is what is usually called the hierarchic structure of the cosmos. I object to the use of the word hierarchic partly because of its historical use, and partly because the implications of the term involve a set of bosses, or rulers passing orders down the line. The word hierarchy comes from the Greek word "hieros", meaning holy, and originally applied to the order of the angels, archangels, seraphim, cherubim, in the theological structure of the heavens. Later this term applied to the organization of the church, the metropolitans, the archbishops, the bishops, the priests, the deacons, etc. But when we speak of a hierarchy of structures, though in this sense there are various levels in the structure, we have in mind a more explicit feature of the organization. Namely, that any structure is made up of components or substructures, and each of these substructures in turn is made up of components, sub-subcomponents, if you will, which bear structural resemblances to the microscopic structure. I want to introduce for this type of structure the term taxoreotaxis, from taxis, the Greek word for structure, and xoreo, the Greek word for contain. A structure containing a similar structure,taxoreotaxis. The taxoreotaxis of the universe has been recognized since ancient times

TAPE #2

The taxoreotaxis of the universe has been recognized since ancient times although the extensions to the microscopic and macro-macroscopic have occurred only in the past 150 years. The first slide is the list of the various aggregates which occur in nature and their taxoreotaxic relationships with one another. It is not known how far this series continues into the microcosmic nor how far it continues into the macro-macrocosmic. At the moment the largest accepted structure which occurs in the universe is the cluster of galaxies, large aggregates whose diameters are around sixty million light years and which contain possibly a thousand galaxies. At the present time it is under investigation whether or not there may exist even larger structures whose components are clusters of galaxies themselves. Today I would like to examine the upper portion of this sequence of the taxoreotaxis. We will examine stars, galaxies, clusters of galaxies, and see if we are able to discern any structural patterns which these various aggregates may possess in common. Not too many quantitative parameters for these various aggregates have been successfully measured but there is one parameter which is known with a fair degree of accuracy for each of these aggregates. This is the ratio of the mass of the aggregate to its radius. We shall assume all of these objects are roughly spherical and may be approximated in their first order properties by spheres. The ratio of mass to the linear radius of an object is determined in quite different ways using quite different techniques for each of the three or four aggregates which we plan to consider. For a star, the ratio of the mass to the radius may be determined in the case of the type of star known as an eclipsing variable or eclipsing binary. These are a pair of stars orbiting about one another in which the plane of the orbit happens to pass through the earth. In this case, we see the stars eclipsing one another, and from very simple relationships known since the time of Kepler, and I might add very importantly these relationships are empirical not theoretical, we may derive the masses and the radii of the stars, and hence, their ratio of $\frac{M}{R}$. This is independent of the distance to these objects. Now for galaxies, $\frac{M}{R}$ may be derived in at least two ways and to a less certainty, in a third way. The two basic ways of determining the ratio of the mass to the radius are to observe the spectra of the rotating galaxy and measure the inclination of the spectral lines from the normal. This angle of inclination together with the angular radius and the linear value of the Doppler velocity, allow us to determine the ratio of $\frac{M}{R}$ for a galaxy. A second method of determining masses and radii of galaxies is from observing pairs of galaxies and assume they are in Keplerian orbits about one another. The results from these two methods are in fair agreement. To determine the $\frac{M}{R}$ ratio for a cluster of galaxies we resort to what is known in mechanics as the verial (sp?) theorem which gives the ratio of $\frac{M}{R}$ in terms of the dispersion of the velocities of the members of the cluster. Since velocities can be determined from the redshifts, it is possible without any assumptions whatsoever concerning the distance to the cluster, to evaluate the $\frac{M}{R}$ for the cluster directly. In the case of the suspected second order clusters the same technique can be used but also the mass and radius can be built up from counts of the number of clusters in the second order cluster. The second slide displays a basic observational data for each of these objects. Also we provide the basic mass and radius of the hydrogen atom which will be used as our basic units for mass and radius. The interesting thing in Slide 1 is that whatever the mass or whatever the radius we observe that the ratio is the same for all of these cosmic aggregates, a number of the order of 10^{-23} power in terms of grams per centimeter. If we express $\frac{M}{R}$ in terms of the mass and radius of the hydrogen atom, we find that in each case we have a number of the order of 10^{-39} power. This in itself is an interesting number which has occurred both in atomic physics and in cosmology and is known as one of the basic Eddington numbers of structure. The ratio of the strength of the electric forces to the strength of the gravitational forces is a number which is equal to 10^{-39} power. It is also of interest,as pointed out by Eddington, that the radius of the universe divided by the radius of the hydrogen atom turns out to be 10^{-39} power. The radius of the universe is the velocity of light divided by the Hubbell parameter. The nature of this large number 10^{-39} occurring both in atomic physics and in cosmology is one of the basic curiosities of physics. This, together with Eddington's other structural number, the inverse of the Summerfelt (sp?) fine structure constant, a number whose value is close to 137 which appears repeatedly in structural properties of atomic physics, is also one of those numbers which occurs in cosmology and which point to some at present unknown basic relation between atomic physics and cosmic physics. There are two schools of thought at the present time with regard to these relationships. One school of thought we may call the Machian school which believes in a interrelationship between all structures large and small of a compensatory nature. The other school is the Eddingtonian school which believes there exists some underlying structure, a transphysical, a mathematical, or geometric structure, which manifests itself in physical properties - the atom or the cosmos. These basic structural numbers are far more basic than the laws of physics. Eddington, in fact, believes that the laws of physics derive from the number theoretic properties of these basic structural constants.

Most experience indicates that there exists a functional dependence between structure and behavior. However, it is important to distinguish between behavior as a compensatory response to environment, and behavior as dynamic self-contained process deriving from internal structure. Behavior which derives from internal structure is usefully divided into two forms - short range or processing behavior, and evolutionary or modifying behavior. Depending upon the extent to which Machian relations govern structure, we may find there is no such thing as a dynamic process deriving solely from internal structure. All process and modification of structure may be Machian, as well as the structure itself. This statement is equivalent to rejecting the concept that the geometrically internal is the only significant structure governing behavior. A Machian construct would state: first, that structures internal and external to every hypersurface are inseparable; and second, all behavior is a consequence of total and not just internal structure. Thus, no system is isolated nor can any system be regarded as consisting only of what is geometrically interior.

We may further amplifly the above distinction between short range and evolutionary behavior as follows: by short range behavior we shall mean behavior which plays no part in the modification of the structure except possibly aging. Evolutionary behavior, on the other hand, is a process of whatever time duration which affects a change in the structure. Short range behavior processes energy in some form. Evolutionary behavior modifies the information which is stored in the structure. In short range behavior, there is an input and output of energy, a portion of the energy being consumed in the processing. A star is an example of a structure in which evolution and short range behavior are mixed. It is because the substance processed in the short range behavior of a star constitutes an intrinsic part of the structure, and through being processed, the structure in turn is modified. Specifically in the case of the star, the short range behavior is the process of conversion of mass into radiation. Gradual loss of mass changes the structure and this evolutionary change in structure in turn modifies the details of the short range behavior.

Three dimensional space has been generalized in the theory of relativity to four dimensional space-time, through inclusion of time as an equivalent geometric coordinate. The concepts of structure and behavior are related and may be generalized in the same way. Behavior thus becomes the structure of a system in space-time.

Let us consider now in more detail the basic ideas relating structure and behavior or form and function. The behavior of an organism, be it man, or animal, or star, may be divided into three categories; that which is internal; that which is functional, such as consumption of energy, or energy processing; and finally, which is evolutionary, reproductive, or structure modifying. Each of these types of behaviors requires transmission of energy to all parts of the structure. The traffic density, however, required for each type of behavior is different. A mononucleated city, for example, requires a much higher density than is required between the nuclei or in intercity commerce. Hierarchies occur whenever there is a drop in the necessity for a certain type of communication traffic. In understanding any organism, we must know what types of messages must be sent and how frequently each type must be sent. We must know those synapsis which must be in communication frequently with one another and those which need to be in communication only occasionally. We are led, therefore, to a characteristic time related to a characteristic size through a characteristic frequency of communication.

One of the most important properties of structure is stability. Stability refers to some sub-set of properties which remain invariant for an extended period of time. Ultimately the period of time must be referenced to a characteristic period of time for the observer. For an observer to interpret behavior as stable, it must endure long with regard to his own characteristic time. In another sense, a stable structure may be said to be a structure whose component parts may be altered without disruption of the whole. Thus, the most stable structure is put together so as to permit the maximum readjustment of components without the destruction of the whole. If the total structure replicates the structure of its sub-components, it has the unique property in that it permits experimentation upon its sub-components to determine what successful modifications may be derived and those which are successful in the sub-components may then be adopted for the structure as a whole because the total information of the structure is contained within the sub-structure. It is very interesting to note that the human body is constructed in precisely this way in that every cell of the body contains the total information required to reconstruct the whole body. Organization of this type we will call epitactic. An epitactic organization affords a maximum stability plus freedom for readjustment and the optimum method of achieving that stability.

If these abstract properties are true it should not be surprising to find them not only in biological organisms, but also in other organisms which are hierarchically constructed. It should not then be surprising to see certain properties of cosmic aggregates replicated at different levels, and this is precisely what we find in the study of stars, galaxies, clusters, and higher order clusters.

We must now distinguish between energy processing behavior and the structures which support it, and information processing behavior and the structures which support it. A machine is a processor of energy. Its information is stored in its structure in the setting of the valves, the operation of the pistons, the size of the cylinder. A mold, or castings, or a program for a turret lathe, are one and the same in the sense that their structures contain the information which determines the behavior of the machine and how it processes energy. An information processor, on the other hand, has certain fixed energy components, circuits, memory banks. These forms are put together in different ways to process, that is, to alter the structure of the information contained within the system. An organism or organization which processes both energy and information and effects a symbiosis may be said to exhibit most of the properties exhibited by the life process.

SIU - "Some Principles of Hierarchal Structure"

Data and Equations:

Kepler's 3° Law: $P^2 = \frac{4\pi^2 a^3}{G(M_1+M_2)}$; $\frac{1}{a v_0^2} = \frac{1}{G(M_1+M_2)}$; $\frac{G(M_1+M_2)}{a v_0^2} = 1$

Sample	M/R ($\log_{10}$)
77 stars	23.3 gm/cm
20 galaxies	23.6
14 clusters	23.5
2° cluster	23.2

$\frac{G}{c^2}$ -28.13

28.13
23.50
-4.63

$\frac{GM}{c^2 R} < \frac{\alpha^2}{2}$

Galaxies $\frac{\omega^2}{4\pi G\bar{\rho}} = \frac{1}{3}\left(\frac{R}{a}\right)^3 = F(e)$

Clusters (unit ρ) $\frac{5}{3}\frac{GM}{R} = \bar{\bar{v}}_r^{\,2}$

$a_0 \sim 10^{-8.2764}$

$\alpha = \frac{2\pi e^2}{hc} = .00729729$

$\alpha^2 = .00005325$

$\sim 10^{-4.274}$

$\alpha c = 2188$ km/sec

d/fa
[redacted] Wilson 12/7/67

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Section 2

WHAT is structure? We meet structure everywhere - in cities, in buildings, in nations, in government, in the cosmos, in our families, in our very own physical bodies and psyches.

Structures consist of two elements: linkage and synapse. We borrow these words from physiology where synapse is defined as the junction point of neurons (the linkage) across which a nerve impulse passes. In a city, linkages are roads, telephone networks and subway lines. Synapses are shopping centers, airports, telephone exchanges, factories, schools, librariers, television studios or post offices. In buildings linkages are girders, synapses are connections; or linkages can be air ducts and heating units synapses. Cities and towns are synapses of nations linked by communication channels and trade routes. In governments, the synapses are centers where decisions are made - courts, congresses, executive, voting precints or constituents. Linkages connecting these centers are procedures for passing decisions or requests for decisions between them or chains for giving commands. Cosmic synapses are celestial aggregates such as stars, planets and galaxies. Linkages are gravitational, radiation or magnetic fields. Human structure have circulatory, respiratory or nervous linkages to functional synapses of heart, lungs, brain, not to mention the familiar structural concept of anatomy - bone linkages joined by elbow, knee or ankle synapses.

Besides linkages and synapses what else is common to structures? Consider the travel over linkages into and out of synapses. The phenomena of traffic is common to all structure. But do automobiles do the traveling or is it the people or goods inside the automobiles that travel? Since we've already gone far enough to anticipate what's needed next, we distinguish carrier from the thing carried. In general, the thing carried is either energy or information - the carrier is on the most basic level elemental particles, that is, electrons, photons, and gravitons. However, our view of the structure observed requires we choose an appropriate magnification of the carrier. For example, to consider the linear linkages called girders in buildings, we must choose the molecular carrier of tension and compression. In cities, structure is displayed by vehicle carriers on freeway networks or messages on telephone networks. Gestures characteristic of psychological states may be considered as one kind of carrier in government structure. We summarize some of these examples in the first chart. This outline of definition serves as a framework for discussing structure - it allows us to consider the traffic common to all these various kinds of structures.

Traffic is a phenomena of an aggregate of carriers. Traffic results in a city from the fact automobiles and trucks must go along existing linkages into and out of existing synapses - airport terminals, factories, shopping centers, etc. Traffic in a telephone system results from the fact that messages must go on existing channels into and out of existing exchanges. The dimensionality of the linkages thus becomes an important parameter in describing structure.

A freeway or road network is one dimensional while an air route is two dimensional. Girder or beam linkage in buildings are linear, therefore, one dimensional. An airplane or balloon is two dimensional because the surface (or skin) carries stress. The human body is presumably one dimensional if we consider only physiological structure. The possibilities for describing human structure by including the multi-dimensional linkages implied in psychosomatic or corticovisceral models are intriguing but beyond this presentation. (Ref: J. of Psychiatry, Sept. 1967)

In government structures containing decision-making synapses, formalized chain-of-command linkages or referendum procedures imply one-dimensionality. We know however that informal channels exist in these structures (Ref:). It would be useful to diagnose these structures to identify their linkage dimensionality and we will go into such analysis in a later section (see page).

We also note here that synapses (or centers) are of zero-dimension. This does not mean that synapses are of zero size for they obviously can extend in space for several miles as in the case of airports or shopping centers. We must abstract the zero-dimension of synapses in order to preserve the idea of junction. In contrast to the abstraction of a point in Euclidean space (that is, of zero-extention as well as zero-dimension) a synapses can have real extention in space but it must be zero-dimension.

Awareness of traffic is experienced as overloads - congestions - jams, etc. We said earlier that traffic is a phenomena of some aggregate of carriers. Besides the inherent limit of characteristic velocity of any one carrier, we can distinguish four additional limits to the travel of carriers. These are: 1) the input/output ~~size~~ capability/per unit time (number of carriers into and out-of) of any synapse, 2) the total number of synapses in the structure, 3) the total number of linkages into/out-of any one synapse, and 4) the maximum carrier density possible on any one link. Number 3) could be included in the definition of input/output size of any one synapse (that is, as in the case of designating electronic equipment by number of channels: a 2 or 4 channel amplifier, for example). Each specific structure defines these limits to travel of carriers. Here we are concerned with descriptive statements about traffic.

(Note something is wrong here)

CHART I

STRUCTURES

Synapse	Linkage	Carrier	Thing Carried
Synapse	Neurons	Nerve impulse	Electrical impulse (energy)
Junctions	Girders	Molecules	Tension or compression force (energy)
Shopping Center	Freeway	Automobiles Trucks	Goods and people (energy)
Telephone Exchange	Telephone channel	Messages	Information (some energy)
Decision-making Center	Chain-of-command	Messages, gestures, tone-of-voice	Information
Stars	Fields (Radiation, Magnetic/ gravitational)	Electrons Photons Gravitons	Energy and information
Cities	Communication channels Trade routes	Messages Vehicles	Information and energy
Heart	Circulatory system - veins and arteries	Blood	Energy

CHART 2

Kinds of Density in Structure

1) Input/output ~~size~~ capability of a synapse per unit time	planes/day at one terminal ~~number of carriers in neighborhood of a synapse~~ trains/week
2) Number of synapses per unit length, area, or volume	cities/thousand sq. miles mailboxes/mile stars/cubic parsec schools/sq. miles houses/sq. feet
3) Number of linkages per synapse:	neurons into one synapse air routes into one airport roads into one town girders into one connection chemical bonds into one atom channels into one amplifier
4) Number of carriers per unit time on one linkage:	messages/hour / automobiles/hour photons/sec./from decisions/day / from Sec. of State to Sec. of Defense elect~~r~~ions/year (use in hierarchy) ~~votes~~/

No 4. No 3 = No 1

Section 2

WHAT is structure? We meet structure everywhere - in cities, in buildings, in nations, in government, in the cosmos, in our families, in our very own physical bodies and psyches.

Structures consist of two elements: linkage and synapse. We borrow these words from physiology where synapse is defined as the junction point of neurons (the linkage) across which a nerve impulse passes. In a city, linkages are roads, telephone networks and subway lines. Synapses are shopping centers, airports, telephone exchanges, factories, schools, librariers, television studios or post offices. In buildings linkages are girders, synapses are connections; or linkages can be air ducts and heating units synapses. Cities and towns are synapses of nations linked by communication channels and trade routes. In governments, the synapses are centers where decisions are made - courts, congresses, executive, voting precints or constituents. Linkages connecting these centers are procedures for passing decisions or requests for decisions between them or chains for giving commands. Cosmic synapses are celestial aggregates such as stars, planets and galaxies. Linkages are gravitational, radiation or magnetic fields. Human structure have circulatory, respiratory or nervous linkages to functional synapses of heart, lungs, brain, not to mention the familiar structural concept of anatomy - bone linkages joined by elbow, knee or ankle synapses.

Besides linkages and synapses what else is common to structures? Consider the travel over linkages into and out of synapses. The phenomena of traffic is common to all structure. But do automobiles do the traveling or is it the people or goods inside the automobiles that travel? Since we've already gone far enough to anticipate what's needed next, we distinguish carrier from the thing carried. In general, the thing carried is either energy or information - the carrier is on the most basic level elemental particles, that is, electrons, photons, and gravitons. However, our view of the structure observed requires we choose an appropriate magnification of the carrier. For example, to consider the linear linkages called girders in buildings, we must choose the molecular carrier of tension and compression. In cities, structure is displayed by vehicle carriers on freeway networks or messages on telephone networks. Gestures characteristic of psychological states may be considered as one kind of carrier in government structure. We summarize some of these examples in the first chart. This outline of definition serves as a framework for discussing structure - it allows us to consider the traffic common to all these various kinds of structures.

Traffic is a phenomena of an aggregate of carriers. Traffic results in a city from the fact automobiles and trucks must go along existing linkages into and out of existing synapses - airport terminals, factories, shopping centers, etc. Traffic in a telephone system results from the fact that messages must go on existing channels into and out of existing exchanges. The dimensionality of the linkages thus becomes an important parameter in describing structure.

A freeway or road network is one dimensional while an air route is two dimensional. Girder or beam linkage in buildings are linear, therefore, one dimensional. An airplane or balloon is two dimensional because the surface (or skin) carries stress. The human body is presumably one dimensional if we consider only physiological structure. The possibilities for describing human structure by including the multi-dimensional linkages implied in psychosomatic or corticovisceral models are intriguing but beyond this presentation. (Ref: J. of Psychiatry, Sept. 1967)

In government structures containing decision-making synapses, formalized chain-of-command linkages or referendum procedures imply one-dimensionality. We know however that informal channels exist in these structures (Ref:). It would be useful to diagnose these structures to identify their linkage dimensionality and we will go into such analysis in a later section (see page).

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Stars	Fields Radiation, Magnetic/ gravitational	Electrons Photons Gravitons	Energy and information
Cities	Communication channels Trade routes	Messages Vehicles	Information and energy
Heart	Circulatory system - veins and arteries	Blood	Energy

CHART 2

Kinds of Density in Structure

1) Input/output size of synapse:	number of carriers in neighborhood of a synapse
2) Number of synapses per unit area:	cities/thousand sq. miles
	stars/cubic parsec
	schools/sq. miles
	houses/sq. feet
3) Number of linkages per synapse:	neurons into one synapse
	air routes into one airport
	roads into one town
	girders into one connection
	chemical bonds into one atom
	channels into one amplifier
4) Number of carriers per unit time on one linkage:	messages/hour
	automobiles/hour
	photons/sec.
	decisions/day
	electrons/year

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THE FUTURE OF THE CITY: MEGALOPOLIS OR MERISTOPOLIS?

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Abstract

The technological, economic and psychological forces that attract people to or repel people from urban centers are undergoing fundamental changes. The balance between the forces of aggregation and those of diffusion is shifting. No longer can extrapolated growth curves be taken as reliable guides to the city's future. In view of the increasing ability to create an urban culture outside of large population centers and in view of the increasing difficulties in maintaining an urban culture within large population centers, the future of the city as we have known it is in serious doubt. This paper identifies and discusses the growth of fragmentive forces and the decay of the aggragative forces that have historically shaped the city. Will the projected trend to megalopolis materialize or will a net of meristopolis arise through the fragmentation of present cities into smaller, more uniformly distributed centers of population?

Modern approaches to problem formulation and solving, such as Operations Research and Systems Theory, caution against the common error of defining a problem within too narrow a context. Those who focus on the improvement of the steam locomotive suddenly find that their solutions are irrelevant in a railroad technology switching from steam to diesel power. Those who design faster ocean liners find their solutions aborted by transoceanic air travel. Those whose chips are on higher octanes lose their shirts when kerosene preempts the motor fuel market. The rapid and radical changes of these times provide us with an abundance of examples that teach us to look both broadly and deeply into our problems, not only asking what it is that we are really trying to do, but whether what we are trying to do will be meaningful by the time we are able to do it.

I believe any exploration into alternate solutions for the current problems of urban transportation must take as boundary conditions nothing less than the basic forces that define the city and govern its growth and decay. This especially since a decade has become the typical span of time for the implementation of most programs for new urban transportation systems. An analysis of the forces shaping the city must include not only the economic and logistic factors but the cultural and psychological factors. The fact that many of these components are not easily measured and quantified does not reduce their importance. Our tendency to stress what we can measure and massage mathematically and ignore what we cannot causes us to substitute operations with methodologies for operations on the problems themselves, usually with highly discrediting results.

The evolution of the city is shaped by an interplay of forces and images. The forces are the inertias of past practices and present investments. The images are the visions and models of the future. The forces are the imperatives generated by the individual and collective needs and wants of those who choose to live in or off of the city. The images are mental distillations of the individual and collective ways of viewing and experiencing the city. Since subjective modifications of objective realities are ever creating the future through distorting the present, it is important to recognize the four basic subjective approaches that provide the dynamic for societal structuring and restructuring.

A fundamental anthropological invariant is the structuring of societies, both primitive and advanced, around four basic social functions, which echo their origins in the four psychological types. In India a strong caste system traditionally differentiates the levels of priest, prince, warrior and tradesman. On the opposite side of the globe in the pre-columbian city of Uxmal in Yucatan the same basic division of function according to priest, prince, warrior and craftsman was made architecturally an integral part of the urban plan. At the present time the bushmen of the Kalahiri in Southwest Africa adopt a similar fourfold structure--shaman, headman, weaponman and supporter--for their hunting parties. Thompson (1) has shown how in highly developed societies these four groups are modified through finer differentiations, but still maintain their basic identity.

The institutions of religion, science and education derive from the shaman function; government and management from the headman function; the military and defense establishments from the warrior function; and the sector of business, industry and art from the tradesman-craftsman function. The universality of this fourfold structure of social organization gives weight to the primacy of the four analagous causes usually credited with being responsible for the origin and continuance of cities: Cities are for generating, storing and disseminating culture and learning; for governing and administering the state; for protection and security; and for providing centers for manufacturing and markets for trade. While detailed economic, physical, psychological and cultural advantages and disadvantages of cities can be elaborated, the existence of cities for over six millenia has depended on the satisfactory servicing by the urban form of the requirements of these fundamental social functions. So long as the urban form fulfills these functions, cities will presumably continue to exist. But it is precisely this issue that throws doubt on the future of cities as recorded history has known them.

The technological revolution of the past two centuries and especially its recent accelerated phase since World War II has done more to challenge the basic institutions of society than any set of events since the neolithic revolution of 10,000 years ago (2). Even the family and the timeless tradition of freedom to procreate are challenged by the condition of today's world. By and large technology has contributed to the centralizing forces that have resulted in the aggregation of increasing percentages of the population in urban centers. The economies of centralized production of energy, mass production of needed goods by a limited number of centers, and non-competitiveness of family agriculture have all contributed to the urban implosions of the 19th and 20th centuries. But it is only to a point that technology has enhanced the centripetal forces enlarging cities. More recently the effects of technology seem to be switching to the other side, enhancing the centrifugal forces that tend to diffuse and erode cities.

First, the matter of protection and security. Certainly the walled city of ancient and medieval times provided fairly good security from the brigandage of nomadic bands, at least until technology introduced the cannon and the walls came tumbling down. Since then both technology and nomadic bands have done quite a bit of evolving. Today the city has become a stack of chips in a game called "Nuclear Deterrents" and the only protection it offers is that of flash incineration over the slower radiation death of the down wind rural areas. As for security, Atilla the Hun has abandoned the countryside for the streets and parks of the city. It is a well established statistic that the level of crime and violence goes up with the density of population reaching its maximum in our largest cities. It appears that the traditional function of security is today better met outside urban areas than within.

Second, the changes in transportation and communication technologies have reversed the implosive trends in manufacturing and marketing. Decentralized industrial parks are springing up at various distances from urban centers in suburbs and in smaller communities. Fewer people must go to the central city for work. In Westchester County New York 70% of the people no longer commute to New York City and the number who do is decreasing sharply. Trucking and "piggy-back" carriers have liberated manufacturers from the umbilical cord of the railroad track and its centralizing restrictions. Containerization requires large amounts of open space and contributes to the forces of decentralization and value of lower density. Branch merchandising bringing the top name stores to suburban shopping centers results in fewer shoppers undertaking a hajj to the central city. Developments of the past 20 years have clearly demonstrated that manufacturing and marketing can be as effectively or more effectively conducted in smaller semi-urban areas than in the city.

Modern communication and transportation technology has also removed the necessity for concentrating government into a small area. We are governed from California, Florida, the Maryland Hills and jet aircraft about as well as from Washington D.C. Administrators can meet more conveniently and securely on beaches and in mountain retreats than in cities. The weapons of the nuclear age have made both decentralization and mobility desirable design features of government, with physical propinquity being replaced by wires (both direct and attached) in the administration of the affairs of state.

Perhaps the greatest impact of modern technology has been on the function of the city as the source and storehouse of learning and culture. For over a century the university has replaced the city as the womb of new knowledge. And while today non-academic research centers and think tanks are the runners to which the torch is passing, neither the campus nor the research institute needs the city. With the libraries, theaters and museums in the central city becoming increasingly difficult to reach, the media are decentralizing the storage and dissemination of culture. TV has shown the feasibility of bringing culture directly into every habitation. We all look forward to the time when this demonstrated feasibility will be implemented. The spread of the do-it-yourself movement from house repairs to the crafts and arts and most recently to the performing arts, has created a new amateurism that could care less for the historic sanctity of a centralized professional culture. (It might be added that this feeling is reciprocated.) Technology has struck a deep blow at the cultural function of the city.

From this brief sketch, which is primarily to bring to mind your own examples of how the technological revolution is rapidly modifying the historical functions of the city, we see that aggregating forces are becoming diffusing forces and centripetal forces are being replaced by centrifugal forces. At the present time we are witnessing a curious paradox in the summoning of the know-how of technology to help save the city that technology is rendering obsolete. Technology is asked to come up with new fuels, new engines, new vehicles and new systems to overcome the disruptive effects brought into being by technology itself. Can a specific application of technology overcome its total impact? Vaccination has not been known to work after the disease has struck. Can a few mercenaries hired from the forces of an invading army turn back the invasion? Those who feel technology has its own imperatives and that humans are no longer in charge will answer no. Those who feel that technology can overcome everything--even technology, will try. I personally am with those who choose to try, not from an illusion of the ultimate restorability of the city to its former place, but as a holding action to make the transition to new approaches to security, administration, business and culture as painless and expeditious as possible.

What about the Future:

There is reason to suspect that tomorrow's developments will be even more unsupportive of the city than today's. First is the matter of energy shortage and the admonition that we are going to have to "cool it". Present cities are not organized to minimize the amounts of energy necessary to provide needed goods and services to all the inhabitants. Cities require more miles of transport, more storage, refrigeration, loading and unloading, etc. than needed to feed the same population living at a lower density adjacent to open agricultural spaces. But efficiency as regards energy consumption has not been a critical value in the past and, if some of the exotic new sources of energy now on the drawing boards become feasible, it may not be a critical matter in the future.

Nuclear fusion as a common source of energy may prove to be one of the greatest centrifugal social forces yet introduced by technology. The fuel--probably heavy water--will not require pipe lines, tankers, or a heavy duty transportation system. A few pounds will go a long way. If the reactors are small, it is likely that independent generators will take the place of large distribution networks and we may see for the first time an abundance of non-polluting energy wherever it is wanted liberated from large central generating plants and distributing networks. The effect of this will be that people can live wherever they wish yet have a reasonable standard of living. Abundant energy will permit all kinds of recycling and other economies with resources. The amenities now found mostly in urban areas will be available on mountain tops, islands or wherever people might wish to live for esthetic or other self actualizing reasons.

As said earlier, the future of the city will result from the interplay of forces and images. The forces appear to be shaping against the city. What about the images? The image of megalopolis is a negative one for most people. A Gallup poll taken in 1968 found the preferences of Americans distributed as follows: For cities, 18%; for suburbs, 25%; for small towns 29%; and for farms 27%. That is about 80% of Americans do not prefer the city.

Images of the future city showing architectonic multi-level shopping arcades with fountains and greenery, connected by moving sidewalks and individual monorail cars fail to energize the support needed for their realization. And if an image does not energize it will not materialize. The positive images of the city are now found mostly amid the growing heap of nostalgia for the good old days. The charm of the shops, the excitement of the streets, the magnificence of the buildings are only in the memory. They are obscured with lurking crime, snarling traffic and choking smog. So perhaps even more negative than the technological and social forces mounting against the city is the fact that the American image of the good life has emigrated from the city and now resides in the open spaces amid green trees, clean water, clear air and still skies. A net of small pluralistic communities, each surrounded by unspoiled or reclaimed open space--a meristopolis--fits more closely both the force future and the image future than the megalopolis predicted a decade ago.

(1) Thompson, William Irwin, At the Edge of History, Harper and Row, N.Y. 1971

(2) Plumb, J. H., "An Epoch That Started 10,000 Years Ago Is Ending." HORIZON, Summer 1972, page 4.

MORPHOLOGICAL CONSTRUCTION*

From Technological Forecasting 1974

Albert Wilson

In all levels of forecasting and planning, it is important that we have a systematic exploratory technique providing a survey of all the policies, approaches, strategies, and opportunities that may become available. Morphological construction is a methodology for the systematic exploration of the totality of possibilities within an explicitly defined situation. The term, *morphology*, was adapted by the astrophysicist, Fritz Zwicky, to stand for three basic techniques of systematic exploration. These are: **systematic field coverage** which is concerned with delineation and the search for limits; **negation and reconstruction** which is concerned with varying basic assumptions; and the **morphological box** which is concerned with the totality of alternatives within a defined domain. To these three, a fourth called **morphological spaces** has been added by Ayres to describe the dynamics of technological development.

Morphology may operate at the frontiers of feasibility to find a route or may operate behind the lines to discover alternative routes. According to Zwicky, there are three types of problem that morphological analysis attempts to solve:

What devices are necessary to obtain all of the information about a given set of phenomena;

What is the sequence of all effects issuing from a given cause;

What are all the solutions of a given problem.

In addition, the morphological box is a useful taxonomic matrix for indexing and classifying the information, effects, or solutions which have been given parametric entitation.

For the survey of alternatives, we shall be primarily concerned with the construction of morphological matrices, but the delineation of limits and variation of assumptions are also useful techniques for futurologists and will be briefly described.

The technique of systematic field coverage is a technique of infiltration of unknown territory, usually by successive approximations, using extrapolations, interpolations, analogies, and inversions. Extrapolation, interpolation, and analogy are meant in the usual sense, but by **inversion** is meant the identification of any dualism and the interchanging of parts or roles. An example of inversion would be the design solution for a dipole antenna for high speed aircraft when location in the airstream is not feasible. A dipole may be *either* a linear conductor surrounded by a non-conductor *or* a linear non-conductor slot imbeded in a conductor. The *inversion* of the usual approach solves the problem when a tubular slot is placed within the conducting fuselage. A favorite Zwicky example of a problem solved by inversion is How to moisten a postage stamp that has fallen on a dirty floor and there is no sponge or water nearby—lick the envelope, not the stamp.

Edward de Bono illustrates **inversion** with the example of the old grandmother who, knitting by the fire, could not keep her two-year old grandchild from tangling her wool. Put into a playpen, the child howled so much she still couldn't knit. Grandmother solved the problem by getting into the playpen herself, leaving the toddler free but out of reach of her yarn.

Rather than being barriers, **limits** frequently turn out to be clues to deeper understanding and the opening of entire new fields. One of the first limits discovered was the fact that no more than five regular polyhedra can exist in three dimensional Euclidean space. This limit fascinated the Greeks and Euclid's geometry was supposedly formalized solely to prove this fact. The limitation that water could not be pumped over thirty-three feet at sea level led to the discovery of atmospheric pressure. Today the absence of meteoroids with hyperbolic velocities and the existence of the Schwarzschild limit in gravitational potentials have led to important concepts about space and matter.

The technique of **negation and reconstruction** is very important both for enlarging the spectrum of possibilities and for breaking out of theoretical cul-de-sacs. The basic approach is simply to reverse the truth value of each basic assumption. The century old frustration with Euclid's fifth axiom of parallels was ended and fruitful fields of research were opened when it was negated. Even when an assumption is valid, a deeper understanding of its role in the system can be obtained by its negation. Some of the most imaginative possibilities are disclosed by this technique.

The construction of **morphological matrices** to exhaust all of the possibilities lying in a defined situation may be summarized by the following steps:

- The problem to be solved must be exactly formulated;
- All of the parameters which might enter into the solution of the given problem must be identified and characterized;
- The multidimensional morphological matrix for the given problem is constructed with one dimension corresponding to the sets of values assumed by each parameter, i.e., if there are n parameters, there will be $n + 1$ dimensions;
- All of the possible solutions (each possible combination of values for the parameters defining one solution) are evaluated with respect to the purposes which are to be achieved and assessed according to state-of-the-art, economic, sequential, axiological criteria;
- The optimally suitable solutions are selected for implementation, in practice this reduction usually requires a supplementary morphological study.

The most critical feature of the method is that step three and step four be kept independent and that step three be complete before step four is begun. That is to say, the generation of the matrix must continue without prejudice regarding the feasibility, desirability, or even, plausibility of any one solution. Only *after* the complete matrix has been constructed is evaluation to begin.

As an illustration of the construction of a morphological matrix, let us consider the morphology of solutions to the problem of world-wide population limitation subject to the restrictions imposed on us by the present state-of-the-art, but not to the proscriptions of any value system.

Putting the problem on a global scale removes emigration from possible solutions—emigration to other inhabitable planets being beyond the present state-of-the-art. Placing large sections of the population in "deep freeze" or some form of suspended animation or lengthening the gestation period from say, nine months to nine years, are also excluded from possible solutions on the basis of state-of-the-art. Our considerations then are reduced to the prevention of life and to the termination of life.

We have therefore arrived at the first parameter which we may call the *phase* parameter. Its values are the phases during which limiting actions take place. There are four distinct phases: pre-

*adapted from the forthcoming book, *The Four Faces of the Future*, by Albert Wilson and Donna Wilson. Copyright 1974.

sexual union, sexual intercourse, conception to birth, and post birth. The first two phases relate to the prevention of life, the last two the termination of life.

A second parameter has to do with the *type* of preventive or terminative action. Five categories occur: 1)cataclysmic interference with life or reproductive processes; 2)sustinence deprivation; 3)prey or disease; 4)rythymic or time factors; and 5)psychological modifications.

A third parameter has to do with whether the actions are unintentional (accidental), voluntary, or coerced. A fourth parameter differentiates between actions performed by or on an individual, sub-group, or mass—individual defined here to also mean a couple. The morphological matrix takes the form:

Morphology of Population Limitation

P_1 phase when terminated	pre-sexual	sexual	pre-birth	post-birth	
P_2 method of termination	cataclysmic interference	sustinance deprivation (food, air, energy, hormones, sperm, etc.)	prey or disease	time factors: rhythm, aging, decay	psychological modification
P_3 mode of action	unintentional (accidental)	voluntary	coerced		
P_4 recipient of action	individual	sub-groups	collective		

An inventory of specific actions or approaches to population limitation can be made using the morphological characterizations of the above matrix. The four digit indicators of a specific action need only give the values assumed in the matrix by P_1, P_2, P_3, and P_4 respectively. Thus in the example of

miscarriage (3, 1, 1, 1)

the phase parameter, P_1, takes on the value 3, the period from conception to birth. The type parameter, P_2, assumes its first value—cataclysmic interference. The mode parameter, P_3, is usually (not always) unintentional and therefore value one, and the aggregate is the individual or value one for the fourth parameter, P_4.

Inventory of Solutions

Abortion	(3, 1, 2, 1)
Miscarriage	(3, 1, 1, 1)
Infanticide	(4, 1, 3, –)
Famine	(4, 2, 1, –)
Plague	(4, 3, 1, 2)
Genocide	(4, 1, 3, 3)
Pill	(1, 2, 2, 1)
Condom	(2, 2, 2, 1)
Sterilization	(1, 1, –, 1)
Celibacy	(–, 5, 2, 1)
Impotency	(2, 5, 1, 1)

A hyphen in the description indicates an under-determined matrix.

Many of the named solutions cover more than one box in the morphological matrix. This is due to the non-specificity of many of the terms in our language. For example, sterilization (vasectomy) can be represented by:

individual, voluntary (1, 1, 2, 1)
individual, coerced (1, 1, 3, 1)
sub-group, voluntary (1, 1, 2, 2)
sub-group, coerced (1, 1, 3, 2).

A finer structure can be introduced into the matrix through additional discriminations such as whether sterilization is of the male or female, is reversible or irreversible, etc. However, since the parameters elaborating the fine structure of sterilization are irrelevant for the species of sustinence deprivation, rather than make one matrix containing all of the refinements, it is better to use a hierarchy of several matrices. A morphological matrix of a broad field should not contain parameters suitable only for the morphology of a sub-field.

Of course many of the individual solutions listed are excluded from realization because of our value systems. But it is only *after* all of the possibilities are listed that we should look at the solutions axiologically to decide which are acceptable and which are not. For example, many would immediately exclude solutions with $P_3 = 3$, that is, solutions of a coercive nature. A morphological matrix is seen to be a useful display for exploring our values and value systems.

The difficult task in morphological construction is the determination of a good set of parameters, i.e., a set that generates a matrix such that every box in the matrix represents a different solution and no solution can be formed that does not correspond to one box. The identification of a set of meaningful parameters or descriptors is one of the most basic epistemological activities. It is the task of relating complex and unique entities through their differences and similarities, a basic human cognitive process closely related to our perceptive and conceptive abilities.

Both differences and similiarities intrigue us. Differences intrigue because of the uniqueness of every individual, the great possibility for variety within constraints or variations on a theme—all basic to art and creative expression. Similarities intrigue because they suggest unifying principles, the unity and relatedness of everything, the economies and symmetries of all organization—all basic to science and systematic knowledge. The charm of varieties and uniqueness balance the elegance of symmetries and invariance. The artist searches for new ways in which things can be different, the scientist searches for additional ways in which they are the same. The morphologist must do both.

In the morphological study of any system or problem, we are searching for both unifying principles and essential differences. We are looking for the set of primary parameters or *ortho-parameters* which will show these attributes most trenchantly and succinctly. Only in a few systems has significant headway been made toward the discovery of ortho-parameters. In classical mechanics, the original Newtonian parameters of mass, force, and acceleration were replaced by the more elegant representations of generalized coordinates and Lagrangian functions (differences of kinetic and potential energy). These in turn were replaced by even more elegant and symmetrical relations—the Hamiltonian functions. The ortho-parameters of the systems of classical mechanics seem to be the generalized coordinates of momentum, energy, and time. Another example of elegant parameterization displaying a wide variety of possible relations is the periodic table of chemical elements and electron distribution in shells.

The basic question of how do we find the otho-parameters of other systems has no simple answer. In fact, it may have no answer since much of the structure of nature is in our conceptions and an ortho-parameter is what we define it to be. None the less, we seek parameters with economical and unique representations that are as comprehensive as possible. How do we do this? There is no explicit procedure. All we can do is list several aids for morphological parameterization.

Aids for Morphological Parameterization

- Start with a list that includes a large number of known solutions. Cluster or group these known solutions according to common characteristics. Common characteristics are clues to parameters. For example, a list of solutions to population limitation may look like:

  contraceptive
  abortion
  war
  famine
  celibacy

  Next, cluster the list according to common characteristics such as:

  life preventing: contraceptives, celibacy
  life terminating: war, famine, abortion.

  Continue to add clusters of commonality such as:

  cataclysmic intervention: abortion, war
  psychological intervention: celibacy
  sustinance deprivation: famine, contraceptive.

  The list should be clustered in as many ways as come to mind. Do not censor or rule out any possibilites at this stage. These sets of clusters suggest candidate parameters such as the **phase** parameter which emerges from the first two clusters or the **type** parameter which emerges from the second three clusters. Remember that solutions are *not* parameters. Each solution is represented by the intersection of a set of values of the parameters.

- Proceed by successive approximations. Attempt to parameterize solutions by two's, three's . . . approaching synthesis per analysis.

- Use whatever theory there is. The basic variables of theory are usually the ortho-parameters being sought.

- Redefine the limits. Oftimes a modification of the definition of the limits of the original problem leads to the detection of parameters.

- Change your viewpoint. For example, assume an active view of being in complete control, then assume a passive or deterministic view.

- Test candidate parameters for inclusion, that is, whether they are sub-cases of other parameters. Reject dependent clusterizations.

- Draft a candidate morphological matrix using test parameters. Test the draft matrix on known solutions purposefully ignored in the process of construction to see whether these known solutions are also uniquely generated.

The morphological box is not complete so long as a solution appears in two or more boxes, or if two or more solutions fall in the same box. If a solution shows up in two or more boxes, it usually means that you have an incorrect parameterization. If two or more solutions fall in the same box, you need to find additional parameters.

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Meetings

Hierarchical Structures

Everyone is aware of significant groupings of things—in taxonomy, in biological structures, in social structures, and in material objects from crystals to stellar systems. An interesting aspect is how the characteristics of a group are related to the nature of the parts and to the characteristics of other groupings—the properties of order and disorder. Applications of these ideas in biology, crystallography, cosmology, and philosophy were discussed by some 50 scientists, each an expert in one of five or six different disciplines, at a symposium organized by Albert G. Wilson (astronomer), Ralph W. Gerard (biologist), Lancelot L. Whyte (historian), and Donna Wilson (sociologist, who prepared a bibliographical outline circulated in advance). The symposium was held at the Douglas Advanced Research Laboratories, Huntington Beach, California (18–20 November 1968).

The term "hierarchy" was first applied to social and religious organizations in which the relation between groups was one of control or dominance. Mario Bunge (philosopher, McGill University) stressed the importance of asymmetric relations between levels, the members of each level being "bosses" of the next lower level. However, in the history traced by L. L. Whyte and C. D. Leake (University of California Medical Center, San Francisco), it was clear that Aristotle and Theophrastus applied hierarchical structures to the taxonomy of animals and plants, where a species member cannot be said to boss or control a subspecies.

Even more obviously, the fundamental particles in the lowest level of Harlow Shapley's hierarchy of material systems [*Of Stars and Men* (Beacon Press, Boston, 1958)] are not bossed by the atoms, molecules, cells, men, and galaxies in levels above them. In fact, this type of materials hierarchy some think may arise in the mind of man—a psychological result of our upbringing that makes it easier for us to conceive of things arranged in branching, pyramidal hierarchies. The French philosopher Ramus wrote in 1550 that "everything is formed of little units, and the mind groups these." Alternatively, the ranking of levels, and their relations in a hierarchy, may reflect the process of formation, as in Darwin's evolution of biological species.

Of course, it is necessary to have discrete units to form a hierarchy; continuous fields or smooth distributions will not suffice. Cyril S. Smith (metallurgist, M.I.T.) described the history of understanding metals as aggregates of crystals, magnetic domains, and impurities. Generally, imperfections form the unit boundaries in pure substances, and interaction energies often impose a regular pattern on these boundaries (which have been extensively studied in soap-bubble froth and by mathematical models of space-filling polyhedra). Many patterns have emerged, corresponding to various forms of equilibrium, and Smith feels that artists, rather than scientists, may be better able to study these patterns.

Digital computers handle discrete inputs and outputs in large quantity. F. E. Tonge (mathematician, University of California, Irvine) noted that the use of subroutines makes computer programming hierarchical, but that this is for the convenience of human programmers rather than the machines, which are linear processors and must be specially coded for subroutines. R. W. Lucky (Bell Laboratories) reported efforts to produce error-free codes (for the transmission of information) by "concatination," or codes within codes, that form a system similar to a hierarchy, and may bear on the DNA genetic codes of interest to the microbiologist, or the operation of brain and nervous system.

Leake stressed the structural hierarchies of biology, based on the cell theory dating back to 1839. Cells of various types form the organs in a human body and all other living organisms except viruses. These structures, probably the result of evolution, are organized by principles of purpose and process, replacing the dominance or "bossism" in social hierarchies. In one organism, such principles seem to control the organs and processes at all levels, revealing an elaborate network of influence based on the chemical action of enzymes from the interior, and of other chemical agents from the environment. In fact, the environs set up a whole new hierarchy—the topic of ecological studies.

H. H. Pattee (biophysicist, Stanford University) spoke about the chemical hierarchy within living cells, contrasting statistical models and detailed physical theory whereby characteristics of atoms should control their groupings in proteins and DNA. It is clear that these aggregates control details of growth. Just why the relatively few forms of polymers are preferred from the billions of billions of possible forms cannot be rigorously explained by detailed physical theory of the strengths of chemical bonds. Robert Rosen (biochemist, State University of New York at Buffalo) feels that the organizational principles within cells may be derived from a kind of chemical statistical mechanics, but this will not be possible until we discover some new subcellular observables comparable to the perfect gas laws in ordinary statistical mechanics. Both Rosen and Pattee pointed to the very complex molecular growth patterns simulated by a sequence generator that adds units on the front, right, or left of a structure, according to simple rules.

Turning to cosmology, where "purpose" is not assumed, nowadays, E. R. Harrison (astrophysicist, University of Massachusetts) noted that the laws of physics appear adequate to handle the various levels of the hierarchy from atoms to galaxies. The frontiers of physics where there are strong disagreements lie principally in the realms of the very small (fundamental particles) and the very large (cosmology). We are well aware of the discrete nature of atoms, stars, and galaxies, but cosmologists treat the material of the universe as if it were a uniform fluid. From gravitational theory and zero cosmological constant, we get models in which matter is very hot and highly compressed 10^{10} years ago. (The initial "big bang" at that time seems to have been confirmed by recent observations of the 3°K background of radio waves.)

Harrison raised the basic question: How did the presently observed hierarchical structure of planets, stars, and galaxies arise from a fluid that was originally compressed to extreme density? Jeans's idea was that the expanding fluid would be gravitationally unstable, so that small, chance excesses of density would grow. However, the billion-degree temperature during early stages allows no density excesses that can grow to the size of a galaxy in 10^{10} years. More recently, Novikov suggested "lagging cores" to explain quasars but these have too short a lifetime to explain the far more numerous galaxies. Efforts to use matter and antimatter appear quite promising, but Harrison stressed that until we have a satisfactory cosmogony, capable of explaining the origin of galaxies and their salient features, we shall not be able to understand why structure on the smaller scale exists.

Michele Kaufman (astrophysicist, Brown University) reported her calculations of galaxy formation by electrostatic forces, assuming (with D. Layzer of Harvard) that the early stages were not so hot. (The present 3°K background must then be explained as the remains of intense stellar radiation scattered by interstellar dust about 10^8 years after creation.) She predicts a hierarchy of density concentrations about 1000 seconds after creation, and shows that they would form objects the size of star clusters and galaxies today.

Some details of the regularity we see in the universe today among nonorganic objects were summarized by Albert G. Wilson (astronomer, Douglas Advanced Research Laboratories) who sees a hierarchy of interacting "modules" or groupings. The interactions are different at different levels, which range from atomic size up through meteorites, planets, stars, star clusters, galaxies, and clusters of galaxies to clusters of clusters. Interactions are roughly symmetrical between members of one level (horizontal interactions), but highly unsymmetrical between members of different levels (vertical interactions). The

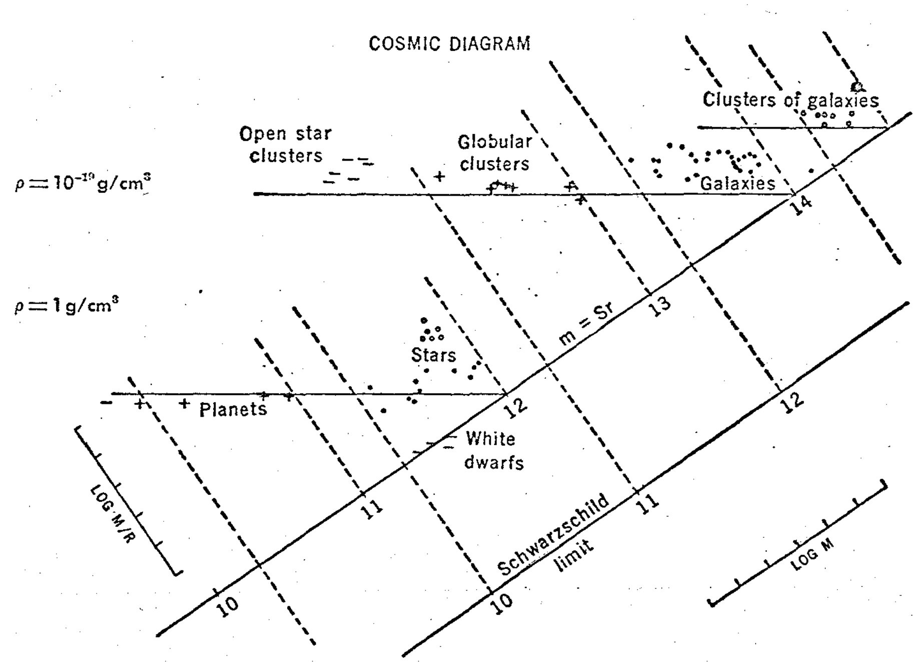

Fig. 1. Wilson's relations between masses and radii of celestial objects. The axes, log m (in grams) versus log m/r (in g/cm) are tilted at 45 degrees. One heavy line shows the limit, $m/r = S = 10^{39.4}$, and the other shows the Schwarzschild limit, $m/r = c^2/2G$. The numbers along these lines are powers of $S^{1/8}$ used by Wilson as frequencies characteristic of the various types of objects.

structure at different levels is probably associated with the nature of space and time at each level, an extension of Leibnitz's views of structure and space.

At the atomic level there are three dimensionless constants of possible significance: a quantity defined by Hopf, $S = e^2/Gm_pm_e = 10^{39.4}$, Sommerfeld's fine-structure constant, $\alpha = 2\pi e^2/hc = 1/137.03767$ (recently found from quasar spectra to have remained constant for at least 2 billion years), and the proton-electron mass ratio, $m_p/m_e = 1836.12$. Note that $8\pi^2 S = 2^{1/\alpha}$. At the galaxy level, astronomers have determined the expansion parameter (Hubble constant), $H = 100$ km sec^{-1} Mpc^{-1} $= 1/10^{10}$ years (age of the universe), and the present mean density of the universe, $\rho = 10^{-30}$ g/cm^3. Eddington noted that the radius of the universe, $R = c/H$, is such that its ratio to the Bohr orbit (size of the hydrogen atom) $a_o = h^2/4\pi^2 m_e e^2$, is $R/a_o = S$, and that the mass ratio, $\bar{\rho}R^3/m_p = S^2$, where $\bar{\rho}R^3 = M$ is about one-fourth the mass of the visible universe.

Admitting that this analysis is close to numerology, Wilson infers that modules in the universal hierarchy should be characterized by mass (m) and radius (r), both well known for atomic particles, planets, and stars, and fairly well known for galaxies and clusters of galaxies. He reports additional "vertical relations" between atomic and cosmic quantities. Over the ranges r/a_o (from 1 to S) and m/m_p (from 1 to S^2) cosmic bodies are limited in m/r to about 3×10^{24} g/cm. On the plot of log m/r versus log m shown in Fig. 1, Wilson finds that the moon, planets, and stars fall close to one line of slope 2/3, which corresponds to densities of the order of 1 g/cm^3. Star clusters and galaxies fall close to a parallel line corresponding to densities near 10^{-19} g/cm^3, and clusters fall close to a third line corresponding to densities near 10^{-29} g/cm^3. All three lines terminate at log $m/r = 23.3$ (in g/cm), or at $m = Sr$. Wilson has had some success in predicting bounds on the masses of planets, stars, globular clusters, galaxies, and clusters of galaxies from a series of powers of S corresponding to overtones of frequencies characterizing each of the modules.

It was generally agreed by the conferees that little progress has been made in understanding the nature of hierarchies and the possible relations between groups of discrete entities. It would be important to find relations that can be transferred from one set to another, although there is the danger that some sets are not homologous with others (for example, biological versus inorganic, or upward-growing versus downward-growing). Undoubtedly, the interactions between entities account for the emergence of significant modules, or levels, or wholes which have properties other than expected from their components. One of the difficulties is that several different hierarchies can often be found in the same set of entities. When the levels are lasting, they would seem to be formed of stable structures, but Rosen thinks that biological levels are centered on unstable equilibria.

The proceedings of the symposium will be published in book form, and will hopefully stimulate further discussion of the fascinating problems of order and disorder.

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Immunology of Mouse Mammary Tumor Virus

Several different antigenic components have been found in the virion of the mouse mammary tumor virus (MTV). The MTV antigens fall into two classes: whole virion or coat antigens and soluble antigens. They can be demonstrated by the induction of specific antibodies in rabbits; also, mice proved to be capable of producing antibodies to some of these antigens. These new findings were brought out in a working conference on "Immunology of Mouse Mammary Tumors" held at the Institute for Medical Research, Camden, New Jersey, 11–13 November 1968.

The virion as a whole or a large subunit thereof seems to be capable of inducing precipitating serum antibodies in rabbits and agent-free mice. This reaction was reported by Phyllis Blair (University of California, Berkeley) and was confirmed by several laboratories. Virus from all mouse strains tested by Blair demonstrated a common coat antigen. Robert Nowinski (Sloan Kettering Institute, New York) reported on antibodies to a soluble antigen which presumably is located in the interior of the particle; this fact, also, was confirmed by several other groups. Louis Sibal (National Cancer Institute) reported finding two antigens after treating virion preparations with Tween-ether. With the aid of immunofluorescence, Peter Bentvelzen and J. H. Daams (Netherlands Cancer Institute, Amsterdam) found an antigen thought to be an early protein of the virus, in hemopoetic organs and in the mammary gland of infected mice. In the GR strain of mice, in which the MTV cannot be eliminated by foster nursing, this antigen was found in all organs. Using both immunological methods and bioassays, these investigators demonstrated that MTV can be released after irradiation or treatment with urethane in mouse strains which were assumed to be without MTV.

The opening session of the conference was chaired by Werner Henle (University of Pennsylvania, Philadelphia) who discussed similarities and differences of MTV and the myxoviruses. These complex viruses, rich in lipids, have much in common.

Chemically induced premalignant tissues of the mammary gland, which have been serially transplanted for more than 4 years, proved to contain new antigens, which are not MTV-derived, in spite of the presence of the virus. In this work reported by Glenn Slemmer (Institute for Cancer Research, Philadelphia), no difference in antigenicity could be detected between these premalignant tissues and the tumors which arose in them. Transplants of the premalignant tissues used to immunize the animals frequently gave rise to normal outgrowths. This was probably due to selection of a normal cell population present from the beginning in the transplant. Obviously, these normal cells do not contain the new antigens.

MTV antibody production in mice was a major topic of the conference. For many years after the discovery of the milk agent, attempts to demonstrate antibodies in mice were unsuccessful. It was believed that MTV was nonantigenic in mice. Contrary to these earlier results, MTV antibodies in mice were reported from almost all laboratories. With the possible exception of the GR strain of mice, there is no true tolerance to MTV. In most cases the antibodies were to the whole virion, or a major component of it, because treatment of the antigen with ether resulted in loss of the immunodiffusion line. Blair, who first demonstrated precipitating MTV antibodies in mice, usually used a few small inoculations of impure preparations from mammary glands without adjuvant. She was able to demonstrate antibodies to what appeared to be the whole virion. Otto Plescia and M. Menon (Rutgers University) reported on the enhancement of antigenic reactions caused by coupling the MTV virion with a strong antigen, such as bovine serum albumin. The reports from the various laboratories emphasized the dependence on methodology for detection of antibodies in mice. Some procedures seemed to induce antibodies to the whole virion coat and still others to a soluble internal antigen, as well as the coat. Weekly intramuscular inoculations of a virus in complete Freund's adjuvant in adult C57BL male mice, followed by a final booster without adjuvant, and bleeding 3 to 4 days later, gave, even after ten inoculations, no discernible antibodies by immunodiffusion test according to Dan Moore and Jesse Charney (Institute for Medical Research, New Jersey). However, when cells from an induced tumor were grown intramuscularly in isologous agent-free, C57BL/Haag mice, a good antibody response was obtained when the absorbed mouse sera were tested against purified virions. However, if the virions were pretreated with ethyl ether, no precipitation line was observed, thus indicating that the antibodies were against the whole virion or one of its major ether-sensitive components.

In another immunizing procedure, male and female mice from several strains were given a single, intraperitoneal injection of purified virus in complete Freund's adjuvant. A small booster dose of virions was given 90 days later. (This procedure has been shown by Sibal *et al.* [*Proc. Soc. Exp. Biol. Med.* **127**, 726 (1968)] to be effective in producing good titer antiserum to Rauscher virus.) Seven days after the booster inoculation, all the sera contained antibodies. Females in all strains gave stronger immunodiffusion lines than their littermate males. Strains BALB/c and RIIIf gave stronger lines than did types Af and C57BL.

The effect of thymectomy was reported by Edmund Yunis (University of Minnesota). Thymectomizing neonatal mice of high cancer strain C3H caused a decrease in incidence and a delayed development of mammary tumors. The question of tolerance and tumor development was discussed at some length. It was hypothesized that MTV-associated antigens cause a breakdown in tolerance followed by (i) a virus-host cell interaction; (ii) damage associated with immune response; and (iii) development of malignancy. The way in which thymectomy delays and decreases tumor incidence may be in

MORPHLGY.P54 1974

IN Technological Forecasting

MORPHOLOGICAL CONSTRUCTION

Albert G. Wilson

In all levels of planning and forecasting, it is useful to have a systematic exploratory technique which can provide a survey of available and potential policies, strategies, and opportunities. *Morphological construction* is a methodology for the systematic exploration of the totality of possibilities within an explicitly defined situation. The term, *morphology*, was adapted by the late astrophysicist, Fritz Zwicky[1], to stand for three basic techniques of systematic exploration. These are: **systematic field coverage** which is concerned with delineation and the search for limits; **negation and reconstruction** which is concerned with varying basic assumptions; and the **morphological box** which is concerned with the totality of alternatives within a defined domain. To these three, a fourth called **morphological spaces** has been added by Ayres[2] to describe the dynamics of technological development.

Morphology may operate at the frontiers of feasibility to find a route or operate behind the lines to discover alternative routes. According to Zwicky, there are three types of problem that morphological analysis attempts to solve:

- What devices are necessary to obtain all of the information about a given set of phenomena;
- What is the sequence of all effects issuing from a given cause; and
- What are all the solutions of a given problem.

In addition, the morphological box is a useful taxonomic matrix for classifying and indexing the information and solutions that have been given parametric representation.

We shall be primarily concerned with the construction of morphological boxes or matrices, but for the survey of possible alternatives the delineation of limits and variation of assumptions methodologies will be briefly described.

The technique of systematic field coverage is a technique for the infiltration of unknown informational territory, usually by successive approximations, using extrapolations, interpolations, analogies, and inversions. Extrapolation, interpolation, and analogy are meant in their usual sense, but by inversion is meant the identification of any dualism and the interchanging of its parts or roles.

An example of inversion is a solution for the design of a dipole antenna for high speed aircraft when location of the antenna in the airstream is not feasible. A dipole may be either a linear conductor surrounded by a non-conductor or a linear nonconducting slot imbedded in a conductor. Inversion solves the high speed aircraft problem by placing a tubular slot within the conducting fuselage.

Zwicky's favorite didactic example of a problem solved by inversion is how to moisten a postage stamp that has fallen on a dirty floor and there is no sponge or water nearby. Lick the envelope, not the stamp.

Edward de Bono[3] illustrates inversion with the example of the old grandmother who, knitting by the fire, could not keep her two-year old grandchild from tangling her wool. Put into a playpen, the child howled so much she still couldn't knit. Grandmother solved the problem by getting into the playpen herself, leaving the toddler free but out of reach of her yarn. But on a more profound level, the centuries old frustration with Euclid's fifth axiom of parallels was ended and entire new fields of mathematics were opened when the axiom was negated.

The technique of negation and reconstruction is seen to be useful both for breaking out of cul-de-sacs and enlarging the spectrum of possibilities. The basic approach is simply to reverse the truth value of every assumption and explore the consequences. Even when an assumption is valid, a deeper understanding of its role in the system can be obtained by its negation. It should be mentioned that this method of inversion was first proposed in ancient times by the Greek philosopher Parmenides.

Rather than being just barriers, limits frequently turn out to be clues to deeper understanding and the opening up of new fields. One of the limits discovered in classical times was the fact that no more than five regular polyhedra can exist in three dimensional Euclidean space. This limit fascinated the Greeks and reportedly led to Euclid's formalization of geometry solely to prove this fact. The limitation that water could not be pumped over thirty-three feet at sea level led to the discovery of atmospheric pressure. Today the absence of meteoroids with hyperbolic velocities and the existence of the Schwarzschild limit in gravitational potentials have led to important concepts in astronomy and cosmology.

The construction of morphological matrices to exhaust all of the possibilities lying in a defined situation may be summarized by the following steps:

1. The problem to be solved must be exactly formulated.
2. All of the parameters which might enter into the solution of the given problem must be identified and characterized.
3. The multidimensional morphological matrix for the given problem is constructed with one dimension corresponding to the sets of values assumed by each parameter, i.e., if there are **n** parameters, there will be (**n + 1**) dimensions.
4. All of the possible solutions (each possible combination of values for the parameters defining one solution) are evaluated with respect to the purposes which are to be achieved and assessed according to state-of-the-art, economic, sequential, and axiological criteria.
5. The optimally suitable solutions are selected for implementation, in practice this reduction usually requires a supplementary morphological study.

The most critical feature of the method is that step three and step four be kept independent and that step three be complete before step four is begun. That is to say, the generation of the matrix must continue without prejudice regarding the feasibility, desirability or even plausibility of any suggested solution. Only after the complete matrix has been constructed is evaluation to begin.

As an illustration of the construction of a morphological matrix, let us consider the morphology of solutions to the problem of world-wide population limitation subject to the restrictions imposed by the present state-of-the-art, but not subject to the proscriptions of any value system.

Putting the problem on a global scale removes emigration from possible solutions, (emigration to other inhabitable planets being beyond the present state-of-the-art). Placing large sections of the population in "deep freeze" or some form of suspended animation or lengthening the gestation period from say, nine months to nine years, are also excluded from possible solutions on the basis of state-of-the-art. Our considerations then are reduced to the prevention of life and to the termination of life.

We have therefore arrived at the first parameter which we may call the phase parameter. Its values are the phases during which limiting actions take place. There are four distinct phases: pre-sexual union, sexual intercourse, conception to birth, and post birth. The first two phases relate to the prevention of life, the last two the termination of life.

A second parameter has to do with the type of preventive or terminative action. Five categories occur: 1) cataclysmic interference with life or reproductive processes; 2) sustenance deprivation; 3) prey or disease; 4) rhythmic or time factors; and 5) psychological modifications.

A third parameter has to do with whether the actions are unintentional (accidental), voluntary, or coerced. A fourth parameter differentiates between actions performed by or on an individual, sub-group, or masses. (Individual defined here to also mean a couple.) The morphological matrix takes the form:

Morphology of Population Limitation

P1 Phase when terminated	Pre-sexual	Sexual	Pre-birth	Post-birth	
P2 Method of termination	Cataclysmic interference	Sustenance deprivation	Prey or disease	Time factors	Psycho-logical modifi-cation
P3 Mode of action	Unintentional or accidental	Voluntary	Coerced		
P4 Recipient of action	Individual (couple)	Sub-groups	Collective		

An inventory of specific actions or approaches to population limitation can be made using the morphological characterizations of the above matrix. The four digit indicators of a specific action need only give the values assumed in the matrix by P1, P2, P3, and P4 respectively. Thus in the example of miscarriage, [3, 1, 1, 1] the phase parameter, P1 takes on the value 3, the period from conception to birth. The type parameter, P2 assumes its first value of cataclysmic interference. The mode parameter, P3 is unintentional and therefore takes on the value one; and the aggregate is the individual or value one for the fourth parameter, P4.

Inventory of Solutions

Abortion ....[3,1,2,1]
Miscarriage ....[3,1,1,1]
Infanticide ....[4,1,3,-]
Famine ....[4,2,1,-]
Plague ....[4,3,1,2]
Genocide ....[4,1,3,3]
Pill ....[1,2,2,1]
Condom ....[2,2,2,1]
Sterilization ....[1,1,-,1]
Celibacy ....[-,5,2,1]
Impotency ....[2,5,1,1]

A hyphen in the description indicates an under-determined matrix.

Many of the named solutions cover more than one box in the morphological matrix. This is due to the non-specificity of many of the terms in our language. For example, sterilization (vasectomy) can be represented by:

individual, voluntary [1,1,2,1]
individual, coerced [1,1,3,1]
sub-group, voluntary [1,1,2,2]
sub-group, coerced [1,1,3,2]

A finer structure can be introduced into the matrix through additional discriminations such as whether sterilization is of the male or female, is reversible or irreversible, etc. However, since the parameters elaborating the fine structure of sterilization are irrelevant for the species of sustenance deprivation, rather than make one matrix containing all of the refinements, it is better to use a hierarchy of several matrices. A morphological matrix of a broad field should not contain parameters suitable only for the morphology of a sub-field.

Of course many of the individual solutions listed are excluded from realization because of our value systems. But it is only after all of the possibilities are listed that we should look at the solutions axiologically to decide which are acceptable and which are not. For example, many would immediately exclude solutions with P3 = 3, that is, solutions of a coercive nature. A morphological matrix can thus be used to explore and display our values and value systems.

The difficult task in morphological construction is the determination of a good set of parameters, i.e., a set that generates a matrix such that every box in the matrix represents a different solution and no solution can be formed that does not correspond to one box. The identification of a set of meaningful parameters or descriptors is one of the most basic epistemological activities. It is the task of relating complex and unique entities through their differences and similarities, a basic human cognitive process closely related to our perceptive and conceptive abilities.

Both differences and similarities are intriguing to human thought processes. Differences intrigue because of individual uniqueness and its many possibilities, and basic to all art and creative expression are the possibilities of variety within constraints and variations-on-a-theme. Similarities intrigue because they suggest unifying principles, the oneness and relatedness of everything, the economies and symmetries present in all organization, all basic to science and systematic knowledge. The charm of varieties and uniqueness balance the elegance of symmetries and generalization. The artist searches for new ways in which things can be different, the scientist searches for additional ways in which they are the same. The morphologist must do both.

In the morphological study of any system or problem, we are searching for both unifying principles and essential differences. We are looking for a set of primary or ortho parameters that will show these attributes most clearly and succinctly. Only in a few systems has significant headway been made toward the discovery of ortho-parameters. For example, in classical mechanics, the original Newtonian parameters of mass, force, and acceleration were replaced by the more elegant representations of generalized coordinates and Lagrangian functions (differences of kinetic and potential energy). These in turn were replaced by the symmetrical relations given by the Hamiltonian functions, which seem at the present to be the ortho-parameters of the systems of classical mechanics. Another example of an elegant parameterization displaying a wide variety of possible relations is the periodic table of chemical elements.

The basic question of how do we find ortho-parameters of systems has no simple answer. In fact, it may have no answer since much of the structure of nature lies in the history of the order of our discoveries and inventions. Ortho-parameters will change with time. None the less, we seek parameters with economical and unique representations that are as comprehensive as possible. How do we do this? There is no single procedure. All we can do is list several **aids for morphological parameterization:**

Start with a "laundry" list that includes a large number of known solutions. Cluster or group these known solutions according to common characteristics, which are our clues to parameters. For example, a list of solutions to population limitation may look like the following:

contraceptive
abortion
war
famine
celibacy

Next, cluster the list according to common characteristics such as:

life preventing: contraceptives, celibacy

life terminating: war, famine, abortion.

Search for additional clusters of commonality such as:

cataclysmic intervention: abortion, war

psychological modification: celibacy

sustenance deprivation: famine, contraceptives

The list should be clustered in as many ways as come to mind. Do not censor or rule out any possibilities at this stage. These sets of clusters suggest candidate parameters such as the phase parameter which emerges from the first two clusters or the type parameter which emerges from the second three clusters. Remember that solutions are not parameters. Each solution is represented by the intersection of a set of values of the parameters.

- Proceed by successive approximations. Attempt to parameterize solutions by two's, three's . . . effecting synthesis by analysis.

- Use whatever theory there is. The basic variables of theory are usually approximations to the ortho-parameters being sought.

- Redefine the limits. Ofttimes a modification of the limits placed on the original problem leads to the detection of parameters.

- Change your viewpoint. For example, assume an active view of being in complete control, then assume a passive or deterministic view.

- Test candidate parameters for inclusion, that is, whether they are sub-cases of other parameters. Reject dependent clusterings.

- Draft a candidate morphological matrix using test parameters. Test the draft matrix on known solutions purposefully ignored in the construction process to see whether these known solutions are also uniquely generated.

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AGW - dictated - May 15, 1960 - thoughts on militarism last part lost - dictaphone -

The change that has taken place in the fifteen years since 1945 in the American attitude toward the military ethic is only a part of a gradual evolution. There has been a gradual evolution in Western thinking and in Western Ethics since, let us say the French Revolution. Lets take that as a starting date altho it may go back even earlier. Perhaps, Fredrick the Great, Russia ??? Let us take the French Revolution as a starting place since certain ~~maks~~ marked changes did take place then.

The historically Western Ethic, which is largley the Christian Ethic has been since the French Revolution in struggle with a second ethic which we can call the Military Ethic. Now both of these ethics have a long background in history which we won't go into. The Christian ethic is donomant in certain phases of western life - this is clear if ones goes to Asia and see that this has not penetrated Asian life in many areas. But the military ethic is also dominant in certain areas of western life, particulary in nationalism - historians talk quite frequently about the rise of nationalism - It is my own thesis that we might ~~look~~ learn something by looking at the rise of the military ethic (maybe you can find a better word) Let us define terms --- The military ethic is the ethic - the value that has come to us from the middle ages or even earlier - its the code of the warrior - the code of chilivary - the code of the Samuri - which does place emphasis on the glory of arms - on heroism. We won't go into a philosophical treatment of chilivary - it would be an interesting studey - itz evolution. Its evolution has been dominated in large part by the evolution of weapons themselves - the code has changes with the weapons ....

Let us return to the Freanch Revolution, which we will assume is the jump off point ~~afxthexMk~~ at which the Military ethic became the dominatnt ethic of the West. In the French Revolution the iconoclastic times overthrew most of the idols, at least temporarily - not the state - the Bourbon state of France that was overthrown, but most things associated with the old order, the regime assione Everything was overthrow, including the Church, adn the Christian Ethic - and there was a vacuum created into which all kinds of wild ideas rushed.

In the first ten years after the revolution there were some amazing and even some amusing ideas - everything was overthrown ane new idols were set up. Well into this vacuum, the military ethic rushed in. It was the most successful displacer of old orders and values. The idea of democracy spelled the idea of all men sharing in the defense of the country - and in France this took the form of conscription and quickly being under them hands of military leaders and militarists like Carno, they built up a military machine. This had its ultimate expression in the career of Napoleon Bonapart. Militarism in its modern form was born there in the French Revolution in which the armies of the past - armis of professional soldiers and soldiery were displaced and the large numbers of the citizenery themselves were pressed into service, conscripted, and there was Napoleon marching across the fade of Europe with new artillery and artillery techniques . with large masses of citizenry armies - a new phenomena on the face of the ezrth Not used for defense as our own militia - but used for wars of agression.

Well, this quickly caught on. Now Napoleon himself was destroyed, but his concept was copied and advidly seased upon by Prussis, by Austria, by all the countries of Europe. It became more or less an accepted matter everywhere - a policy to have large citizen armies and to draft these armies by having each male citizen serve a certain number of years in the army. Now, whether this was done without protest, I don't know. The revolutions that swept Eutope in 1848 may have been in some extent a protest of this.

This evolution took poace gradually, larger and larger defense budgets, larger and larger standing armies, The epitomy of the extolment of this sense of power took place in Prussia and finally in Bismarks united Germany and we heare a lot about of how Kaiser Whilhelm II who played a major role in the precipitation of WWI - his concept of the power - of might makes right, so on.... This was just the evolution of these basic ideas -- that found expression in ghe German militarists such as Kaiser Whilhelm....

Now lets look at the US's reaction at this time -

Going back into the US history - the American revolution was foungth by volenteers there were many Torries who opposed the revolution. The early wars were fought by volunteers, although we did have a militia - an militia act of 1792 ----- this was more of any army on paper - but it is alwo important to note there is a cited difference between an conscripted army ane a militia - Conscripte d army can be used for offense and a conscripted army doesn't necessarily live at home the way the militia does - so lets distinguish between these two.

The US did not copy this trend in Europe - in fact it opposed it, altho there were certain military leaders - even G. Washington seemed to favor this large standing army and militia concept. The first time the conscription was used in the US was in the Cvil War and at that time tere were riots in NYS against the draft - there was a great deal of opposition when Lincoln instituted conscription. (Confedracy have conscription?) Immediately after the war, standing armis were sliced back and conscription was abolished - our next contact with this thing was in WWI and we finally entered after abhorance of the very thing we had to copy ourselves - Kaiser Whilhelm and his expression of militarism was abhorant to Americans - the draft was abhorant but we got into this and somehow altho the German cause was defeated, the German principles left their stamp on us...

But there was a reaction - after WWI, not only in America, but throughout the qorld there were efforts to retreat from this military ethic and the dominance which it had obtained in the world.... Disarment conferences and these were the expression of those who tried to get the Cristain Ethic to gain control in the WESt. These talks never really got anywhere - Mussilena, Hitler, the Japaneese and strong military groups in every country, including our own had naught for this position of retreat from the MILitary Ethic. (Here point is raised that failure of disarment ~~dixx~~ due to those satisfied with the status quo accpted disarmament and those not satisfied did not) ----- Point in this discussion is that methods used to correct a wold imbalance were based primarily on what is allowable in the constraints of the Military

ethic

What case can be made for the facts of history explained in terms of the military ethic? That just as this imbalance can be corrected in many ways, the fact that the West has chosen the Military path to correct these things is the point I'm driving at. Whatever the issues brought to the floor might be by men such as Hitler - those not satisfied by the status quo or whatever -

Well then, we have these attempts to retreat from the Military Ethic -- I think Woodrow Wilson was a very sincere idealist person and by idealistic, I mean someone who was opposed to the military ethic - We have the League and other attempts to free the world from the proclevity to solve all its problems by resorting to arms - ThexUSx in the US, the abhorance to militarism, the reaction to WWI resulted in a revived isolationism - Then we jump to there WW II where again the military ethic was dormant due to this attempt to retreat. ((quote Bush) — from the Military E. Question then was settled not by philosophers - but by Adolph Hitler and his allies -- in many acts of agression which at the time were outrages here in the US - the bombing by Mussilena - one of the most horrifying things - Mussilinas sons pmm poem about the beatties of war ------------ This was translated into English and circulated in this country and people were horrified - but here is again a expression of the ME in one form or another ---

Then of course, WWII broke out in Europe, people started by being very careful to protect cities ---- Roosevelt cautioned both sides xx that he hoped civilian populations would be spared the horrors of war and for awhile, most agred on this. Now who started it - I don't know ---- it doesn't really matter who started it -- It would have happened anyway and the principle of massive extermination - the bombing of cities was introduced and certainly the Blitz against London was an expression of this. on our side of the ocean, we have the first peace time draft which was a staggering thing for us ---- Congress and the people were divided against participation or not --- isclationasim or whatever - but in a larger sense, we were debating this old question of what is our ethic - and isolationism in spite of the bad name it had doesn't mean exactly that --- it also means that an idealsim of a slightly different sort....

Well, war went on and it became more brutal, more ruthless and people during the course of a war do change their ethics and values. The principle of mass extermination became rather firmly accepted everywhere. We fire bombed Tokyo, cities in Germany -- of course the principles of Mass Extermination seemed to horrify us when they were applied selectively by the Nazis, ie if you select those who you mass exterminate - geonicie - that is the Jews -- whereas we seemed to feel that the random mass extermination where you dn't welect but just let the bombs fall on whomever is underneath - this is acceptable. -- We were shooken up by the death houses were people were exterminated systematically and selectively by the Nazis -----

The A bomb was the next thing --- I don't know, we just never reacted fully - It was horrible, we explained it away by saying it saved American lives and those who criticized it's use or asked why did men lack the imigaination to explore the possible alternatives such as demonstrating the bomb to the enemy and showing what could be done... There was an opportunity here in history to show imiganition - to show vision - but evidently those involved were so embued with ME and hypnotic principles of pwer that they failed to exercise this vision ----

Nov. 16, 1961

FEEDBACK SYNTAX AND ATTITUDE ALGEBRAS

I. INTRODUCTION

The assertion that man is not a rational creature is tautological. Whereas, man has developed a sophisticated discipline of logic and rational thinking which he has applied with success to the explanation and prediction of phenomena ~~of the physical universe~~ and to the adaptation of the materials and forces of the earth for his own purposes; in all attempts to apply this so-called discipline of rational thinking to phenomena involving himself, man has not attained any significant measure of success either in constructing meaningful models or in making predictions. The processes of history, problems of social dynamics, conflict, group and individual behavior cannot be satisfactorily represented by any purely logical mathematical model. Even in the areas of economics and organization theory there has been only limited success with rational models. In fact ~~with rational models~~ wherever psychological parameters begin to enter a problem the classical laws of logic begin to fail.

Psychological research has in recent years been successful to a degree in ~~such~~ applications, such as advertising, where motivation research has been able to make valid predictions for limited times over limited subjects - but these calculations may backfire unexpectedly and disasterously. At best this area is an art and not a science.

From such experience and from the experience of economists, politicians, and other social scientists, one is inclined to give up hope that a science treating these social areas can be developed along the lines which physics and other natural sciences have followed. (This is not merely a matter of complexity, although it is readily admitted that the problems in these fields are of a much higher order of complexity than ~~the~~ problems of physics or even biology.) There are two reasons why ~~this is the case~~ classical approaches are inadequate. First: logic, science, and rational thought deal principally with propositions which ~~are~~ may be proved to be either true or false by observation, experiment, or deduction. However, most propositions which involve human ~~beings~~ ~~mental processes~~ reactions and attitudes are not of this nature. Their truth or falsity is not ~~clear cut~~ precise and the process of proof, or even of assertion of the proposition, introduces a feedback component which ~~xfx~~ effects their truth or falsity.

It is useful to divide all propositions into three categories. The first category consists of "S" statements which are the type of statement with which science deals. These are either demonstratably true or false and independent of what we say about them. "The sun will rise tomorrow," "There will be an eclipse of the moon on March 13, 1960." A second category of propositions consists of statements whose truth or falsity is affected by our ~~xxrxxxxxx~~ verbalization of them. "You look ill," "There is going to be a depression." Such statements have a feedback element which tends to make them more true the more ~~times~~ they are enunciated. We may designate such statements as "P" statements. The third category of propositions consists of statements whose truth or falsity also depends on their verbalization, but which tend to become more false the more they are uttered. Examples include the Life Magazine pre-election picture of Thomas E. Dewey captioned, "The Next President of the U.S." From American reaction, Kruschev's statement, "We shall bury you" is also tending to become more false the more it is uttered. Such statements with feedback tending to make them more false upon re-utterance we may designate as "Q" statements.

It is quite apparent that a discipline like politics or economics which involves P and Q as well as S propositions must fall short in its predictions if it cannot take into account the modifying influences caused by ~~predictions~~ predications made about their present and future states. A logic extending classical deductive systems to the cases involving P and Q statements is given in the second section on Feedback Syntax.

The second reason why a science utilizing classical logic in its development will fail when applied to an area involving human reactions and attitudes is that these attributes act in a way which is ~~totally~~ quite different from the ~~natural laws~~ basic ideas on which classicial logic is founded.

As a simple example, consider two sets $\{A\}$ and $\{B\}$ with $\{A\} \neq \{B\}$

If $e_1 \subset \{A\}$ and $e_1 \subset \{B\}$

and $e_2 \subset \{A\}$ and $e_2 \subset \{B\}$

then $e_1 \subset \{A + B\}$

and $e_2 \subset \{A + B\}$

and the pair $(e_1, e_2) \subset \{A + B\}$

This is a straightforward proposition in Boolean algebra - completely logical and rational.

Now let the set $\{A\}$ represent the society of protestants in a certain U.S. community. Let $\{B\}$ be the set of Jews in this community. If e_1 is a protestant who becomes a Jew, then according to the above Boolean theorem he should belong to both groups.

i.e. $e_1 \subset \{A + B\}$

Or if e_2 is a Jew who becomes a protestant, then e_2 should belong to both groups. $e_2 \subset \{A + B\}$

But the facts are that both e_1 and e_2 are rejected by both groups, i.e., e_1 and e_2 $\in \{\overline{A \circ B}\}$ and not $e_1\ e_2$ $\subset \{A + B\}$ as would be predicted.

From this example showing the failure of the rational Boolean algebra to validly designate a social situation, arises the question of whether it is possible to formulate some other algebra which can be applied to problem areas involving this type psychological factor.

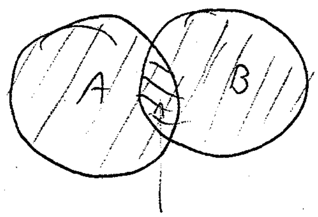
Postulatory systems with quite arbitrary rules of operation have been constructed giving a large class of "non-euclidean" systems. But all of these systems are rational and even if they do not have a real counterpart in the natural world, they all are at least self-consistent. Is it possible to formulate a - one cannot say logical - symbolic structure which validly maps human behavior for certain purposes and which is not subject tothe postulate of consistency?

An example of such an algebra is given in the third section on <u>Attitude Algebras</u>.

Attitude Algebras

Notation

→ likes, wants to join
↛ dislikes,



⊂ belongs to

A+B

shaded = A∘B

Topological (Boolean)

If $e \subset A$

Attitude

$\bar{A} \nrightarrow e$

$e \nrightarrow \bar{A}$

i.e. people dislike what is different.

Fundamental Forces.

1. ∃ an A ∋ e wants to belong to A
2. also e wants A to be distinctive

i.e.

∃ other e's he wants excluded from A.

All e's feel this way

3. All e's resent this feeling in other e's.

If $e \subset \{A\}$ and $(B \neq A)$
$e \subset \{B\}$
then $e \subset \{A+B\}$

Rational

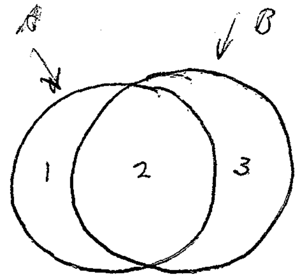
If $e \subset A$
$e \subset B$
then $e \nrightarrow \overline{A \circ B}$
and $e \nleftarrow \overline{A \circ B}$

Irrational

Grades of like ↛
Grades of belong to

∋ by choice, of e
∋ by nature

⊃ by choice, of group
⊃ by nature



1 = $(A \circ B) - B$
2 = $A + B$
3 = $(A \circ B) - A$

1 consists of elements wanting to be in 2

3 consists of elements wanting to be in $\bar{2}$

The groups of importance are $A + B$ and $\overline{A \circ B}$

$\{A + B\} \rightleftarrows e_1 \not\rightleftarrows \{\overline{A \circ B}\}$ unstable

$\{A + B\} \rightleftarrows e_2 \not\rightleftarrows \{\overline{A \circ B}\}$ stable

$\{A + B\} \not\rightleftarrows e_3 \rightleftarrows \{\overline{A \circ B}\}$ unstable

Predjudice is a way of assuring stability and hence survival of a minority

Discuss Assimilation in this way:

	Assimilation Mandatory by Majority (State)	Assimilation		
Pluralistic				
Monistic				

Assimilation Diagram

	Mandatory	Arbitrary	Forbidden
by State	X		
by Majority			
by subgroup			

It is assumed that the state may or may not be majority

Assimilation Diagram

		MANDATORY	VOLUNTARY	FORBIDDEN
LURALISTIC	BY STATE	BUT BY SUPREME COURT	ALL EMIGRANTS	SOUTH AFRICA
	BY MAJORITY	NORTHERN WHITES ?		WHITE PROTESTANTS
	BY MINORITY	NEGROES		JEWS FORBID ASSIMILATION
ONISTIC	BY STATE	USUAL MONISTIC PATTERN e.g. USSR		NAZIS FORBID JEWISH ASSIMILATION
	BY MAJORITY			AN UNLIKELY EXAMPLE
	BY MINORITY			JEWS FORBID ASSIMILATION

shaded area excluded from possibilities by logical contradiction of terms

• Monism : Pluralism

Parameters: in Assimilation Diagram of Minorities to Majorities

For 12 choice assimilation or persecution?

Assimilation is
Mandatory
Voluntary
Forbidden

by
State < pluralistic / Monistic
Majority > (in Power
Minority > not in Power)

Pluralism supports differences (are good per se) but must take an attitude on assimilation but voluntary

Some of these define Monistic, some Pluralistic societies.

Assimilation Diagram	by State	by Majority	by Minority
Mandatory	Monistic		
Voluntary	Pluralistic		
Forbidden	Either *		Jews

* A state may be pluralistic and mandatorily pluralistic by forbidding assimilation but protecting rights of minorities e.g. South Africa

A state may be monistic ~~by~~ yet ~~for~~ forbidding assimilation preferring genocide ~~of~~ or exile minority groups.
e.g. Nazi Germany

For or against assimilation
indifferent to

Best situation (Short term)

State	Majority	Minority
Voluntary	indifferent	Free

U.S. Situation

State	Majority	Minorities
Mandatory	adverse	Some for Some against

South Africa

State	Majority	Minority (white)
Forbidden	For	Adverse

USSR

State	Majority	Minority
Mandatory	indifferent	Mandatory

Nazi Germany

State	Majority	Minority
Forbidden	Forbidden	Forbidden

Ideal state ~~pluralistic~~

here is seen need for monistic / pluralistic parameter.
in addition to assimilation parameter

State	Monistic	Pluralistic
Assimilation Mandatory	USSR	X
Voluntary	X	Society will become monistic unless Minorities forbid assimilation
Forbidden	Nazi Germany ∴ genocide	South Africa U.S. South

pluralistic societies

May be either forbidding assimilation S.A.

or

Leaving it voluntary in which case the society remains pluralistic only at the will of [illegible]

Ag/dw [illegible]

Notes on IOD Dectectors -- July 29, 1960

Let us review the thinking of the last few days which we have not ~~as~~ yet recorded. We have been concerned with what we shall define as IOD feedback -- Inadequate or delayed feedback and its consequences in various types of human problems. Now we know historically that human beings have been able to adapt themselves, shouldn't say only human beings - rather all organisims can adapt themselves to their environment and adjust to maximize their ability to survive by a cybernetic mechanism called feedback. For example, a child will put its hand on a hot stove, pain tells the child to withdraw its hand - consequently the hand is saved from damage while at the same time the child learns about hot stoves.

Note: What is the minimum interval of change to permit awareness (12.2.67)?

Now to define terms, we won't bother to define feedback -- this is done by Wiener, et al,

IOD feedback -- feedback which either conveys back such a small amount of infomation that decisions and judgements cannot be based upon it - or the feedback of information comes so late that it is not useful in making the decision when the decision must be made. For example, if the hand is anethisized when you put it on the stove, you do not get the feedback information of pain to tell you to remove it.and the hand could be destroyed... on the other hand if your responses were such that you would feel the full pain but that it would come 10 seconds instead of the fraction of a second it does take after putting the hand on the stove, the hand would also be destroyed -- ie, delayed feedback.

Now in general, in most of our problems we are trying to optimize something, such as freedom of choice , the gaining of experience, wisdom, knowledge, or whatever, hence the enhancement of the adaptability or control or survival potential. At the same time, we attempt to minimize the destruction or the price we must pay to gain this knowledge or wisdom.

Hence, the mzximation - minimazation problem is to find the least possible destruction of the greatest survival potential.

Now our problem is to balance these factors with ~~thisxbalancexmaximatianxxminimazatianxprablem withxavailablexfeedback;~~ both normal and IOD. feedback situations.

Now let me give a couple of examples of IOD feedback situati ons ---

Lew Bohn's Focus on leaders aan be recast into IOD feedback situations,

Problem is now defined as a maximazation - minimzation problem of experience versus destruction, with IOD feedback.

Now then, we don't yet have the answers of how to do this, but at least we have already seen several of the delEminas:

One delemina is soon encountered when we think of the world possessing the absolute of adequate and timely feedback - ie, the advantages that may be accrued from IOD feedback.

One analogy can be pictured by discussing the basic differences between the Yen and Yang -- Training as a mother emphasises the Yen aspects. She stive to sense the needs ~~as well as dangers~~ of her children, her family and fulfill them as much as possible. She is aware of the dangers -- such as touching the hot stove - on up through dangers of adolesence -- and strives to make these experiences as painless as possible. Yet if she is a wise mother she realizes the child does have to touch the stove to know what fire is. Now the opposite, traing for the Yang world requires exploration of all new encounters in an attempt to gain knowledge and as such requires that we turn off the feedback once in awhile in order to venture into regions of the unknown, which more than likely will yeeld dangers.

So, in summary, adequate detectors lead to static worlds (ie, the Yen element is the preserver of culturs) while IOD detectors allow the possibility of new experience. (The Yang goal.)

GRANTED, Lew Bohn's Focus on Leaders will certainly reduce IOD feedback - but do we really want adequate detectors? which lead to static worlds.

One important feature in explaining this new idea, establishing the jargon, defining terms, etc.... is to somehow show the reader how this insight came to us. There seems one way to do this -- that is to use the personal analogy of reaching a cliff situation wherein there is no way to turn but to keep climbing -- the world today with the same cliff situation of nuclear distruction of civilization.

You do the abstracting later, I have to talk personally, my insights come this way ---- Well, you came home from India with this new experience -- The questions that keep running through my head (similar to all the hand wringing many in the world today are doing) is How in the world could somethig like this happen??? Al is not bad, he could not possibly want to hurt me nor Anita, he is not inconsistent and yet this cliff situation of asking Anita to marry him while he has and wnats to keep me for his wife.....All the possibilitis of concluding he was weak and I was strong, etc etc....just do not fit. So now the insight, that Al just did not at the time of New Delhi have the feedback necessary to see that this is where his action was inevitably leading.
This is not all because in looking back - he still would have the experience of meeting & loving Anita if he could choose.
It appears to be a complete violation of both his and my code -- similar to the same violation of america's traditional code (ie acceptance of mass extermination) Question???? Can we show a relation between morality/conflicting values and IOD feedback? Certainly new experiences lead to conflicts of present configurations
Question is do we always seek to destroy present constraints - ie are new codes always better?

What are some of things people do in cliff situations?? They become cynical, they become paralyzed, the become calloused, they jump off the cliff. In our personal cliff situation, the four possible configurations available just will not do --- that is, Al and Anita, Al and me, the three of us togethe or the three of us separate --- none will bfing about effectiveness for any of us....

Note on page 3

With regard to cliff situations —

everyone is always trying to simulate cliff situations — motivated I suppose by the desire to gain knowledge of ourselves — ie, the desire on part of two people in love to spend hours discussing will you love me when I'm old and gray — will you love me if I'm poor and down & out — etc -------

Same with game theory and like approaches —

or also with the shock treatment in attempt to seek out significance —

however there's nothing like a real cliff to force an earnest seeking or pursuit of truth —

I dare say no simulation can take the place of the real thing.

Back to the question of conflicting values and IOD feedvack ----

Today people say that whats wrong with America is a new immorality -- that is acceptance of mass extermination - genocide.

The matter of dropping fire bombs on millions in Tokyo -- how is this possible. IOD feedback allows people to do things which they weould Bind completely unthinkable xx under normal response situations. I say this is made possible by the horrible monster of technology. This is what technology has done. But tox argue that technology is wrong is not the answer either.... then what does this mean when we have created a dulling of the senses that would normally limit the powers of destruction by means of technology? It means we have a lot of work to do on the feedback problem.

The basic problem then is to determine the right amount of feedback necessary - to increase it in dangerous situations/ ie cliff situations, or to decrease it in the case of vegatating situations where people are paralyzed by the overwhelming response to environments.

What are the factors which do control feedback???????

In the social order what are the factors that control feedback?

Now let us try to tie together the idea of thoughts on Yen and Yang of this morning to our discussion. You talk about the end which the Yen element seeks - is to dampen and to preserve whereas the Yang element is something different. Lets talk about these Yen and Yang aspects of the feedback problem --- In the case of Yang where one wants to go out and have new experiences and hence increase control, adaptability, your survival potential permitted by IOD feedback. On the other hand, the Yen is a preservative and it assures survival by avoidig risks and staying in a castle so to speak, Is the absolute then of the Yen goal, adequate feedback? The question is how to balance these two. We see now how they are tied in with feedback -- how the Yen is really a condition of suppressive feedback and the Yang is a condition of IOD feedback. But let us go back to our original problem --- must always keep this in mind: The maximation of survival potential and the minimization of destruction.

It is clear that both Yen and Yang play siginificant roles in this optimization problem. When should man leave the cradle and venture out and when should he hole up in the castle? If we would hole up in a castle for all our lives, we should probably survive for a period of time, but then a new disaster which we could not comprehend should suddenly be upon us and we could be swept away by it (Example -- maybe such as hiding in a cave, everything is fine until an earthquake comes - a situation for which you were not prepared nor does the cave protect you.)

Now since our race is composed of individuals who are definitely mortal and not indispensible - this determines how we solve this problem.... If our race consisted of one organism which would live or die, I think we would face this problem entirely differently. This means of course that the individual human in looking at the universe and thinking of his own preservation will arrive at a differently morality than the morality which the race itself must adapt.

Now all classicall religions have been concerned (unfortunately) with the individual and the individual's role -- concern with whether he goes to heaven or hell, and so on -. It has been somewhat concerned with the social obligations of the individual, but no discussion has yet appeared of what we might call Race Religion. No discussion of the ultimate destiny of our race itself. And the morality for the race, by morality I mean the pattern of behavior which will insure survival,or the end which we are seeking; will be quite different for the race than it is for the human. Because the race itself has expendable parts.

Now to go compbetely all the way - absolutely Yen or absolutely Yang is disasterious. I think this is the old departure and return. That for a period of time one must do one and for another period one must do the other - that to settle in one or the other states permanently invites disaster.

I can see how disaster would overcome a society which settles permanently in a Yen environment and I think we are close to witnessing a culture which has drifted into a Yang sistuation permanently. without catching up with itself so to speak -- but I'm looking for the abstract formulation (and models) of how the Yang situation, if maintained without departure and return to Yen inevitably results in a loss of survival potential. I have never been able to prove the theorem of this optimization through the departure and return process, but I'm sure this is involved - it crops up all the time.
Is is true that complete obsession with Yang activities will inevitaably result in disaster??? I'm not clear on this point, I think it is true.
But I do not see the necessity of retreat from Yang -- I see the necessity of biasing your feedback so you never attain IOD feedback, but you allow yourself departure from ruts by minimizing you feedback from time to time..

I submit that one without the other is disasterious --- the result of intentional IOD feedback for the sake of cliff situations results in power madness, any other madness whatever, you go through a barrier ----

How does this happen -- well the disciple of Yang goes out into the world seeking new experience - regions of unknown for the sake of gaining experience, seeking notes to take down in his notebook -- seeking insights -- but someplace in this Yang persuit, you cross a barrier from which there is no return - rather one becomes obsessed with creating cliff situations - an end in itself. You are no longer able to return to Yen environments.

True, if departure and return is necessary and you can reach a point where you can no longer return, then this means disaster - but lets ask the question, why is return necessary? It may have something to do with the learning process - it may have something to do with the digestive process.. that experience undigested is useless experience ---

Do I understand your question completely? You say you can not concieve of fixation on creating cliff situations???? This fixation is something like saying to someone, I don't believe you can invent a bigger - or more distructive bomb - what happens is that he'll accept your challenge and try.

But back to the question, why is return necessary? How does one stop seeking the wisdom or knowledge to be gained from cliff situations and become obsessed with creating cliff situations?

Perhaps this is something like a Parkinson law where you are no longer concerned with your primary purpose of optimization of survival, but rather you become dedicated to the ideal of seeking new experience itself with losing sight of what this new experience is for....something like the charity institution set up to help blind people, but somehow eventually 95% of its income is spent on administration and raising of new funds ---- or the beatnick who seems to be obsessed with rejection - having forgot why he began to reject socity.

Here then, if Shiva is important in Yen activity - then it is ever bit as important in Yang activity.. It is necessary to destroy the fixation on creating cliff situations.

Now then, one necessary task is how do we set up criteria for detecting when we have crossed this barrier in the Yang situation?

Lewis Mumford in his article of Morals of Extermination, argues that we crossed this barrier in World War II when we accepted bombing of cities -- therfore divilians -- before that time we had maintained bombing of military targets only ---and once we crossed this line (it is no different than when the Germans crossed the line and began to exterminate Jews) there is no return..

Alright then, what are the parameters envolved:

We have the amount of the feedback, the delay time of the feedback, the parameter of knowing when it is time to change the feedback; (ie when it is 'time to depart and when is it time to return). So the problem is not a static problem - it is sort of a hpyer oscillation where you oscillate between a state of taking off and a state of say, vegitative oscillation.

There are external factors involved too, which will require you do these things -- one of these external factors is technology itself. A breakthrough in technology forces you to a position far in advance perhaps of the position you would have reached by plodding along on the Yang course. Perhaps such breakthroughs will/even advance you far over the barrier... Certainly there was no adequate feedback at the time the decision was made to use the H bomb. Well, the decision was made, but important is what did we do afterwards -- That was the time that it was crucial to sit down and find a way in which to obtain adequte feedback -

Certainly there has never been adequate feedback from Hiroshima. One can go to the nuseum theme and perhaps begin to get a feel - perhaps adequate feedback, but we know most people are apathetic to Hiroshima. Surely apathy is a sympton of IOD feedback. Contrast this to Germ warfare - you can talk about sickness -- people get very alarmed about this - here there is more capab ility to comprehend - one is experienced with disease caused by virus, by symptons of vomiting, spasims, fever, etc.

Capability of comprehension is then a part of feedback. Feedback means something to you or it doesn't/and even though the external stimulus may be at the same level unless this stimulus is resonant with human experience it becomes IOD feedback.

So here is an intresting paradox -- technological breakthroughs inevitably create IOD feedback whereas IOD feedback is useful in promoting technological breakthroughs. Its like this, you are in an IOD feedback situation, this leads to a new experience, but this new experience itself will lead to an even more lower level of feedback, hence you find yourself with less adequate feedback and if this continues you soon find yourself completely out of control of the situation entirely and this is ~~is~~ the reason return is necessary. You described it as power madness -- but it is really lack of control.... Do you see how this works??

Now let us recapitulate, let us say there were two analogus technilogical breakthroughs, one was the invention of the Hydrogen Bobm, the other the invention of germ warfare, Now these two things coming simulataneously -- we have in our experience, ability to comprehend what sickness is but we have no ability to comprehend what radiation is. and therefore we are much more abhored at contemplation of use of germ warfare than of H bombs falling.

Now let us return to the classical mathematical formulation of these things. This has all been worked out and I think this discussion has shown that we varitably have a feedback situation. The present political, technical configuration of the balance of terror is precisely and IOD feedback situation and this situation is such that it is creating an environment which reduces daily, the feedback which exists and it is already inadequate and it is taking us on out expotentially into an area which rapidly becomes beyond control and salvagability, hence reduces survival potential. Katz is always talking about we are learning how to answer obselte questions and this is IOD feedback. IOD feedback will inevitably lead you out expotentially from the realm of human experience and from the realm in which you have any control and even learning. Now the other situation where you have the suppressive feedback, where you oscillate comfortably without getting anywhere or doing anything. Now, we have to hit this singular case in between (and there is the singular case) which will allow you to grow, to absorb new experience and at the same time remain in control of the situation all the time. We can now see that the Yen - Yang thing breaks down entirely here - the point or goal, rather is to remain in control. Yen and Yang are concepts which were devised in the past to describe two states in evolution or periods in a culture. and this whole oscillation, this whole precess of departure and return has been nothing more than a hunting phenomena when we didn't understand the situation and had no way of controlling it. Now our fundamental task in the years ahead is to acquire the method of control so we can establish the singular solution of providing both growthin knowledge and wisdon which increases our survival potential and yet at all times remaining in control so that the situation does not get beyond our responses and our understanding. Because in this case we are lost and in the other case we may not necessarily be lost but we are no longer men. Another factor which comes in here is the absolute level at which a culture operates. If it is in a vegitative situation oscillating at a very low level, say an agraian culture, then its survival potential is not high, but I think the survival potential of a Yen culture increases with the level of that culture, but the point is the level of the culture never increases without the Yang experience. There may be some who would say we are at a high enough level to be Yen and be happy now, We now have enough control over nature, over disease, etc. that we can just sort of vegitate without progress - lets have no more technilogical breakthroughs Isn't that the argument? Well, if the men from Mars arrived tomorrow, I am not sure we are adequately prepared to survive in our present situation.

This is the argument that Yen is fine because it is adopted to a certain set of stimuli, to a certain set of experiences, but a new experience that comes along will threaten it with distruction. Here then is a meta problem involved of always understanding a situation, and understanding how to achieve new expereince, when to achieve new experience to optimize our survival potential. The meta problem here is the once concerned with the digesting of the new experience.

ALTERNATE DYNAMICS OF NORMATIVE SYSTEMS

Albert Wilson

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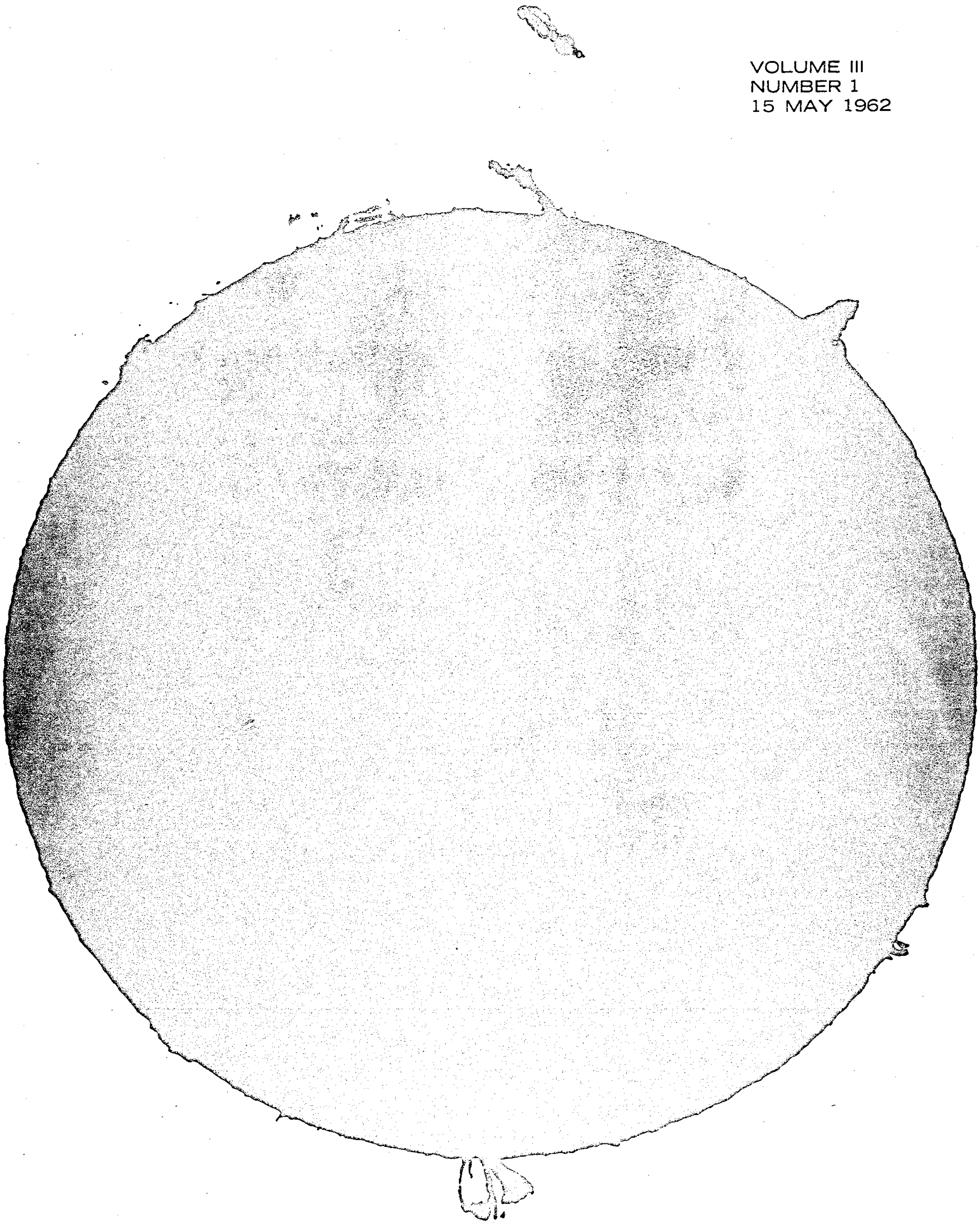

PROCEEDINGS OF THE

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ALTERNATE DYNAMICS OF NORMATIVE SYSTEMS

Albert Wilson

Four basic informational functions are common to all control systems from simple thermostats to corporate headquarters. On the system level of the individual human, these system information functions correspond to the four psychological functions formulated by C. G. Jung in his researches on psychological types. On the social level the functions correspond to the four governing and professional categories found almost universally in both primitive and advanced cultures. Following Jung's typing of individuals according to the relative development of the functions in their personality, cultures may be typed according to the relative emphasis of the four functions within their social structures. Four basic types of social dynamic are identified that are useful in characterizing organizations and societies.

The plan followed in the paper is to develop the fundamental functions from the properties of elemental control systems, then examine the forms that the functions assume in more complex systems. [1]* The principal focus of the paper is on the attributes of the functions as they operate in individuals and social organizations, which is to say in normative systems, or those systems that possess a continuum of stable states corresponding to the spectrum of human norms and goals. The principal results of the paper lie in the homologies, or correspondences between part-to-whole-relations, found to exist between psychological and social functions. These homologies are of general interest in that they show the four functions constitute a meaningful integrative schema of wide applicability, which provides insights into the nature of man and the structure of systems on all levels.

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* Numbers refer to notes and references at the end of the paper.

The Four System Functions

The study of physical systems in the eighteenth and nineteenth centuries provided us with basic concepts such as energy, entropy and probability that have proved to be powerful tools for formulating and solving technical problems. The study of control systems in the twentieth century through the development of concepts such as information, feedback and programming is furnishing us with tools that are helping to formulate and solve problems associated with higher order systems including biological and social systems. One system concept that is important throughout behavioral and systems sciences is that of function. This is a word used with several meanings, but in the general systems sense used here, a function will be defined as a set of one or more elemental operations that is performed repeatedly in the same manner in order to enable the system to fulfill its tasks or purposes. The tasks or purposes of the system may themselves be functions when the system is regarded as imbedded in a larger system. In this paper we shall be concerned primarily with control systems, which means that the sets of operations that make up the functions are operations on and with information. Some typical elemental informational operations are filtering, storing and replicating information,or they are arithmetic and logic operations such as comparing and grouping data.

As a specific example, let us consider one of the simplest control systems, the ordinary thermostat, whose purpose is to hold the temperature of a room as close as possible to some pre-selected value through the control of heating and cooling devices. Ordinarily such a system is studied from the point of view of negative feedback operations, but here we shall look at it in terms of three basic functions: First, the thermostat must perform that function or set of operations that allows it to measure the room temperature and generate a signal corresponding to the existing thermal state. This signal may appropriately be called the "is" signal. Second, the system must perform that set of operations that generates a signal corresponding to the pre-selected thermal value. This signal may be labeled the "ought" signal. Third, the thermostat must perform the set of operations that generates the "is minus ought" or "error" signal, and on the basis of whether this signal is negative or positive, switch a heating device on or off. We shall name the first of these functions whose task is to sense the system context the <u>sensing function</u> ; the second, whose task is to provide a standard or norm, we shall call the <u>normalizing function</u>; and the third whose task is to compare the existing and desired conditions and make a decision among the available options, we shall call the <u>deciding function</u>.

It is apparent from this functional description of the simple thermostatic control system that parts of the functional operations are not performed <u>within</u> the thermostat proper. One basic operation of the normalizing function, the pre-selection of the desired value, must be performed by an external agent such as a human. Should this agent be considered as part of the system? If the systems analysis is made according to system components and sub-systems, the source of the "ought" value would be put into and external black box and the pre-selected value conveniently regarded as a system input. But in a systems analysis made according to functions, it is essential that no operation which is part of the set of operations belonging to the function be treated as outside the system. The delineation of what may be taken as the system boundary depends on this criterion. Systems analysis by components may be atomistic/reductionistic, but systems analysis by functions must remain wholistic.

Let us next consider a more sophisticated control system, one that has the capability of self-modification. Such a system might be, for example, a thermostat that can minimize fluctuations in room temperature by anticipating environmental changes. In one model of such a system the periodic components of the room temperature changes could be harmonically analyzed and their periods and amplitudes supplied to the deciding function which could phase the switching of heating and cooling devices so as to anticipate the expected changes. Failures to anticipate would be used to modify the program through the inclusion of additional harmonics and sub-harmonics of the room temperature pattern. If the temperature pattern proved to be purely periodic then through a sequence of program modifications the thermostat could eventually derive a program which would replicate the temperature pattern and allow the deciding function to anticipate them. In this more sophisticated system a fourth function is present. In addition to the original three operations of sensing, normalizing and deciding, there is the capability of introducing new operations and altering existing operations in the system program. The set of operations by which the system program is modified will be called the modification function. In the simple thermostat the system program consisted simply of comparing the "is" and the "ought" signals and throwing a switch on or off. There was no way to modify this program. In the anticipatory model in addition to the "is" and "ought" signals a third signal that we may call the "adaptation" signal is fed to the deciding function. The adaptation signal is learned from analyzing the actual temperature changes and is modified whenever it fails to replicate them. The set of operations that generate and modify the adaptation signal belong to the modification function. However, after the modifications have been completed and the program can successfully anticipate, the adaptation signal becomes part of the routine program and its custody is transferred to the deciding function.

It is a general feature of systems that the sensing, normalizing and deciding functions maintain custody and responsibility for their sectors of the system program, while the modification function turns the product of its modification operations over to the other functions once the modifications have been completed. In some systems certain modification processes themselves become routine. The set of operations involved in such modifications are then taken over by the other functions. The modification function has worked itself out of a job so to speak. So a more refined definition of the modification function would say that the task of the modification function is modification except when the operations of modification have already been learned. It is the residual tasks that are the essential operations of the of the modification function. These are the design of operations for coping with unprecedented situations and developing programs for adapting to them. So long as unprecedented situations arise and so long as the system has not reached some limit of modifiability, the modification function has the job of developing alternatives and creating new options.

The modifications of the anticipatory thermostat were software or program modifications. Systems that modify their hardware components belong to a higher level of the scala. Bio-organisms, in general, are capable of hardware modification but alterations are usually effected in steps through a series of different individuals (evolution) rather than within the same individual. The sets of operations constituting hardware modification through genotype and phenotype phases, though of great importance in the subject of control systems lie outside the scope of this paper. [2]

Each of the four functions is present in bio-systems, but through inter-functional programming, each involves more sophisticated operations: The sensing of the environment becomes multi-channeled and complex; normalizing involves internal monitoring and operations capable of system repair and healing. The deciding function becomes highly developed and operates on both autonomous and conscious levels. The modification function rewrites programs and becomes especially important in the higher organisms through various types of learning procedures.

At this point, we can characterize the system functions in a more comprehensive way than was possible from the properties of simple thermostats:

The sensing function is primarily associated with operations having to do with the system's interface with its physical context, with sensing, perceiving and data collection, with displaying the present or "is" conditions to the organism. Interfacing is at root information exchange.

The normalizing function is concerned with operations that maintain standards or norms and display the "ought" conditions to the system. This function initiates correction and restoration operations for both system parts and the system whole, guiding them in accordance with reaching equilibrium with the state defined by the norms. Stability is at root standards maintenance.

The deciding function governs established and routine operations, selecting,choosing and switching. It makes comparisons, correlates, groups, etc. In brief does all operations that constitute administration. Control is at root decision making.

The modification function initiates operations that alter the system's routine operations and norms. It focuses on operations having to do with adaptation to unprecedented situations and is the receiver or the generator of novelty and innovations and the creator of alternatives and options. Modification is at root option creation.

As systems become more complex, the functions acquire additional attributes. In sophisticated systems the functions may more properly be termed "functional sectors" with each of the four sectors containing aspects of the other three functions. In other words functions and functional sectors homologously related in the sense that each functional sector takes on the four-fold functional pattern within its own operations. The homologous nature of the relation between functions and functional sectors can be conveniently displayed using a cross and a cross-crosslet. In the simple cross of Figure 1. each arm represents one of the functions. The right hand arm the sensing function, the upper arm the deciding function, etc.

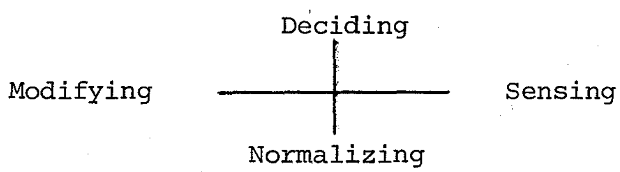


Figure 1.

Functional sectors may be represented using the cross-crosslet of Figure 1b. In this figure the right hand crosslet represents the sensing sector, the upper crosslet the deciding sector, etc. The arms of each crosslet represent the corresponding functions within the sector. The right arm the sensing function etc.

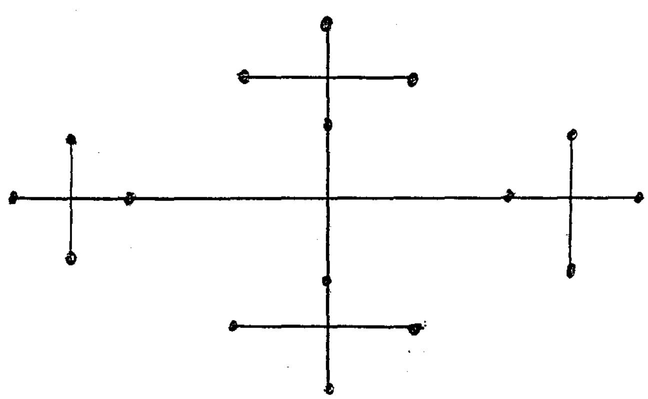


Figure 1b.

Using this representation the crosslet representing each functional sector of Figure 1b. may be amplified as in Figure 2. In the upper crosslet of Figure 2. the three ingredients on which decisions are based--situational data, standards and options-- are displayed together with the types of programs related to each function. The right hand crosslet of Figure 2 shows the distribution of the three types of data collected by the sensing sector. This sector supplies the deciding sector with data required for operations of a routine nature; it supplies the normalizing sector with data required for assessing and evaluating contextual norms and supplies the modifying sector with data of a novel nature or descriptions of unprecedented situations. The lower crosslet of Figure 2. shows the three sources of standards used by the normalizing sector. The standards whose sources are in the present prevailing conditions are shown on the sensing arm of the crosslet; those norms that come from routine and past practice, from tradition, etc. are shown on the deciding arm; and those coming from desired modifications and goals for the future are shown on the modifying arm of the crosslet. In the left hand or modifying crosslet, the three types of innovation and modification are displayed: New and unprecedented experience, on the sensing arm; new organization, programs and operations on the deciding arm; and new norms and goals on the normalizing arm.

The cross-crosslet displays the homologies between the functions as constituted on different systems levels. It is not reducible to a tree. The right, left, upper and lower arm positions represent relations in addition to the "boss" or "source" relations displayed in conventional trees. This form of representation will be used throughout this paper for displaying homologous relations between psychological types and societal functional sectors.

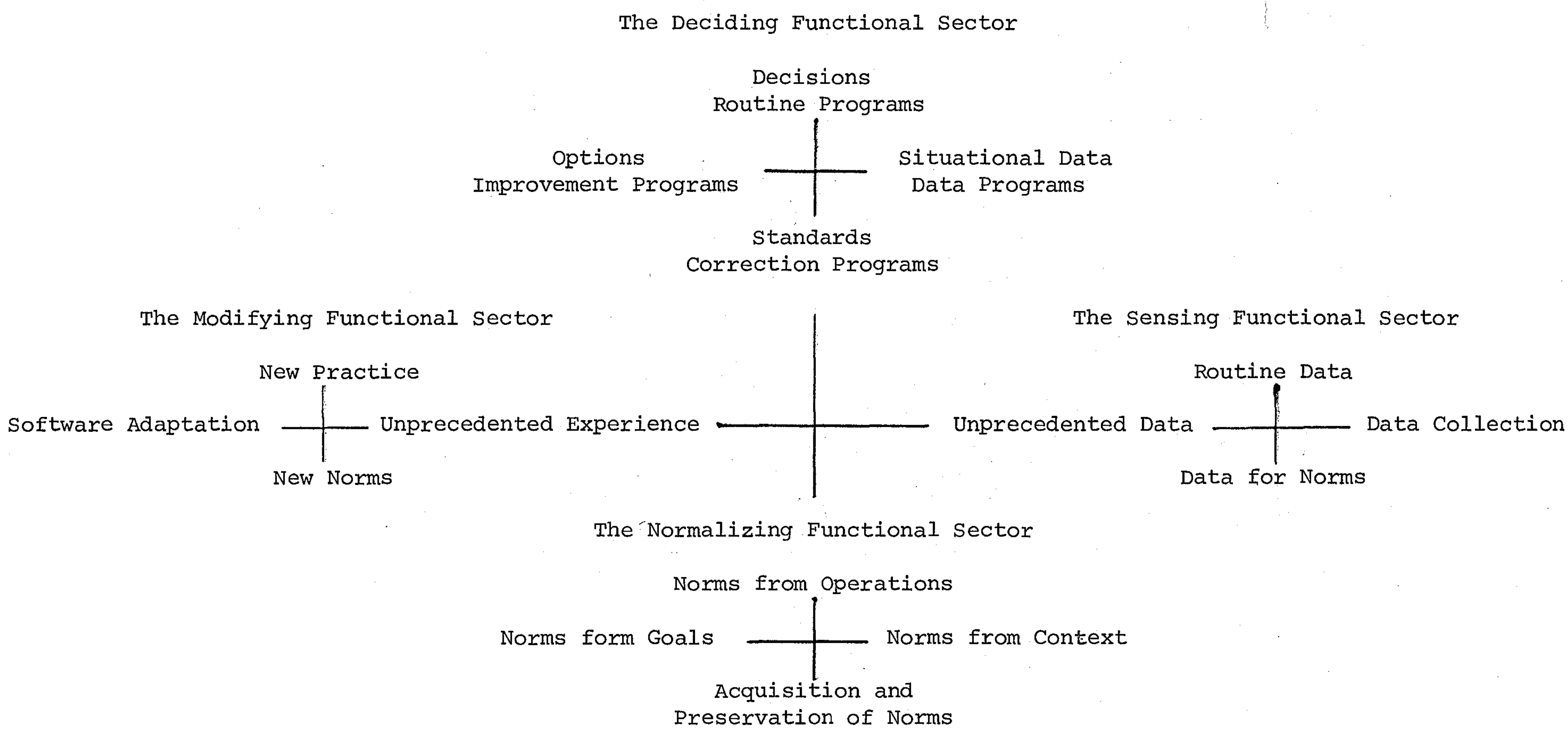


Figure 2.

HOMOLOGIES IN SYSTEM FUNCTIONAL SECTORS

Jung's Psychological Types

Many typologies have been proposed to compare the psychological and physiological characteristics of individuals. To mention a few: Hippocrates suggested a typology of physique and temperament corresponding to Empedocles' four basic elements--earth, air, water and fire. Rostan in the nineteenth century recommended a four-fold digestive, muscular, cerebral and respiratory typology. Kretschmer in the twentieth century advocated a system based on the categories: asthenic, athletic, pyknic and dysplastic. That typologies need not be four-fold, we note Sheldon's more recent system based on his Atlas of Men which led him to his classifications of endomorph, mesomorph and ectomorph.[3] Yeats used a system with twenty eight categories while William James divided people into those with tender-minded and those with tough-minded temperaments. As useful as these several typologies have proven for various purposes, our interest is drawn to the typology of C.G. Jung which is based on four psychological functions--sensation, thinking, feeling and intuition--which Jung abstracted from his clinical studies. Jung's studies of psychological types originated in his attempts to help people --husbands and wives, parents and children-- understand their differences. His taxonomy of four basic types depends on the relative development of the functions within the temperament of the individual. A sensation type, for example, is a person in whom the sensation function is especially well developed while the other three functions are under-developed. Jung's system is of central importance in this paper because of the homologies that exist between his psychological functions and the system informational functions.

Jung's four psychological functions may be described briefly as follows: The Jungian sensation function is almost identically the system sensing function, both being the function governing the operations having to do with information acquisition from sensing and interfacing with the physical environment in general. The Jungian thinking function is also an homologous extension of the system deciding function. It controls not only the usual lower level system deciding operations but being on a cognitive level is capable of complex logic operations involving several levels of self-reference and all that is usually associated with the operations of thinking. The Jungian feeling function plays an analogous role in humans to the system normalizing function in lower order systems. That this is so is not quite so apparent as in the sensation and thinking cases. Feeling for Jung is not a matter of emotion or affect but a matter of like and dislike, a matter of evaluation according to tastes and values held by the individual. Feelings in this sense have to do with judgements of whether actions, people, situations or things come up to expectations or conform to standards. It is in this sense that Jung's definition of his feeling function is analogous to the system normalizing function. Jung's fourth function, intuition, is the function governing symbol formation and imaging operations. It has to do with the perception of gestalts, insight into fundamental patterns and the acquisition of concepts and solutions through a "recognition" process--which may be multi-sensory or "extra-sensory"--that 'knows what it is looking for as soon as, but not before, it finds it'. The analogy of the intuition function to the system modification function lies in both being the innovational functions. On the psychological level the sources of innovation--new ideas, discoveries, inventions--are the new images that form in the minds of people. System modification on psychological and social levels originates in the innovations deriving from these new images. In this way Jung's intuition function plays the role of the system modification function. [4]

Psychological type may be characterized either by the relative degree of development of the functions in the personality of the individual, the method adopted by Jung, or may be characterized by the principal function that the type performs within the higher order system--organization or society--in which it lives. Both of these ways of characterizing the types are reflected in Table I. The first five rows compare the attitudes and roles that each type emphasizes in a social context. Rows six through nine compare some paradigmatic views, while rows ten and eleven compare anxieties and response to stress.

From the first five rows we get the picture of the sensation type as primarily centered in the external world, stressing action and the concrete. choosing occupations having to do with practical down-to-earth matters. What is important is workability. We see the thinking type as factual and logical, involved in organization and administration. What is important to him is what is true and valid. Feeling types are strong for law and order, for stability and justice. They are the critics and judges of society. Their approach is primarily people centered and what is important to them is what is good for people and society. The intuitive types emerge as creative and innovative people. They point out alternatives, design new approaches, and generate new options. They focus on potentialities and on what may be. What is important is the "big picture" and how we relate to it.

In rows six to nine, we see how the different types through their respective views and emphases create paradigmatic differences. Consistent with the present centered nature of sensing, the sensation type tends to focus consciousness, energy and will on the present. He is a "now" person, living in and for the moment. He has a short memory and discounts both

TABLE I

ATTRIBUTES OF PSYCHOLOGICAL TYPES

		Sensation	Thinking	Feeling	Intuition
1.	Preferences:	deeds and action	facts and organization	rules and values	possibilities and innovations
2.	Emphases:	implementation, getting the job done	procedures, coordination	criticism, correction	alternatives, options
3.	Tends to be:	empirical and pragmatic	logical and rational	evaluative and lubricative	speculative and imaginative
4.	Wants solutions to be:	workable	systematic	agreeable	open-ended
5.	Focus is on:	the realizable what works application	the probable what is true verification	the preferable what is good evaluation	the conceivable what is important signification
6.	View of time:	focus on the moment, "Now" is all	linear, with past, present and future	cyclical with emphasis on precedent	future or extra-temporally oriented
7.	View of change:	probabilistic	causalistic/ deterministic	normative	finalistic
8.	Approach to the future:	discounts the future	future, an extrapolation from past and present	emphasis on stabilization	emphasis on fluidity
9.	Method of validation:	body counts	logical or internal consistency	authority, law precedent	authority of self
10.	Fears:	loss of gratification	loss of capability and self-confidence	loss of relationships	loss of meaning
11.	Response to undue stress:	binges and excesses	methodical rituals and procedures	depression and illness	withdrawal and fantasy

the past and the future. He feels few ties to either yesterday or tomorrow and projecting his personal view onto the world, considers it to be free of both causal chains and great ultimate purposes. What happens, happens. The world thus seen becomes probabilistic in nature. The matter of validation is usually not a major concern, sense gratification and the pleasure principle in general provide their own validation. However, when something comes up for which validation is required, the sensation type likes to resolve it through body counts: "What is the gang doing?", "What do the polls say?"

The thinking type shares the physicist's view of time--linear with a present dividing the past from the future. He feels that events are interconnected by causal chains and it is knowledge of these chains that lead us to the laws of nature and make science and the application of science possible. The thinking type believes that we can forecast the future by making extrapolations from the present since the laws of nature will be the same tomorrow as they were yesterday. Validation is one of the central concerns of the thinking type. Validity is established primarily through proof of consistency with the established body of knowledge. [5].

Feeling types choose to be governed by precedent and become past focused. They think of time as cyclical with continual recurrence of archetypal situations.[6]With nothing new under the sun, the past provides the keys to the present and the future. The world is not immutable, however, and we can move it step by step into better accord with our norms. The cosmic or collective will to correct and heal is stronger than any causalistic chain. As for validation, it is no problem. We have but to turn to our established codes, to our sacred books and the wisdom of the past to guide us.

Intuitive types, like sensation types are "liberated" from the constraints of time. While the sensation type frees himself from the past and the future by shrinking time to be only the present moment, the intuitive type, soaring on the reality that for him resides in his own images, leaves the time-line of the physicist and lets consciousness range freely to past, to future, to elsewhere. But since possibilities,in order to be possible, must in some way be linked to the physical world and since there are fewer and fewer far away and unexplored places in which the possible may reside until it is captured and tamed, the possible must increasingly take refuge in the future. Intuitive types have thus become largely future oriented. [7] They feel the finalistic attraction of the system's potentialities to be a force capable of overiding all deterministic/causalistic obstacles. The future is wide open; we are limited only by our visions. As for validation--no need for concern--we know when we are right.

Lines ten and eleven of Table I compare the fears and defense mechanisms of the four types. The primary anxiety of the sensation type is the loss of immediate gratification. A delay or shortage that threatens continuity of gratification triggers such excesses as hoarding, going on binges and indulging addictions. The thinking type's security rests on his ability to perform and his greatest anxiety centers on loss of capability and the accompanying loss of self-confidence. His defensive response to such an eventuality is to exaggerate his normal logical behavior and wall himself about with methodical rituals and procedures, such as locking and re-locking doors, recording, copuing and filing trivia, etc. Feeling types fear most of all the falling out of relationship, being rejected. They respond to such a situation by a self-induced depressive illness calculated to regain sympathy and affection. The intuitive type's anxiety is over loss of meaning and orientation. When this anxiety presses heavily they tend to withdraw from the existing world and build new worlds in fantasy to replace the one that frustrates them. Each type's unbalanced emphasis of its own function is usually at the root of its troubles. But not realizing this, it thinks the answer to difficulties is to apply more of what has on other occasions been successful for it, what it is adept in--its own function. This leads to greater imbalance and difficulty. Whence the absurdity of seeing people (and societies) apply in great measure what fails in moderate measure. 'If we just try a little harder, harder what we have been trying will work.' No alternative is conceivable.

Frequently we encounter such questions as, "Which is the right type?", or "Which type has the correct perspective?". These questions and their like stem from a "type chauvinism" that exists in every culture and sub-culture. For, example, the type chauvinism in the United States at the present time is one strongly prejudiced in favor of sensation types. With estimates that some 80% of our population is of the sensation type, sensation types are better understood in our society and are more liberally rewarded than other types. But basically there is no single 'right' type. All of the types are right when taken together; all are wrong when taken singly. Each is partial and incomplete by itself, needing the others to achieve effectiveness. Every workable social group needs all four types and each individual needs to develop all four functions. Each function is essential to the successful operation of the whole. Whether the system is an individual or a society, the critical matter is <u>balance</u> among the functions rather than dominance by the 'right' function. This does not necessarily mean equal numbers of each type in an organization or society, but means an unimpeded flow of each type's inputs and contributions. The real usefulness of this typology is not as a static indicator, but as a vector showing which functions need most to be developed in order to achieve balance. [8].

Functional Sectors in Social Systems

The importance of the system informational functions and of Jung's psychological types lies not only in the insights afforded into individual behavioral differences but in the illumination they give to the basis of social organization. Although no demonstration of the necessity of an isomorphism between the psychological structure of individuals and the structure of their societies can be made, the reflection in social organization of the psychological patterns identified in individual humans, like the reflection in the shape of a crystal of the structure of its constituent molecules, is an expected development from the point of view of general systems theory. We may hold that our social organizations develop these functions because our psychological natures require them. [9]

Four elemental control sectors are found almost universally in human societies. These can be identified with the labels: Prince, Warrior, Prophet and Judge; or in a highly developed society they are recognizable as the control sectors charged with administration, defense, change and relationship. The ubiquity of this four-fold organization of society may be seen in examples from all parts of the world and all eras. It is present in groupings as elemental as a hunting party of Kalahiri Bushmen whose members consist of a headman, hunter, shaman and clown.[10] The same four-fold social organization is manifested in the city structure of the Mayan ritual center at Uxmal. [11] It appears in the traditions of North American Plains Indians and in the caste systems of India. [12] These control sectors are the systems functions and the Jungian types in social form: The headman-prince-administration sector being the system deciding functional sector and the natural abode of the thinking types, the hunter-warrior-defense sector is the societal sensation sector; the critic-judge relationship sector is the normalizing/feeling sector and the shaman-prophet-change sector is the modification/intuition functional sector. (Figure 3)

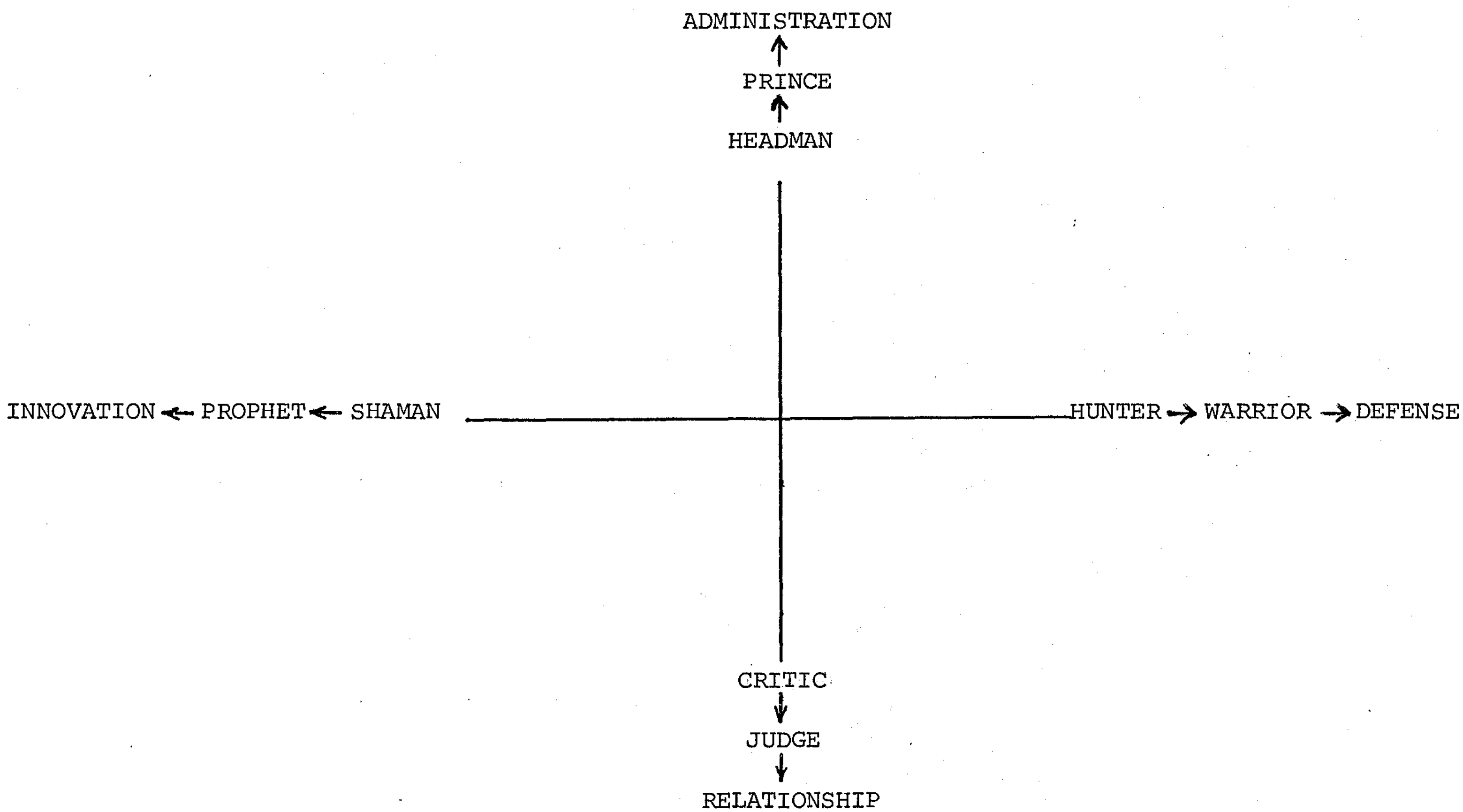


FIGURE 3

FROM CLAN TO SOCIETY

There are many speculative scenarios on the origin of the social functional sectors. We may surmise, for example, that within nomadic hunting clans internal disputes arose over whether to stay with a carcass until it was stripped clean or go after a fresh kill. One choice demanded temporary localization of the clan and loss of freedom of movement. The other choice demanded the willingness to risk going hungry. This decision would bring on disagreements between those types who would feel very uncomfortable if immobilized and deprived of options and those types who preferred to keep risks to clan welfare and stability at a minimum. The future began to be differentiated from the present.

When the saving and the storing of food became a definite viable option nomadism declined and the simple organic hunting party was metamorphosed into a society. This brought about new imperatives: The necessity to protect and defend what was stored, the necessity to count and record, the necessity to share and adjudicate and the necessity to plan and anticipate. Clan became Polis, organism became organization, but the economy alone could not bind great numbers into a cohesive whole. A social mucilage consisting of <u>authority</u>, <u>arms</u>, <u>codes</u> and <u>gods</u> evolved--an adhesive for each psychological type. And with each adhesive a custodian of the adhesive--prince, warrior, judge and prophet The prince was responsible for decisions, the warrior for interfacing with the world beyond the polis, the judge for codifying the norms of the society and keeping relationships in adjustment, and the prophet for staying in touch with the voice of "The Other" and its calls for reform. The four functional sectors had assumed their social forms: Decision and management of the routine, Defense and inter-societal relationships, Stability and intra-societal relationships, and Change, innovation and bridges to the unknown.

Increasing complexity of the social order finds each social functional sector constructing within itself sub-structures that are hierarchically homologous to the whole society. [13] These hierarchical homologies may again be conveniently displayed with cross-crosslets. Figure 4 shows the homologous relations between an administration sector, a defense sector, a stabilizing sector and an innovational sector. We shall here adopt the "S", "T", "F" and "N" notation used by Myers and Briggs in measuring the four Jungian Types. [14] "S" will be used to designate sensing/sensation/defense, "T" will be used for deciding/thinking/administration, "F" for normalizing/feeling/stabilization and "N" for modifying/intuitive/innovation. The upper or "T" crosslet displays government as a particular societal administrative functional sector. The upper "T" arm of the crosslet corresponds to the executive, king or president, who is responsible for administering the laws. The left-hand "N" arm corresponds to parliament, the source of new laws. The right-hand "S" arm represents law enforcement and the lower normalizing "F" arm represents the courts and the law itself--the constitution and the basic body of law and procedures.

The particular "S" functional sector illustrated in Figure 4 is that of the military. (Other important "S" sectors that might be displayed are intelligence, diplomacy and trade.) Within the military sector, the upper "T" arm corresponds to command, the left-hand "N" arm to strategists and think-tank experts who devise new operational procedures and introduce new weapons systems; the "S" arm corresponds to the effective fighting forces and to the operational weapons systems themselves. The lower "F" arm corresponds to the normalizing framework adopted by those that "play the game" of war. This arm would correspond to such items as codes of chivalry among medieval knights or World War I aviators, or in the present day to the Hague and Geneva conventions delineating the rules of war or to the sophisticated interplay of overt and covert threats and postures known as "nuclear deterrents".

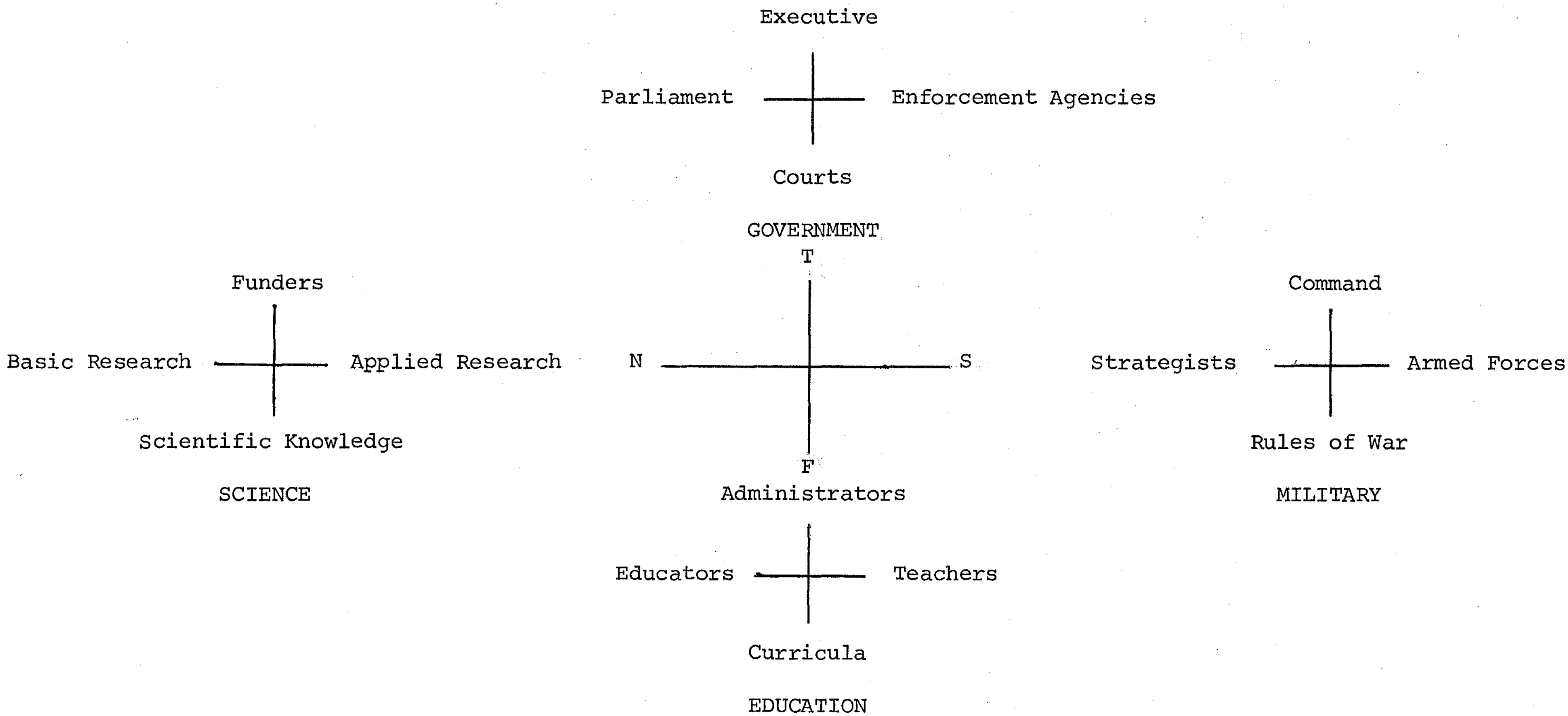


FIGURE 4

Hierarchical Homologies in Social Functional Sectors

The example chosen for the lower "F" crosslet is education, which is a normalizing sector whose task is to preserve standards and cultural forms through inculcating the young. In the educational crosslet the upper "T" arm corresponds to school administration. The left-hand "N" arm represents educational experimentation and innovation; the lower "F" arm corresponds to curricula or the body of information that is selected to be taught. The right-hand "S" arm represents the teachers and students themselves. Other examples of "F" functional sectors are institutionalized religion, the law, and the media, all of which set, preserve and disseminate cultural standards and norms.

The innovational sector picked for the left-hand "N" crosslet is that of science and technology. In this crosslet, the "S" arm corresponds to applied research and to that type of research that consists of filling in the details of a "Kuhnsian Paradigm". The left-hand "N" arm corresponds to basic research and the processes that lead to new paradigms of science. The lower "F" arm represents the established body of scientific knowledge, which is the basic yardstick against which all innovation in science is measured. The upper "T" arm stands for the "top-down" administrative elements that direct research through funding and assignments of priorities. Every field has an innovational sector which could be represented by an "N" crosslet. But, besides science and technology, the innovational sectors with broadest relevance are those of politics, art and religion. [15] Religion as an innovative sector must be distinguished from institutionalized religion as a normalizing sector. "N" type religion has to do with philosophy, world views and the chain of attitudinal and behavioral modifications that ensue from a worldview modification.

We leave hierarchical homologies and the "game of quad" by pointing out in Figure 5 the emerging branches of systems theory that correspond to each of the four functional sectors.

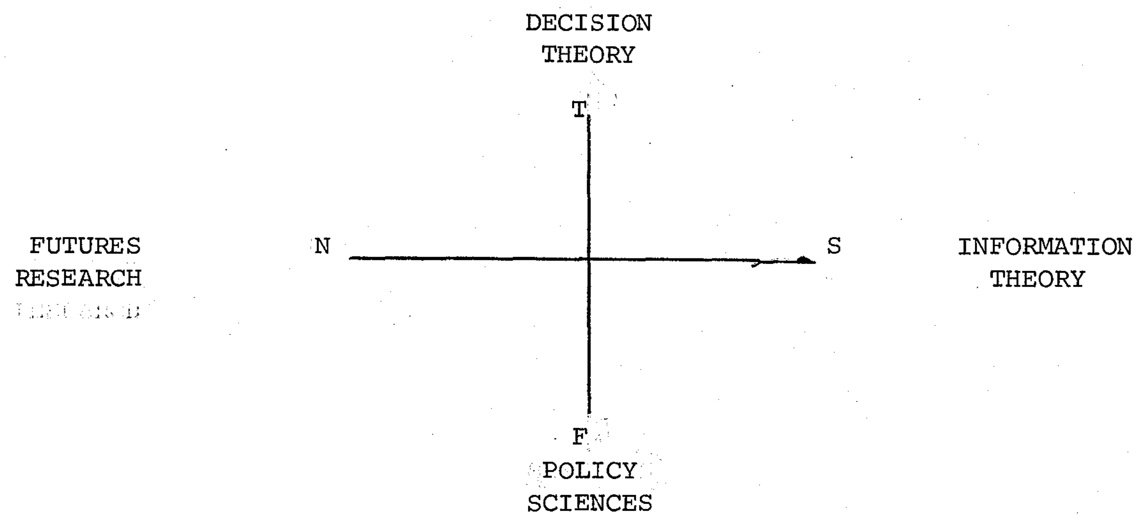


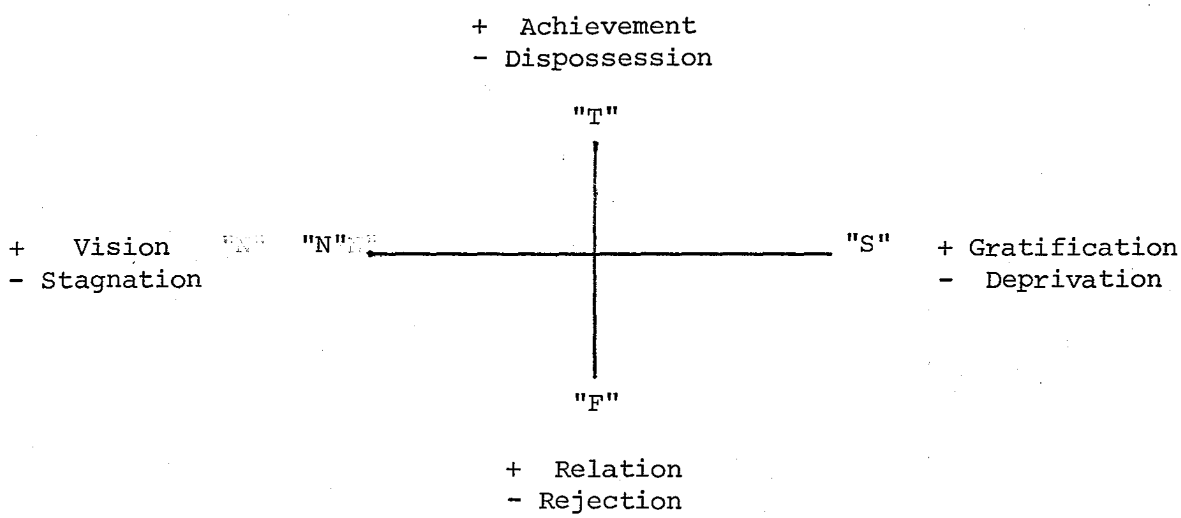
FIGURE 5

The Four Functions as System Disciplines

Dynamics of Normative Systems

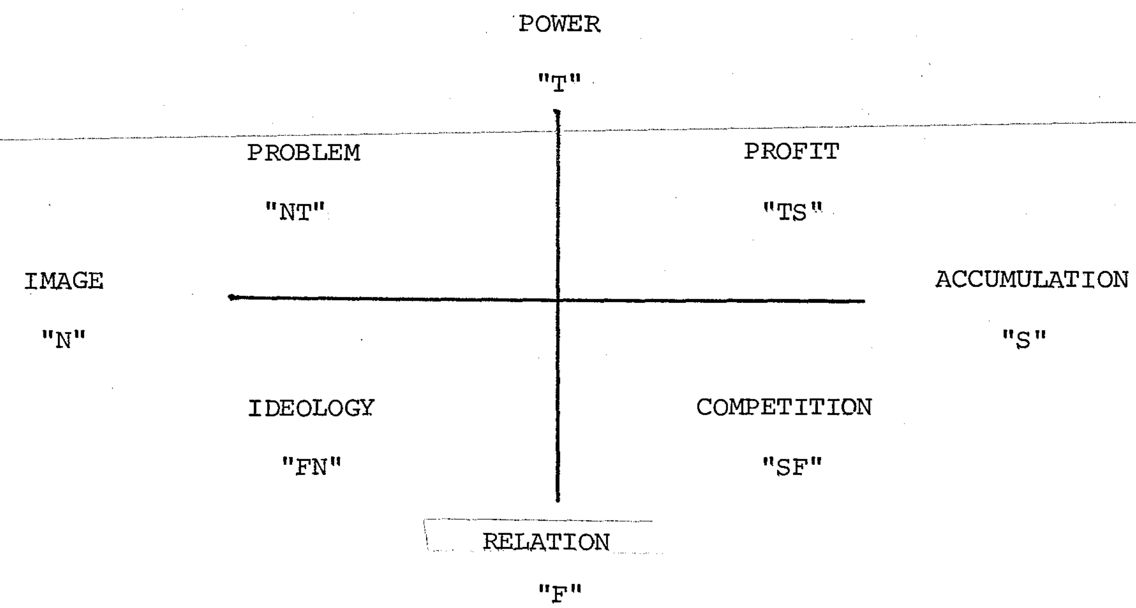
In the survey of psychological types it was noted in Table I that each type has characteristic anxieties, typical defense mechanisms and favored behavioral patterns for coping with stress. More generally, each type possesses a characteristic motivational base or dynamic. A dynamic may be thought of as a'psychological fuel' from which the individual obtains energy and drive. Each type may run on all of the fuels but responds preferentially to a particular one. For example, the sensation type's basic anxiety--loss of gratification--is a key to those things that particularly energize him. His dynamic is primarily sensory gratification. He is energized by those experiences which promise immediate gratification, consistent with the findings of his being "now" oriented and a discounter of the past and the future. But the drive of sensory gratification is only one side of the coin. The sensation type is not only driven by sensory gratifications, but is also strongly energized to action when there exists a threat of deprivation of his gratifications. For him a crisis is a loss or delay in the flow of those items upon which his gratifications depend. Thus each person is motivated by both an aspiration and a fear--the two meta-dynamics--and all of the type dynamics take on both a positive and a negative aspect. In the case of the sensation type, the positive or aspiration dynamic is gratification , while the negative or fear dynamic is deprivation.

The positive dynamic for the thinking type is achievement--college degrees, home ownership, executive positions or is performance--all A's on the report card, records in production, increased profits. The negative dynamic is the fear of dispossession and displacement--threat to authority, position or acquisitions. The positive dynamic for the feeling type is good relationship--friends, belonging to the group, status. The negative dynamic is the fear of rejection, ostracism, exile. The intuitive type is



POSITIVE AND NEGATIVE PERSONAL DYNAMICS

FIGURE 6.



COMPOSITE SOCIETAL DYNAMICS

FIGURE 7.

positively energized by images, visions, dreams of what might be. His negative dynamic is the fear of closed-endedness, the collapse of all opportunity for modification, fear of ossification and stagnation. These personal or psychological dynamics--positive and negative--are displayed in Figure 6.

On the societal level each of these dynamics not only represents the dominant drive of groups of individuals of each type but, depending on which psychological type(s) dominates the culture, characterizes the society itself through the establishment of its principle life styles, norms and definition of success. A 'pure' S-type society would be one in which accumulation of material possessions is the condition of satisfaction and the measure of success. Collectively the S-society is the consumption society. In a T-society the degree of power or control over decisions is the measure of stature in the society. The T-society as a whole measures its success in terms of its power and control over societies outside itself. Such a society is an imperialistic society. In an F-society, status, membership in castes and clubs, possessing the proper pedigrees and titles would be 'in'. Collectively, such a society tends to be chauvinistic. In the N-society, contributions--artistic, scientific, humanitarian--are the principal sources of personal satisfaction and the basis of recognition. The n-society's monuments--its pyramids, cathedrals, courts of law, footprints on the Moon--would be the base of its collective meaning.

Of course, there is no society of a single pure type. Such a society could not long survive. We recognize the existence of each of these dynamics in most societies. What differentiates one society from another is the relative emphasis placed on each dynamic. It is from the mix and blend of these four type-dynamics that the principal societal composite-dynamics emerge. In Figure 7. the four type-dynamics are displayed together with their composite-dynamics--

profit, competition, ideology and problems--which have become the basic societal dynamics.

The S-type gratification and accumulation dynamic combined with the T-type drive for organization and power leads to a dynamic which expresses both. This is the profit motive, which is the principal energizing fuel of the S-T technological society in which we live. Profit, measured in return on investment per annum, measures both accumulation and the success of organization and management. The fact that it is a rate rather than an amount is a feature more in accordance with T view of time than S views, but the short time span of one year keeps the tensions of S types for gratification from building to levels of high dissatisfaction. Most present economic theories are S-T theories. Wealth is measured by material resources (S) and capital or tools (T) and does not include such F and N types of wealth as knowledge and problem solving capabilities. The theoretical economic man is a combination of an S-type consumer and a T-type businessman who always knows and looks out for his own best interests.

The tension of competition--of an unresolved contest--is a powerful dynamic that appeals primarily to S and F types. Brute behavior through normalization has been tamed and given many channels in which to flow. The blend of the S type's drive to acquire and the F type's need for rules of fair play creates competitive games that include not only sports but business, careers and war, each with their definitions of win and lose. Great difficulties are encountered if the game changes and the old definition of "win" no longer obtains. It is in this same S-F quadrant (Figure 7.) that the dialectical dynamics of Heracleites, Hegel and Marx find their support.

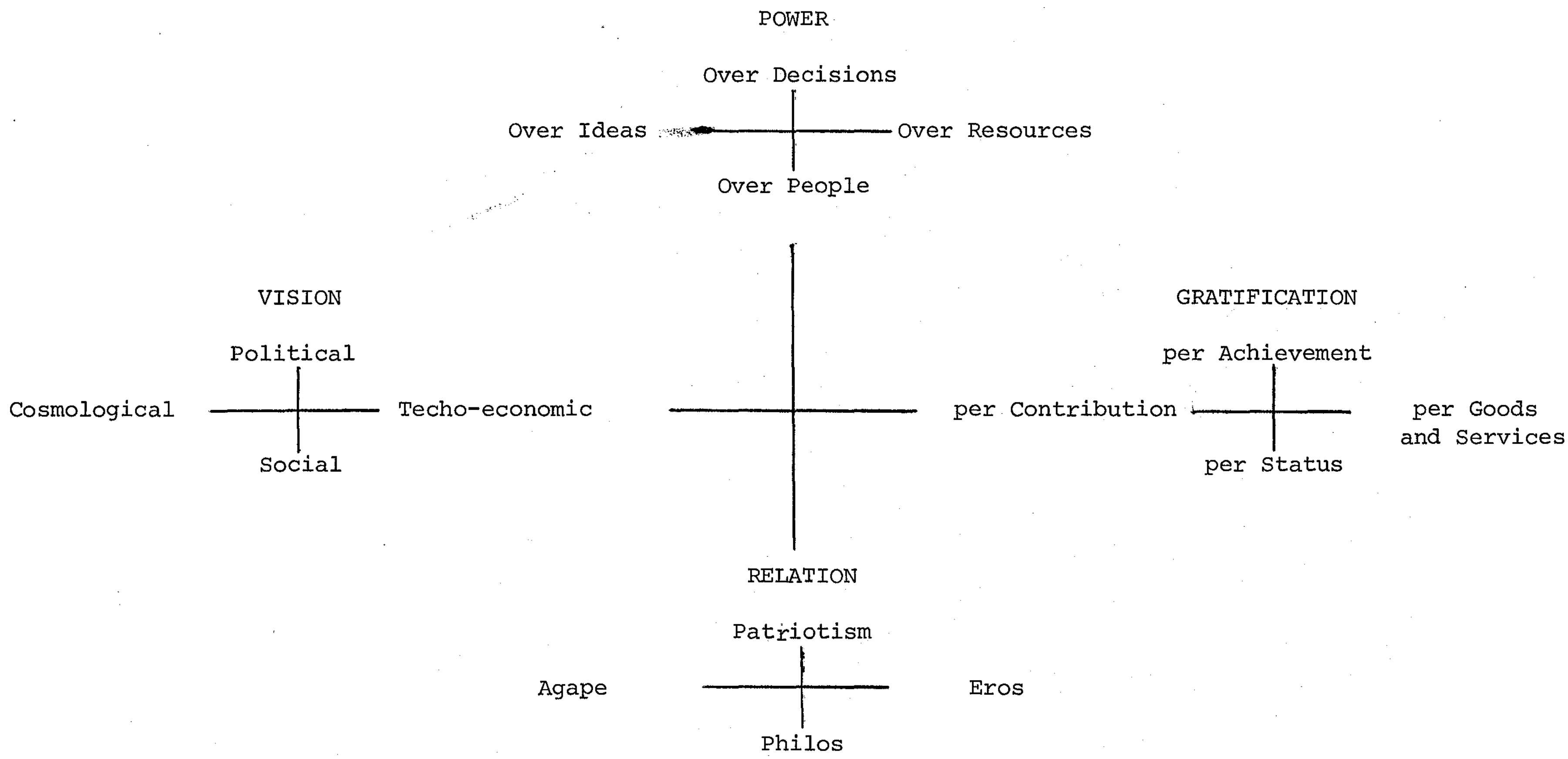
The marriage of N images and F norms gives birth to ideologies --those great 'should be's ' that fire both the imagination and the blood: The 'Alabaster cities that gleam undimmed by human tears', the City of God, the Thousand Year Reich, the World Revolution. When the symbols that represent these ideologies--stars, stripes, crosses, swastikas, sickles, hammers-- march into view, hearts pound, throats lump, tears swell. Psychological energy of great power flows, the parade is joined, the banners move forth and the world is edged a step closer to the dream.

Finally there is the dynamic of the unsolved problem, from the puzzle that cannot be set aside to the timeless mysteries of the cosmos. With the funnels of intuition and the sieves of analysis, N and T ally to meet the challenge of the unsolved. But the problem-dynamic does not cease with the solution of the problem, for more problems grow, Hydralike, for every one that is solved. Flags fade, images cease to energize, acquisitiveness becomes satiated and the competition subdued, but problems persist. Like a breeder reactor, the problem-dynamic generates more fuel than it consumes. It has been claimed that problem creation is the central dynamic of civilization building. [16] "A man on the moon in a decade", was a N-T challenge issued by a President of the United States to an S-T society. It was mete, but the S-T society could never fully grasp the meaning of the enterprize and was unable to gain satisfaction from it nor accommodate it to its S and T yardsticks. It appears that the Apollo Program took care of most Americans' "N-T" needs for some time, and the relatively small "N-T" sector of American society must now do its thing on a more modest scale for some time.

Homologies between type dynamics and societal dynamics emerge in many combinations. One such set is displayed in the cross-crosslets of Figure 8.

The power dynamic is centered on the control of four types of access: Access to decision making (political power); access to resources and capital (economic power); access to information (cultural power) and access to rights (judicial power). Other forms of power, such as military power, depend in the long run on the four basic powers. The importance of political power and the tendency for it to be both monopolized and monopolistic was clearly recognized by the drafters of our Constitution and its Bill of Rights. Their recognition of the basic nature of the other three powers was not so comprehensive or perspicacious and much of our subsequent political history has focused on the issues of access in the other three sectors. Economic monopolism has long been an issue in the Congress and in the courts, but today focus has largely shifted to control of access to information and civil rights. Control of access to information takes many forms. It involves the media, education, and government itself through such issues as protection of news sources, selection of textbooks and executive priviledge. Control of rights involves such issues as abortion, drug use, vitamines, invasion of privacy, questions of to what extent should people's bodies and minds be their own to do with as they please. The central theme of access is fundamental to this crosslet. The decision function here takes the form of closing and opening doors.

The gratification dynamic which is an "S" dynamic has its S,T,F and N arms. The peculiarly S aspect of gratification is the accumulation of goods and services, which are the key to most sensory gratification. The T aspect of gratification is in achievement--production, sales, circulation, membership etc. The F aspect of gratification lies in social, and relational status--clubs, exclusive neighborhoods, family trees, etc, through membership, rank, position etc.



HOMOLOGIES: THE POSITIVE DYNAMICS

FIGURE 8.

The N aspect of gratification is through contribution, the number of scientific papers published, the number of exhibitions held, performances given, souls saved. The theme of counting and number--cardinal and ordinal, body counts and primacies--is central to gratification.

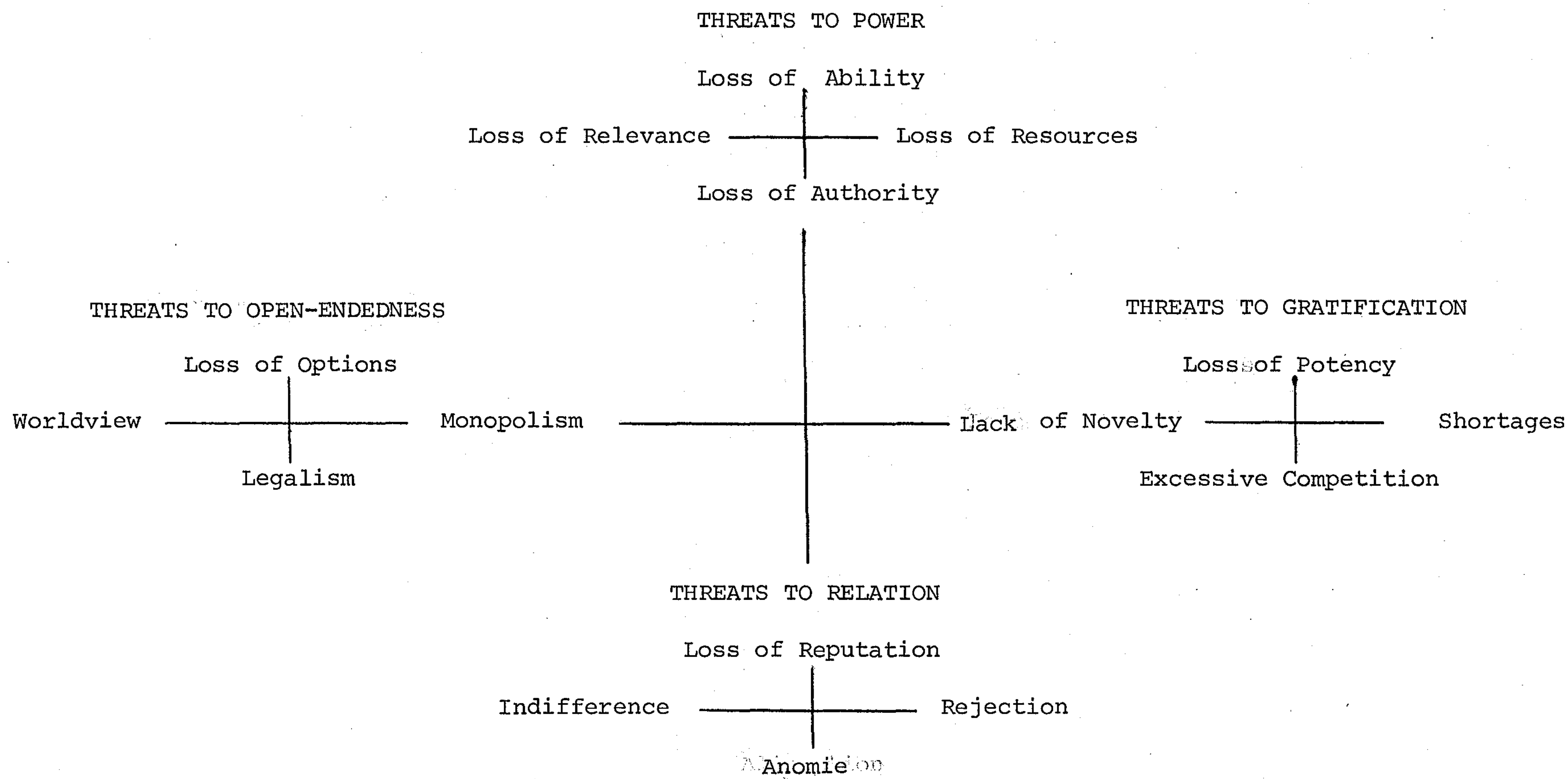
The relational dynamic may be illustrated through the various aspects of love, the strongest relational adhesive known. The S aspect, sensual and physical love, is symbolized by Eros. The F aspect, love of humankind and love of learning and cultural heritage, is symbolized by Philos. The T aspect, love of country (or the organization) by Patriotism and the N aspect, love of God or whatever name one prefers for the "Other" by Agape. The central theme of this crosslet is unity, joining, bringing together.

The visions of "N" may take the T form of imagining some political system that would combine liberty, justice, peace and effectiveness or take the S form of new cities of breathtaking beauty replete with dream machines to take care of all economic matters. They may take an F form which visualizes new people and new societies--Ubermensch and Utopia. Or they may seek a new worldview that removes the scales from our eyes and allows us to behold the world and humankind truer form. The theme that courses this crosslet is the construction of bridges to greater possibilities--what we might become.

The golden ages and the golden moments of history have been those in which the Graal of positive dynamics led humanity to higher plateaus. But of the two meta-dynamics--aspiration and fear--fear has proven the stronger. Our societies are based on the institutions of fear--the military, the police and insurance. In history's Skinner Box the stick has been more prevalent than the carrot. For many, and perhaps for most, threats or actual blows from the stick provide the only dynamic. Whereas the positive dynamics contain their energy within their images, the negative dynamics energize not through the image itself, but through the reaction to it. The perceived image triggers a fear that in turn energizes the response. Figure 9. displays the homologies of the negative forms of the dynamics in their perception phase.

Those who possess or compete for power perceive threats to their position in the form of loss of their ability to perform (T), loss of the material resources necessary to maintain their position (S), loss of their authority (F) and loss of relevance (N). Authority is the mystique of power. It is one of the adhesives that makes the social order work. It is rooted in the divinity of the emperor, in the divine right of kings, in the awesomeness of high office. When authority crumbles through ineptitude, corruption or loss of respect, the positive dynamic of power fast disappears, only habit, fear of or actual application of force permit the exercise of power to continue. But history knows no power that long survived loss of authority. Loss of relevance is even more deadly to power than loss of authority. It comes from obsolescence. There is no challenge to the power, no rebellion, no revolution; the parade just passes by. Support, resources and authority move elsewhere. Though oftimes figureheads remain, many are the hierophants, chieftans, committees and vice presidents who have experienced such displacement of power. The theme of this threat is <u>loss</u>.

The threats to gratification are perceived in shortages and delays in the supply of goods and services (S), in the loss of potency or the ability to experience gratification (T), in an excessive competition that demands more energy than it generates (F), and in the lack of novelty to stimulate, titillate or inspire continued gratification (N). Akin to the effects of sensory deprivation, when there is no novelty the Weber-Fechner Law in time reduces all gratification to boredom. The essence of this threat is deprivation.



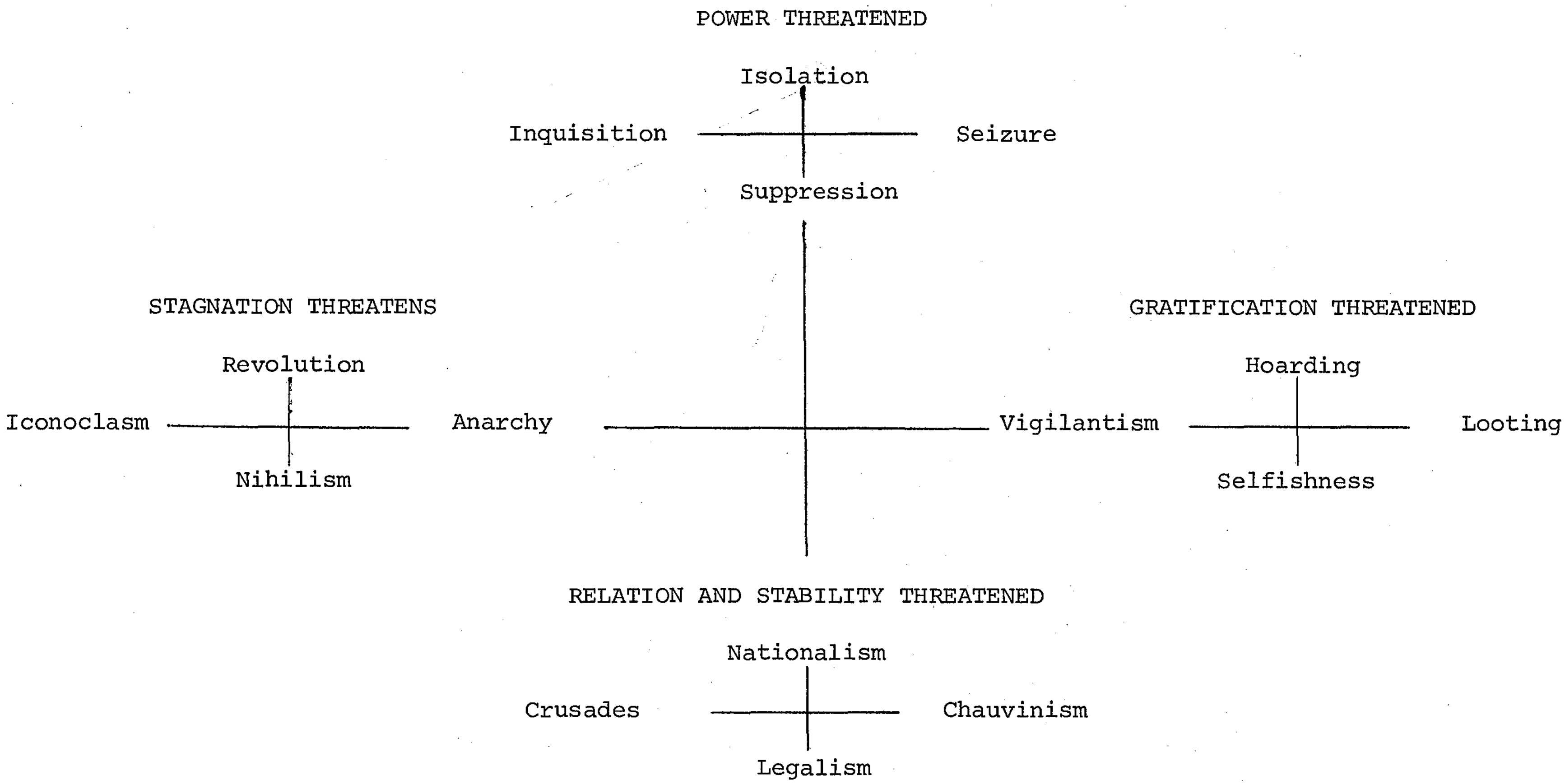
HOMOLOGIES: THE NEGATIVE DYNAMICS
PERCEPTION OF THREATS

FIGURE 9.

The T-like threats to relation lie in the erosion of admiration and respect and in the loss of reputations which, like authority, is one of the mystiques on which society is built. The S-like threats reside in the fragmentation of social groups, in the rejection of those who are different, of those who are not of immediate use or whose use is not perceived. The F-like threats are in being cut off from heritage, from cultural traditions and from the past, from drifting without cultural moorings and direction --from anomie. The N-like threats arise in the relational stagnation of cynicism and indifference to others, to what is known, and even to self. Alienation is the essence of the threat to relation.

The threats to open-endedness, modifiability, opportunity and progress lie in the freezing up of options through political or administrative myopia and fears (T). They lie in the disappearance through monopolism of the market place with its free flow of competitive goods, ideas and services (S). They arise whenever an excessive legalism invades every aspect of life, restricting initiative of all sorts (F). And lastly, threats to open-endedness reside in the unquestioned assumptions that are implicit and explicit in cosmologies and worldviews; in the restrictions contained in the unchallenged images of man and the world (N). The essence of this threat is stagnation.

A threat having been perceived, the second phase of the negative dynamic is the arousal of the energizing fear which puts into motion typical sets of responses. These responses frequently create a positive feedback situation that aggravates the threat and which in turn amplifies the fear and the responses. The response phase of the negative dynamics is shown in Figure 10.



HOMOLOGIES: THE NEGATIVE DYNAMICS
RESPONSES TO THREATS

FIGURE 10.

When power is threatened, typical negative responses are the erection of protective walls around the decision process, the isolation of decision makers from any inputs that carry the aroma of the source of threat.(T); the cutting off of funds and the confiscation of any resources that may be taken from real or imagined sources of threat (S); the supression of opposition and dissent through legal and illegal hharassment and the subversion and abolition of the legal processes that are supportive of opposition and dissent (F); the conducting of witch-hunts and inquisitions, spying, wire tapping and censorship (N).

When gratification is threatened, fear builds up an overiding self-centeredness and extreme indifference to the fate of others. All concern focuses on "Number One". In this state of relational collapse and panic, hoarding, looting and vigilantism ensue. In this sector there is little difference between the response to a threat of deprivation and a threat to life itself.

The threat of the collapse of relation and breakdown of social stability, stimulates the negative response of projecting an enemy. When the positive social adhesives fail, recourse is had to the 'bad guys' and'good guys' model--them and us, those out there and we in here. In practice this negative dynamic may take the form of extreme nationalism, flag waving, super-patriotism, even war, projecting the enemy on other states (T). Or it may take the form of chauvinism, projecting the enemy onto other races or minorities (S). It may take the form of crusades against those subscribing to other ideologies, religions, political and economic philosophies (N). The power of this particular negative dynamic has permitted peoples with obsolete and decadent positive relational adhesives long to continue to survive and maintain their social groupings.

Othertimes when the positive adhesives fail and social stability is threatened, law and order is eulogized and an excessive legalism in unleashed (F). But as with authority, when the positive relational glue, the social covenant to obey the laws is gone, the law continues to survive only through threat and force, and these can never sustain it alone.

When stagnation threatens, and the positive images have no soil in which to take root, the "N" sector responds with a flowering of compulsive negative images that interact with the T and F responses in a deviation amplifying manner. The threats to power and stability result in a repression that the N's perceive as stagnation. Their responses to get the social order off dead center through revolution (T), anarchy (S), nihilism (F) and iconoclasm (N) threaten power and stability further. This results in still more repression and'law and order'. Here the negative dynamics bring the functions into destructive confrontation. The four functions, all of which are needed for the successful operation of the system, when excessive imbalances build up, no longer operate for system health and survival but for its destruction. What the psycho-therapist has learned about functional balance, the politician and political scientist could well heed.

Conclusions

Generalization of the four essential functional operations that are present in elemental control systems leads to a powerful integrative schema that allows systems on all levels to be compared. The "TSFN" schema is able to bring into homologous relation a wide variety of independently developed system typologies and models. The four functions appear in one form or another in personality and temperament typologies, modes of cognition and validation, models of societal structure and political procedure, schools of psychotherapy and futures research. The validity of the schema derives from its independent abstraction from several sets of diverse data and from its ability easily to subsume additional taxonomies and typologies. At this point one suspects that the four-fold "TSFN" schema stems directly from some deep principle that governs the structure and behavior of all organisms and organizations. Whether this proves to be true or not, the schema has great heuristic value for the analysis of relations in normative systems.

The necessity of each of the four functions, T,S,F and N to the successful operation of every control system becomes in normative systems the necessity of functional balance between T,S,F and N. This necessity is widely recognized in psychotherapy [17] but not in political and economic theories. It is, therefore, in the analysis of the malfunctions in organizations, communities and societies that the TSFN schema promises to have its most fruitful applications.

The schema is of importance in conflict resolution. The homologies between psychological types and societal control sectors show why the administration, defense, academic and research sectors within a society encounter the same communication difficulties that arise from paradigmatic differences. [18] An understanding of the differences in the types, the functional emphases and the necessity of balance could go a long way toward establishing effective communication and resolving value differences.

Equally of importance is the application of the schema to the functional emphases within our society and the analysis of how imbalance leads to breakdowns. Although the Founding Fathers were never pleased with the mechanism of majority rule for ultimate decision making, they adopted it as likely to be in the long run the most protective of individual rights. It was not recognized, however, that in our culture where the vast majority is of sensation type, that majority rule would inevitably result in the dominance of S-type values, S-type dynamics and an S-type economic system with S control of the purse strings. This imbalance reflects itself in such items as a greatly over-expanded military establishment, emphasis on consumerism and nearly exclusive focus on short range programs. Everything must be justified in terms of an S-type accounting system. Even research must be shown to be cost-effective in terms of the gratification dynamic. T, F and N concepts of wealth, such as knowledge, size of option space, and problem solving capability go unrecognized or are discounted. Better understanding of the functions and the importance of each should serve to give our social and economic orders the functional balance they desperately need.

Finally, the "TSFN" schema may provide us with a theoretic base on which new axiological, political and economic paradigms can be constructed to replace those that are now collapsing all about us.

Notes and References

1. "Amidst all the variations of system and orders, certain general types and characteristic relations can be traced." This quotation from Josiah Royce is a truism. The tracing of commonalities among sets of different things is often possible, but it is also often misleading. Tracing is not enough. For such characteristic relations to be valid they must be formulated on an abstract level from a few specifics and shown to apply in every specific. Commonalities that cannot be abstracted are but curiosities and coincidences, and abstractions that cannot be applied beyond the cases from which they were formulated are but shorthand notations.

2. The four basic system functions have to do with individual systems. They govern operations taking place entirely within the life span of the system, operations such as metabolism, growth, learning and adapting. Additional functions are involved in the modifications that occur in a sequence of systems, such as a hereditary sequence. Whether these evolutionary or hardware modification functions are homologous to or reducible to the four basic systems functions is an open question.

3. Calvin S. Hall, Gardner Lindzey, Theories of Personality (New York, John Wilsy and Sons Inc. 1970) Chapter 9.

4. Whether the source of innovation and novelty (new images) must have a component outside the system or whether true novelty can originate through a complex sequence of internal operations is another reductionist question. The question of reductionism in the present instance is: Can the modification function be generated through sequential iterations of the other three functions or does it contain irreducible operations of its own? The system sensing ("S"), deciding ("T") and normalizing ("F") functions can operate on an elemental

(note 4. continued) level, as in the simple thermostat, without either a time signal or a memory. Both of these features are essential to the modification ("N") function in the adaptive thermostat. Since it is difficult to see how a time signal or a memory can be generated from elemental S, T and F operations, reductionism does not seem to have the answer in this case. This matter is of central importance to General Systems Theory. There are many who seek to define a GST in such a way as to be derivable from the properties of simple control systems, i.e. from S,T and F. The minimum base for a GST may be S,T,F and N. For a good discussion on the external vs. internal generation of novelty see M. Bunge, Causality, Meridian Books, 1959, Chapter 8.

5. Philosophical thinking seems to reflect the psychological types: Positivism, a "T" school; phenomenology, an "S" school; and the modes of knowing in ancient cultures "F" schools (see H. Frankfort, Before Philosophy) With regard to validation, sensation types prefer Churchman's Lockean approach, thinking types Churchman's Leibnizian approach. Feeling and intuitive types belong in Churchman's Cartesian category in that both hold that "God will not allow us to be deceived". (See C. West Churchman, The Design of Inquiring Systems).

6. Osmond, Yaker, Cheek (Eds.) The Future of Time (Doubleday, 1971) Mann, Siegler and Osmond,"Four Types of Personalities and Four Ways of Perceiving Time", Psychology Today December 1972. Also of relevance here are H. A. Linstone's four basic groups: Discounters (sensation types), Extrapolators (thinking types), Goal Setters (feeling types) and Cyberneticists (who are gestaltists and are intuitive-thinking types). H. A. Linstone "The Paradigms of Futurists" this volume. Rosalie Cohen's excellent work on types also comes up with the same four identifiable categories: Analytic (thinking), Flexible (intuitive), Concrete (sensation) and Relational (feeling). R. Cohen "Four Paradigms:Their Consequences" this volume.

7. The possible may also take refuge in the past. Atlantis, pre-historic astronauts, secret powers of the Great Pyramid etc. all utilize the mists that enshroud the past to give images a place in the physical world. Winston Churchill once said, "Even if the Arthurian legends are not true, they ought to be."

8. It is also of interest that the bias of each psychological type is reflected in one of the principal schools of psychotherapy. Freud's pleasure principle which views the gratification of biological needs as the primary motivation is a sensation type bias. Adler's emphasis on the power principle reflects the thinking type's concern with control. Sullivan and Horney's need to belong supplies the basic principle for a psychotherapy with the feeling type bias. The existential schools of psychoanalysis, such as those of May, Rogers and Frankel emphasize the intuitive type's concern to meaning and authenticity. Jung subsumes all four.

9. While social systems may well reflect the psychological structure of their constituent human elements, a deeper question is involved. This is the question of which is primary--the psychological types or the system functions. Are the types the manifestation of the four basic functions on a psychological level or do we impose the four functions upon all systems because of the nature of our psychological structure. After all it is we who design the thermostats. But regardless of which is primary, the function-types provide a schema of great integrative usefulness.

10. "The Hunters", John Marshall's film describing the pursuit of a giraffe by a hunting party of South African Bushmen, dramatizes the four types and their functions within an organic group of individuals. The 'clown' of the film is the clown as social critic, the Chaplinesque clown with his mirror ever ready to reflect the foibles and absurdities in every situation.

11. The four centripetal forces historically leading to the formation of cities have been: security, facility of administration, trade and ritual. These activities are frequently reflected in city plans and architecture. cf. A. Wilson, "The Future of the City", AIAA Lecture Series, Volume 12, p17-21, 1973.

12. Medicine Wheel Myths of the Plains Indians disclose an intimate familiarity with the psychological types and functions. Unlike the Jungian arrangement, the Medicine Wheel places "T" opposite to "S" and "F" opposite to "N". H. Storm, Seven Arrows, N.Y. Ballantine Books, 1972. See, for example, p 68 ff.

13. An excellent study of this phenomenon is given by William Irwin Thompson in his book, At the Edge of History, N.Y. Harper and Row, 1971. Thompson develops a convincing four-fold homologous hierarchy modelled in part on Marshall's film, "The Hunters" and in part on the types in W.B. Yeats' "A Vision". Thompson's model connects to Jung through Ego, Self, Anima and Shadow, rather than through the homologies with Jung's psychological types as developed here. I want to here acknowledge my indebtedness to Thompson and his brilliant integrative insights, which were the inspiration for the present model. I hope that both models will serve to stimulate further development and perfection of this important schema.

14. Isabel B. Myers, "The Myers-Briggs Type Indicators", Princeton educational Testing Service, 1962.

15 A highly original and comprehensive model of political processes has been developed by Herbert J.Spiro, "Comparative Politics: A Comprehensive Approach", The American Political Science Review, vol. 56, no. 3, 1962. Spiro finds that political procedures and issues naturally divide into four phases and categories. Four political goals emerge that are readily identifiable with the four functional sectors of the present paper: stability (F), flexibility (N), power (T) and effectiveness (S). Spiro's four political styles are homologous to the functional sectors: Pragmatism (S), Ideologism (T), Legalism (F) and Violence (N). I wish to thank Mr. Spiro for alerting me to his early contributions to this schema.

16. Matthew Melko, "Problem Creation: The Central Dynamic of the Civilizational System", Paper presented before the Society of General Systems Research, Geneseo, N. Y. Sep't. 29, 1972.

17. "But any person who perceives from only one of the Four Great Directions [of the Medicine Wheel] will remain a partial man." Seven Arrows, loc. cit. The recognition of the importance of balance is a recent discovery of the scientific culture of the West. It has long been known to others.

18. Magoroh Maruyama, "Paradigmatology and its Application to Cross-Disciplinary, Cross-Professional and Cross-Cultural Communication", "Three Paradigms among Planners: Hierarchists, Individualists and Mutualists" This volume.

METACRESCENCE

ORIGINS OF HIERARCHICAL LEVELS: AN "EMERGENT" EVOLUTIONARY PROCESS BASED ON SYSTEMS CONCEPTS

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ABSTRACT

This paper describes a dynamic process that results in the origins of hierarchical levels in natural systems. It introduces a generalized version of dualistic philosophy (eg. Yin/Yang) as a new principal systems concept named "counterparity". It also introduces "concrescence" and "potential spaces" as principal systems concepts. The 5-step process involves these concepts and general probability to form aggregates that feed hierarchical evolution, which is pictured as a self-organizing, self-referencing cyclical process involving successive events of "emergence" from one level to another, accompanied by developmental proliferation of variants within levels. A brief history of the concept of counterparity, criteria for its more rigorous definition and use, as well as a table of specific examples is provided.

INTRODUCTION

Hierarchical structures are found in all types of known systems (Wilson, 1969). Unfortunately, the word is popular and consequently used loosely. Lists of unambiguous criteria to distinguish between what are and what are not hierarchies or to distinguish between types are still in development (Wilson, 1976). But hard empirical evidence for definite levels in astronomical systems (de Vancouleurs, 1970; Page, 1969; Wilson, 1969; Kauffman, 1969), and to a lesser extent in biological systems (Pattee, 1973; Troncale, 1976; Miller, 1977) are now appearing and are becoming accepted even by practitioners of these specialty fields. These empirical studies purport to show that the naturally occurring entities of these systems are found in "clusters" when compared by quantitative measurement of certain important parameters typical of the entities. Graphs of the appropriate parameters for all entities in one of the systems (eg. all entities in astronomical systems) do not show random or homogeneous distribution, but rather associate into definite groupings separated by large "gaps" wherein no naturally occurring entities are found. The groupings or clusters of entities are called "levels" in a hierarchy. Examples of such graphs are shown in Figure One. The levels often bear subunit-to-unit relationships to each other, and thus the word hierarchy is applied since no other word in our lexicon approaches the phenomenon.

The importance of the concept of hierarchies can be seen in two developments. First, there is a

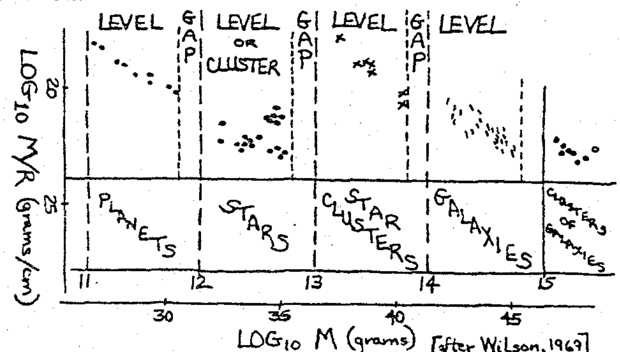


FIG. ONE: Actual observed masses plotted vs. potentials for cosmic bodies show the levels (clusters) & gaps feature of hierarchies (empirically proved).

a growing literature on hierarchies (Wilson, 1969; Wilson, 1976; Pattee, 1973; Mesarovic, 1970; Weiss, 1971; Simon, 1962; de Vancouleurs, 1970; Page, 1969; Wilson, 1969; Kauffman, 1969; Troncale, 1972; Troncale, 1976; Whyte, 1969; Miller, 1977; Koestler, 1969). Odum (1977) points out the utility of the concept to understanding ecological and environmental problems, which indicates further the social significance of studying hierarchies in theory. Both of these developments suggest that a more rigorous understanding of hierarchies would be useful. Several suggestions as to the efficiency of hierarchical organization can be found in the literature (eg. Simon, 1962; Odum, 1977). But the most important question has not been asked.......What causes hierarchies? How are hierarchical levels continuously formed over cosmological time, one from the other, by the natural forces inherent in the entities themselves?

The current concept of hierarchies (devoid of the process that forms them) is equivalent to the concept of distinct, but static species before the introduction of Darwinian and non-Darwinian evolutionary processes. Hierarchical organization should become more understood and their taxa more realistic with the elucidation of the process behind their formation. As suggested graphically in Figure Two, mans limited abilities at perception inhibits his ability to "see" the less stable and transient entities and their dynamics which connect the various levels in hierarchies (shown as *). Man can "see" the entities within the levels (shown as #) because of their greater structural stability and lifespans. This problem of perception of process has occurred over and over again in the history of science - static taxonomy precedes concepts of

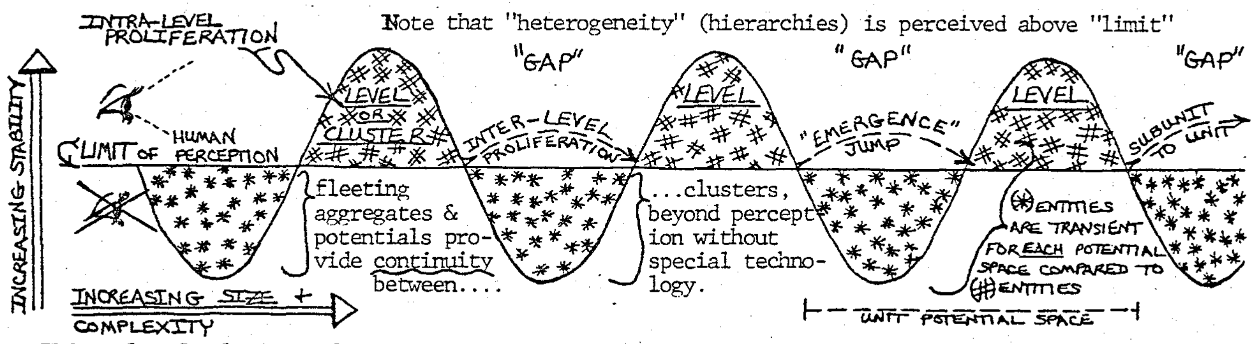


FIG. TWO: Role of Relative Lifespans of Entities in Human Perception of Natural Hierarchical Levels.

evolution, identification of cell structures precedes understanding of organellar functions, anatomy precedes an understanding of embryology, etc. Overall, recognition of structure precedes recognition of natural evolutionary mechanisms. This paper tries to "image" a process for evolution of hierarchical structure.

There are ways to look at the importance of explaining a process other than stating its importance to the scientific understanding of a phenomenon. The ancient myths of man, collected over eons by the wise and sensitive, are as important as science. If we look at such myths we find three major themes or processes which are constantly found across many cultures. These comprise the stories of "creation", "growth", and "change" or "evolution." None of these myths adequately explains the concept of "emergence" which we suggest is the fourth great universal process, and the one most tied to the concept of hierarchy. It is not surprizing that ancient civilizations have no such myth since our modern recognition of hierarchies requires a perspective, an accumulation of data, and types of calculation only recently available. Nevertheless, the seeds of an emergent evolutionary process to explain hierarchies does exist in ancient philosophy. This paper also attempts to unite some of these ancient ideas with modern scientific ideas to provide a measurable, testable, mechanism for origins of hierarchical levels. The ancient idea we turn to first is that of dualities.

COUNTERPARITY AS A PRINCIPAL SYSTEMS CONCEPT

Principal systems concepts (Troncale, 1977) are a select grouping of general systems ideas which are thought to be found in virtually all natural systems. They are fully transdisciplinary. In the 1977 paper, nine criteria are suggested for distinguishing principal systems concepts from other general systems terminology for the purpose of simplifying establishment of linkages between them. A description of the entire knowable set of these P.S.C.'s with their interconnections (linkage propositions), and their "potential spaces" would describe what is true of most "systems" on a theoretical level. We are suggesting here the inclusion of an old, non-scientific idea, significantly updated and extended by scientific studies, as a new principal systems concept called "counterparity." Counterparities, we are suggesting, are a special class of dualities which occur naturally in most systems and play a central role in the emergent evolution of new hierarchical levels.

BRIEF HISTORY OF THE CONCEPT OF DUALITY

The concept of duality is almost as old as recorded history. The earliest and perhaps most generally developed recognition of duality is the Yin/Yang concept which dates back to times earlier than 300 B.C. (more than 2500 Y.B.P.) (see Watts, 1975 and many other translations of the I Ching). Contained in the Book of Changes, the yin (often described as the female principle) and the yang (male principle) refer in general to any complementary pairs of opposites which can be found in nature. These male/female principles are rather anthropomorphically projected on natural systems, so that the idea of dual pairing is extended far beyond the sexual imagery to many of the things and forces that man was aware of in those times. In terms of Eastern thinking the opposite forces never win completely over one another, rather they continue to exist in dynamic equilibrium. The opposite polarities, although named individually are seen as parts of one indivisible unity or wholeness (Tao). The Eastern wisemen felt the Yin/Yang concept as fundamental to all natural and human activities. Later the Yin principle became more abstracted to the passive or static state and it always precedes the active or dynamic principle, the Yang.

Eastern philosophy was not alone in its recognition of dualities. Early Western philosophers (Russell, 1945) such as Heraclitus (ca. 500 B.C.), as well as more contemporary men such as Hegel (1770-1831) recognized and gave prominant importance to dualities of an opposing nature in their philosophies. Heraclitus stated "Men do not know how what is at variance agrees with itself. It is an attunement of opposite tensions like that of the bow and the lyre. ...Couples are things whole and things not whole, what is drawn together and what is drawn asunder, the harmonies and the discordant." He felt the unity was created out of the strife between the opposites. Hegel's famous dialectic method.....counterposing a "thesis" with an "antithesis" to achieve a "synthesis" is clearly a duality in logic similar to Eastern dualities. Generally, the dialectic results in chains of pairings and syntheses - each contributing to the next. These may be seen as hierarchies of logic with built-in self-referencing as is also true of natural hierarchies. Still, Hegel would emphasize the whole over the opposite parts.

American Indians, apparently independently, developed similar concepts of duality. Blackburn (1975) shows that the Chumash Indians of So. Calif. used the concepts of "Negative-Positive Integration" and "A Dynamic Equilibrium of Oppositions" in their oral narratives which were used to pass on their cultural traditions and worldview. Of course these abstract ideas were couched in terms of stories about coyotes etc. for better communication. There are many examples such as this for independent recognition by cultures of the primary importance of dualities. This is, in itself, interesting.

Recently, Levins (1977) pointed out that duality concepts are common to myths of several ancient cultures. These early cultural allegories show a consistent pattern of behavioral duality between images representing opposing forces of cooperation and antagonism (eg. in father/son pairings) which he interprets as the build-up of forces for change.

A.J. Toynbee (1972) notes that philosophers as separate in time as Empedocles and Herbert Spencer use the "complementary opposites" concept in their philosophy in ways similar to that presented here, that is, as a generative force. Spencer even alludes to what we now call hierarchies when he states that matter progresses from "an indefinite, incoherent homogeneity to a definite, coherent heterogeneity" by coupled series of "integrations" and "differentiations "(Spencer, First Principles, 4th edition).

Finally, Niels Bohr, the renowned physicist, introduced the concept of complementarity to physics to resolve the wave/particle paradox by declaring that neither was correct alone, but were merely dual pictures of the same unit phenomenon. He suggested the concept be applied beyond physics and even had the Yin/Yang symbols on his coat of arms.

It is clear from the above examples that duality is an old, reaccuring theme associated with dynamic change. Still the change is not described in terms of process mechanisms, nor is it clearly "emergent" hierarchical evolution. To achieve these features we must marry the concept to other concepts.

DEFINITION OF COUNTERPARITY

We suggest the new term counterparity to name all of the various specific, non-traditional types of duality which may contribute to hierarchical evolution, and secondly to supercede its established, but separate and distinct meanings, in myths, philosophy, and science. This renaming of a fertile concept has a very important significance -- it is our agreement to pursue a use of an idea that is one and the same time more generalized than its previous uses and yet more subject to a more rigorous and controlled usage to allow better specific application than formerly possible. The Yin/Yang terminology is sufficiently generalized, but is too loosely used and defined to gain acceptance by scientists today (our target audience).

Counterparity; parsing the word yields its meaning. The word "parity" may be defined as equality, equivalence, or similarity as in amounts, status, or character. The word "counter" implies the existence or application of a force acting against or opposing some simultaneously coexistent force. Together in the word counterparity we refer to populations of two paired entities occuring in the same system and which exhibit mutually opposed characters, yet which characteristically combine into units. Together the words imply a much more dynamic condition than simply the word duality. Counterparity also denotes the necessary coexistence of the two paired entities in the same ranges of magnitude (i.e. on the same hierarchical level) better than the word complementarity. However, the word is not as good as complementarity in suggesting the role of opposites in forming wholeness. However, we feel that the formation of units is better ascribed to the process generated by the existence of counterparity than to the counterparities themselves. These two interlocked but seperate events are confused in old discussions of complementarity and duality.

Counterparity is actually the modern empirical version of the ancient concept of dualism. This is by no means the first such unification attempt (see Bohr; and Capra, 1975). Simple examples of counterparity abound in science as well as the humanities. On the physico-chemical level, the requirement for pairs of electrons of opposite and complementary spins to complete orbitals in shells of atoms may be a counterparity....Note also that the (+) and (-) charges that exist on both the subatomic and atomic levels induce bonding and neutral pairings. It is important to note in these examples that the entire entity is not required to fully participate in the bonding event as the active agent, or synonymously, the counterparity; it is sufficient that counterparities only at the periphery of the entity act as the active agent. For example, valences in atoms are in the outer shell, not in the interior. This observation is especially true of counterparities involved in emergent evolution as we shall see.

Two states of counterparity exist; they are unsatisfied and satisfied counterparity. Unsatisfied counterparity refers to the unpaired members of a potential couplet of opposite, but equal entities, or parts of entities. These unpaired and therefore unsatisfied counterparities possess residual energies for combination. The lowest energy state for unpaired members is to be coupled with their "complement" at which time they no longer exist as a "potential." The fundamental dualities of matter & energy apparently create the concept of "attraction" or bonding from the lowest to the highest levels of the hierarchy. These attractions lead to an immense number of possible combinations. It is this fundamental attraction potential that provides the large population of variants which are the basic raw material for systems-level, hierarchical evolution. A specific example of unsatisfied counterparity is an atom of hydrogen ($H^{\bullet}$) which could accept another electron of opposite spin in its outer shell, as it does when combined into water, ($H{:}\ddot{O}{:}H$). But note that hydrogen and its potentiality combines with many other atoms producing a wide range of variants.

This is just one example. Even though the attractive forces are different in their specifics on each level of the hierarchy, their general relations are invariant across all levels of the hierarchy. This allows us to recognize and name unsatisfied counterparities.

Satisfied counterparity refers to opposite, but equal entities coupled together in a local space/time configuration such that they have no remaining potential. Completed pairs of electrons in the outer shells of elements in compounds are examples of satisfied counterparity (the subunit atoms, that is, not the compounds). Their opposite nature (consisting, in part, of counterpoised spins) causes them to bind together as if each has what the other needs for wholeness. That is why they exist in pairs when complete and neutral. Being coupled means being satisfied, which also means "not conducive to further combination." The energy used in the combining act appears to come, in part, from the lack of wholeness of each counterparitor when alone. Our central problem in this paper will be to explain how the appropriate "lack of wholeness" is built a priori into each counterparitor before its participation in complementary binding. How does the counterparitor come into being so nicely formed that it appears to have an a priori knowledge of the whole it is yet to form? In any case, when merged, the energy for combination is tied up in the act of structuring, and energy becomes a cluster of matter.

Two generic types of counterparities exist in addition to the two states described above. Some counterparities contribute only to growth in numbers of entities within a level. For example, male/female couplings in most species create the numbers of individuals in the population of the species, but they do not (by themselves) cause new hierarchical levels to emerge. These "growth-in-numbers" counterparities we suggest calling "endocrescent" counterparities because they cause proliferation of entities within an hierarchical level ("endo", L.,= inside of; "cresco", L.,= to grow). A second type we would like to call "transcrescent" counterparity because it causes new, emergent levels of hierarchies to appear, or causes proliferation across the gaps between levels ("trans", L.= across; "cresco", L.,= to grow). An example of transcrescent counterparity would be the combination of atoms to produce the next hierarchical level (a gap away) which we call macromolecules.

The mechanism behind the emergence of new hierarchical levels is the subject of the remainder of the paper. This requires a more exacting definition of counterparity and concrete examples.

CRITERIA DEFINING COUNTERPARITY

Some have pointed out that one of the major problems in general systems theory is the ambiguity allowed in terms by investigators (Troncale, 1972; Oliva & Capdevielle, 1977). The following ten criteria are suggested to distinguish counterparity from other general terms and encourage its unambiguous use;

(1) Dual Morphology - All entities, counterparities included, have general form. In both Eastern and Western formulations the two entities involved in the duality always have a substantially similar form (by "form" here we mean idealized and abstract structure, process, or structurprocess). Counterparities have more in common than different as regards "form."..however, from that substantial sameness the population diverge into two variants which are equally represented in numbers. An example would be the intersex status of the fetus before sufficient hormones are activated for female/male commitment in the development of the human.

(2) Mirror-Image Opposites - for some as yet ill-understood reasons the parities formed appear frequently as simple permutations of subparts of a whole that follow distinctly bimodal distributions. The two variants appear to be the farthest extremes of the potential variation between the parts of the whole. As such the counterparities share in the stability derived from the parent whole, but appear to possess antithetical potentials and directional forces. The appearance of directional force may result from the tendancy of the counterparity to seek its opposite to return to the primal state of wholeness.

(3) Complementary Binding - It is possible that the vectorial force and potential of each counterparity taken alone derives from their origins as permutations of an original unity or wholeness to which they forever seek to return. As such their natural state together is presumed to be their lowest, or at least primeveal energy state. Thus, the counterparities tend to bind together in complexes even though they are opposites. The binding is amenable because of their essential and bulk similarities due to their common source. But since all bifurcations of the original whole are not exactly the same, many variant bindings are possible.

(4) Similar Orders of Magnitude - Paired entities possess the same relative sizes, volumes, densities, and masses. Again, this is partly due to their generation within a level by bifurcation or divergence from a similar primal entity. Any suggested counterparity without this similarity may be confusions between two opposites on two different hierarchical levels.

(5) Similar Stable Life Times - The wholeness from which the counterparities diverge has its own characteristic life span of stability before decay. Since the divergent counterparities are still primarily composed of the wholeness with a few peripheral exchanges they also retain the parents stable lifetime.

(6) Similar Binding Energies and Distances - Since the counterparities arise from the same "potential space" (discussed later) they are restricted to binding with each other within that space with the spaces' characteristic types of forces operating over limited distances.

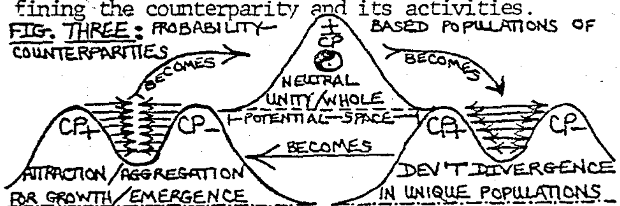
(7) Equal - Neither one nor the other counterparity is ever able to overpower the other in the long term, although in the short term one may temporarily increase in numbers. This equality maintains the dynamic tension between them and provides the force for continued and self-organizing generation of the unities and dualities. They "dance" around an equilibrium position in the potential space forever. The expansion of one automatically becomes the force for the complementary, responsive expanse of the

partner. This self-referencing feature maintains their equality without creating stagnation.

(8) Pairs On Same Level of Hierarchy - Due to the similarities mentioned in (4), (5), and (6) properly defined counterparities will have both partners of the duality within the same level of the natural metahierarchy.....they will not stand in counterparity across levels of the metahierarchy (see Troncale, 1972 for definition of metahierarchy).

(9) When Alone A Counterparitor Creates A Potential In A Potential Space - For many millennia man has recognized static things and named them. Static would be defined here as anything having a sufficiently long stability (lifetime) to be noticed by man or his recent technology. To this dimension of thingness Gerard suggests adding the concept of "entitation". To really "know" a thing you must not only "know" its physical representation, you must also "know" all of its connections with other things (see Troncale, 1977 for "linkage propositions" and discussion of this added dimension of knowing). Another dimension is suggested by the mechanism described for origins of dualities. This dimension concerns "knowing" a thing by knowing the fullness of its "potential space", that is, all of its possible changes and connections. This "potential space" is presumed to be definable (eventually) but not in the Western sense of reductionism. It may be defined mathematically as a totality without full knowledge of all the particulars analogous to treatments of probability. In any case, full knowledge of a thing requires knowledge of its physicalness, its entitation, and its potential space. An unsatisfied counterparitor has many potential spaces of combination with other counterparitors as they all seek their original energy state. So an unsatisfied counterparity cannot rest and is in constant "potentialness" or seeking until it is satisfied.

(10) When Bound To Its Partner, The Unit Complex Is Neutral - When the two pairs of the counterparity bind together they are reestablishing a variant on the wholeness from which they were derived. They are satisfied. They have replaced their potential for their rest state. Below we represent these states including the divergence and concrescence as normal distributions to emphasize in a crude diagram the importance of probability in defining potential space and the importance of potential space in defining the counterparity and its activities.



EXAMPLES OF COUNTERPARITIES

Table One shows specific suggestions of possible counterparities in real systems. They are grouped roughly in the conventional fields for convenience. Actually this grouping is devoid of hierarchical clustering. For information as to the hierarchical levels suggested for these fields see Troncale (1972) and the suggestion of a continuously forming set of levels called the metahierarchy. Future studies will need to apply the ten criteria of the last section to each of these suggested counterparities to eliminate all but those that meet the full set of criteria. Further study would classify counterparities into endocrescent and transcrescent types, examine the meaning of satisfied and unsatisfied states for each, and then collect empirical data relevant to these states for their better definition in each case. Possibly much of the data already collected by the reductionist methodologies of the specialties and disciplines which represent many of the hierarchical levels may be used for these holistic purposes. Each of the surviving examples of counterparity can then be analyzed in detail as specific representatives of the "emergent" evolutionary process at work in origins of hierarchical levels much as Darwin did for many biological examples of speciation in the Origin of Species. The data will be used to test the prediction of a constant range of concrescence ratios across all hierarchical levels leading to emergence.

The specific nature of the binding between counterparities changes drastically over the various conventional systems described in Table One. Focusing on these differences would undoubtedly inhibit recognition of the general similarity of form and function which is true of the counterparities across all of the specific systems surveyed. This is the central problem of perception which separates many reductionists from holists. Some individuals are more comfortable with higher levels of abstraction than others. The cases shown in Table One are certainly all different as regards specifics and their similarities are not noticeable until one permits their abstraction to high levels of generality of form and behavior.

It is also interesting to note that even in this brief survey of possible counterparities one finds they are represented in all complex natural systems cited. This places the concept on a par with concepts like cycling, feedback, etc. -- i.e. it is a major general systems concept that we should begin to use to explain and predict systems structure and function. It is as fundamental to study metahypotheses like counterparity using modern science and empiricism as the early sages believed it was to study its role in philosophically-based cosmologies (metahypotheses are explained in Troncale, 1977).

SEVEN STEP PROCESS RESULTING IN THE ORIGIN OF HIERARCHICAL LEVELS

The headings of the next seven sections should be read as a step-by-step schema. Together their action results in the emergent evolutionary process which for convenience may be called "metacrescence" (or "the process of growing together and beyond). The process is self-organizing in that it arises solely from the nature of the entities on each level and their normal interactions. Despite the tremendous differences in the specific nature of entities between levels (eg. compare galaxies to cells to nations) the process remains generally the same when described in this high order of abstraction.

This model holds best for the natural systems from astronomy to physics, chemistry to biology. It is more difficult to justify on the level of social hierarchies. It also presumes that much of what are called hierarchies today are, in fact, loose uses of that term or not hierarchies at all. Many social and symbolic hierarchies are relatively "artificial" compared to what we might call natural hierarchies. They depend on mans conscious activity. The hierarchies so formed would disappear if man did. In fact, they often exhibit rapid turnover even within the short period of the history of man (Toynbee, 1972). As such they are incredibly short-term, transient, and unstable compared to the natural systems hierarchies discussed in Troncale (1972), and partially shown in Figure Four. These hierarchical attempts of man at present fall into the transient parts of Figure One as he struggles to give birth to the next level of the metahierarchy. In contrast, the natural hierarchical levels of Figure Four last millions and billions of years and do not depend on man (rather vice versa). It is to these levels that the seven-step process of emergent evolution applies best.

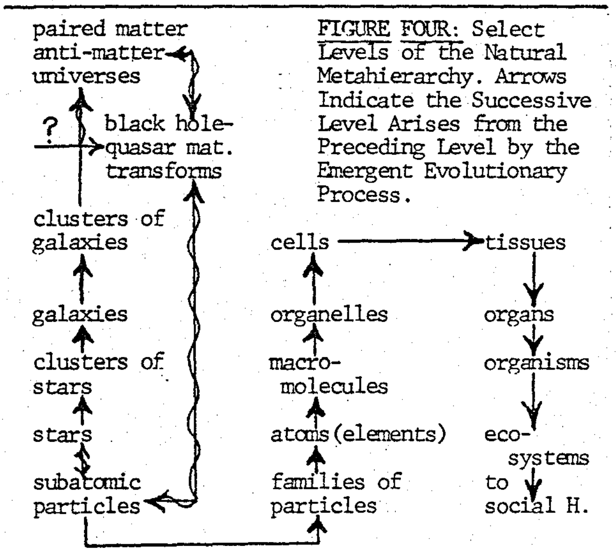


FIGURE FOUR: Select Levels of the Natural Metahierarchy. Arrows Indicate the Successive Level Arises from the Preceding Level by the Emergent Evolutionary Process.

Clearly, the above is a very restrictive and parsimonious definition of hierarchy designed for the specific purpose of simplifying the number of hierarchies to reveal the emergent evolutionary process. Many would argue with it for it excludes hierarchies so near and dear to man. The purpose of this paper is not to challenge these other meanings or discourage work on them but rather to draw attention to a specific and potentially quite profitable set of studies with a rigorously defined set of hierarchies.....which additionally have a large collection of empirical data associated with them allowing tests of hypotheses and predictions. In any case, it is our assumption that the mutual and self-referencing definitions of the natural levels and the evolutionary process are the determinants of what is and what is not a natural hierarchy.

Darwinian evolution can be seen as a special case of this seven step process. Actually Darwinian evolution is a more general process than its usual application to bio-change on earth. Neo-Darwinian sophistications would also apply to living system changes on other planets. Since Neo-Darwinism is such a powerful special case, it has many areas of correspondence with this emergent evolutionary process, which it instructs, and upon which it is based. Perhaps the mathematical and empirical developments from this theory will return the favor by answering for Darwinian evolution some of the recent objections of mathematicians to the incompleteness of the Darwinian process (Moorland and Kaplan, 1967).

STEP ONE: SPECIFIC COUNTERPARITIES FORM FROM POTENTIAL WHOLES NATURALLY, AND AT ALL LEVELS OF ORGANIZATION.

How are counterparities formed? The secret of understanding may lie in not staring so hard at the entities themselves but rather considering their potential as more important than their physicalness. The reason for the bifurcation of a potential whole entity into partner counterparities may involve considerations stemming mainly from the "context" or "environment" of a specific counterparity not from the entity itself. This may be called a self-referencing feature because the event obtains its meaning through its relation to its context and without its context it has no meaning. This self-referencing feature of counterparities (hereafter CP's) may be what leads to the self-referencing nature of the hierarchies they generate (Wilson, 1977). From the above it follows that the magnitudes of size, volume, density, energy, binding distances, life spans, etc. which denote the environment of the potential whole which bifurcates into CP's is of central importance. To understand why the bifurcation happens at all and why it takes the duality form man must shift his concept of what a wholeness is to include these holistic considerations of its potential space.

Let us consider a wholeness not as a material thing but rather a "potential space." Further, let us see the space as limited figuratively to an area of effective and relative stability by the magnitudes of parameters of its environment (mentioned above). Within this space several alternative material wholeness'es are possible. But again the context will select among these since only some will last long enough to function and therefore to "materialize" sufficiently for man to experience their lifetimes. Now among those that do "materialize" from the space, it is generally erroneously thought that they materialize in static form (and become what man calls entity or thing). But this may not be an accurate or complete description! The entities surviving the context are actually still creatures of the "potential space" as much as they are creatures of the material world. Once divorced from preoccupation with man's limited time span of perception, the real vision of things sees that they oscillate around an equilibrium position (E) within the potential space as seen in Figure Five. They oscillate in time and spatial dimensions not easily seen by man's common senses. In the Figure, (P) is the "potential space" (seen here only two dimensionally) and it contains all allowable "wholeness'es" for its context. The oscillating path (O) is a purely figurative representation of one set of instantaneous fates of one entity (other paths of potential wholeness coexist within (P)). The shaded areas are where the counterparities (CP's) arise. They branch off and experience an increase in stability at the extremes, thus becoming preserved entities only in these ranges. The populations of CP's so produced are always dual and opposite to each other in small ways as a result of the dynamic oscillation of the potential "whole" around a never-realized stillpoint (equilibrium position). This oscillation occurs in two directions as most do. Why do the CP's form in the shaded regions? Because here they experience sufficient stability to "materialize" (become perceptible to man). But why do they experience stability here? This is a very difficult question that cannot be answered in our typically Western science manner of linear causality. An explanation would require simultaneous awareness of several sets of causal conditions acting together at once (network causality, see Troncale et. al., 1976). We are told by psychologists man cannot hold more than a few items simultaneously in his memory. Therefore, use of network causality is at present a very fumbling enterprise for man. So we must express why CP's experience stability at extremes in a quasi-linear network of causality.

The field potential provides a dynamic context which works again and again to generate CP's, probabilistically. For example, one portion of the network of causes entails the rest of this paragraph. The distance of the oscillations from the stillpoint is such that the potential CP's that form in the shaded region experience maximum attraction for each other. This "threshold" attraction is required if they are to interact as successful CP's to form new aggregates despite all the counterposed forces in the potential space. By interacting they provide new material units (from each two CP's) which in turn achieve new levels of parameter magnitude stability. These new levels are a new potential space. The CP's are the subunits of these new units with new emergent stabilities. By their participation in the formation of new levels, the CP's are caught in their stable forms and thus experience with the units they form new potential lifetimes. This emphasizes their feature of self-referencing. They partly create their own environment while experiencing it and having it create them. All of these results are themselves the cause of CP's probabilistically experiencing more stability and materializing in the extreme opposite regions of the "potential space" of their parent wholeness. But more than one type of CP emerges at the extremes. Due to the extent of the "potential space" more than one wholeness can populate it. As a result, all bifurcations are not the same. A population of slightly variant CP's form from the figurative range of wholenesses possible. Yet the family of wholenesses are enough similar that all the variant CP's on one level can still interact with each other.

It must be noted that at the present time an insufficient number of CP's have been identified to account in specific ways for generation of the hierarchical levels shown in Figure Four. This paper only explores the hypotheses and formulates some initial predictions to stimulate future work. It has no pretensions as to proof or even completeness as regards elucidation of steps or overall description. See Figure Three for a diagrammatic representation of Step One.

STEP TWO: UNGUIDED PROBABILITY LEADS TO POOLS OF VARIANT COUNTERPARITIES: THE ROLE OF STABILITY VERSUS DIVERSITY.

The field of probability is, in a sense, one of mans first expression of awareness of "potential spaces". All things that can happen, will happen, and we will call the total happenings = to 1. The generator is chance -- of which we know little, so we characterize the results of chance, of which we know a little more. Chance also has a central role in this process. It was pointed out for Figure Five that several potential wholenesses existed per potential space. Each may or may not succeed in generating its set of CP's depending upon many variable influences of its context. Probability theorems may help describe this process, or at least its results, so in Figure Three we used normal distributions to indicate that, given three things, CP generation can be treated as a statistical phenomenon. These three are; (i) some empirical data on the magnitude parameters for that level of hierarchy, (ii) an expression of the range or tolerable limits of the potential space in terms of these parameters, and (iii) some devices to measure the transients man cannot yet perceive. Since having all three is unlikely we may resort to general formulations along the lines of probability theory.

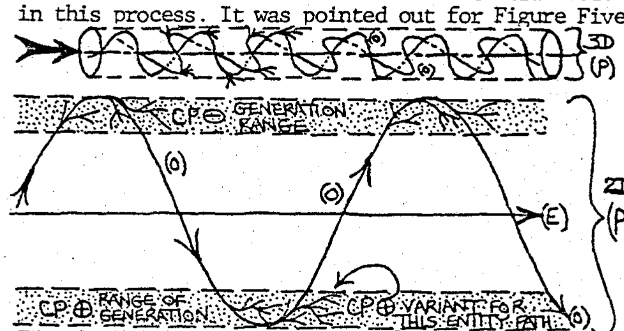


FIG. FIVE: Diagrammatic roles of a Potential Space (P) and Its Oscillations of Entities in Origins of Different Populations of Complementary CP's.

The upshot of these considerations is that besides the family "type" of a counterparity emerging (eg. opposite spins to electrons /or/ matter, antimatter particles) many variants of each CP type also emerge due to chance (in the above, respectively, many orbital combinations, shells, & valences in different atoms /or/ families of subatomic particles). This action of chance in producing populations, not single sets of pairs, is the key insight for this step in the process. The populations allow probability to be used.

In recent ecosystems analysis literature there is a growing debate over the counterposed forces of stability versus diversity -- which is the dominant influence? (McNaughton, 1977; May, 1973; May, 1977; First Int. Cong. of Ecology, 1974). How do they interact? The empiricism and math theory developed in this debate could apply to this step in the emergent evolutionary process. For example, the "materialization" of the CP's involves considerations of their stability relative to their "potential space" while the forces of chance result in the appearance of a diversity of CP's. So these two features also interact in this process and fertilization from the ecosystems field is likely. Study of potential spaces may reveal a "limit" relationship between tolerable stability and tolerable diversity when together in one context, thus helping the ecosystem field.

STEP THREE

CONCRESCENCE AND ENDOCRESCENT COUNTERPARITY: CP+ VARIANTS AND CP- VARIANTS COMBINE INTO A SPECTRUM OF AGGREGATES OF VARIED STABILITY (Formation of Entities Within A Hierarchical Level).

CP's might be expected to show a tendency to decay to the "equilibrium position" from which they arose by oscillation. But in the presence of a similar population of opposites bifurcated from the same whole, and in a deviation from idealized still point in exactly complementary ways, the CP instead experience forceful combination and union with its partner CP rather than decaying. Further, Figure 5 should be a 3-dimensional picture showing a pool of variant CP's arising in the peripheral zone, such that 2 CP's from uniquely different wholeness paths can also experience attraction. This heterogeneous binding of cross-wholeness CP's results from their inbuilt similarities as spin-offs of the same potential space. These bindings yield a large number of new aggregates, arising from different sets of CP's, some of which are stable, some not.

We call this tendency of CP's to recombine, but in new ways....concrescence (L., con = together; cresco = to grow; -ce = the action or process). Concrescence means the action or process of CP's coming together into aggregates. Concrescence is a natural process arising as spontaneously as counter parity and is likewise common to many natural systems and to all levels of the metahierarchy. It is another important principal systems concept deserving study.

The CP+ and CP- aggregations make up the substance of material entities for their "potential space," or hierarchical level. This aggregation is intra-level proliferation of entities. It populates the space within the level and distinguishes it from the gaps on either side that separates this cluster from others. An example of this would be the generation of many elements from the same basic subunits of subatomic particles. All of these elements are built from the same CP type and function, and all are within the same range of parameter magnitudes, (i.e. the same H. cluster). When the full set of CP variants combine, they do so in non-homogeneous ways. For example, an element is not homogeneous - it exists as a nucleus and electron shells. The nucleus and inner e- shells are completely paired sets of CP's. They are stable and give the entity feature to the element. They combine in ways that give a "central" stability to the element by within-level CP interactions. We call these endocrescent counterparities, because their process of growing together operates solely within the level ("endo" L. = inside of). These types are all satisfied counterparities. A future paper will develop endocrescence mathematically.

STEP FOUR: CONCRESCENCE RATIO AND TRANSCRESCENT COUNTERPARITY: AN INVARIANT RANGE OF RATIOS OF SATISFIED TO UNSATISFIED CP'S CAN FORM EMERGENT COMPLEXES (Formation of Entities Jumping to a New Hierarchical Level)

Let us continue with the same example. At the periphery of elements in the outermost electron shells are certain counterparities which have the potential for combination but are not fully complemented. For example, in oxygen, :Ö· , two pairs of e- are satisfied in the presence of their opposites but two others remain unpaired. The unpaired CP's comprise the peripheral instability characteristic of unsatisfied CP's. This enables the elements to combine with other elements within the level at the allowed magnitudes of bonding distances, energies, etc. When sufficiently large units within the level combine in sufficiently complex ways (usually involving several peripheral CP's built on already large complexes built up from endocrescent CP's) they form such large new units, that these new units become the base population of an entirely new level of organization. This new level of organization (or H. cluster) has new characteristic magnitudes of parameters, and therefore new "potential spaces," new variant CP's and new central and peripheral stabilities and instabilities.

These new complexes are called "emergent" because of their new qualities. This process describes how macromolecules emerge from elements but we suggest that this model also holds for other levels. Those peripheral CP's that are unsatisfied and lead to the emergent complexes by seeking their complement, we call "transcrescent" counterparities (L., "trans" = across or beyond). These CP's cause their associated central stabilities to act like subunits forming aggregates that transcend their potential space.

Again probability plays a role. Many types of elements are possible. Most elements, however, do not form the next level (transcend to) macromolecules. The inert elements do not combine at all. The radioactive elements are not stable alone, much less in combination. This range of unreactive to overreactive entities is reminiscent of a statistical distribution in which chance plays a role. It probably occurs at all levels. Some range of entities on each level that have sufficient central stability (satisfied CP) to last long enough in populations....combine with other such entities in significant ways....and yet have sufficient peripheral instability (unsatisfied CP) to promote emergence of new aggregates and new levels. The relative amount of satisfied to unsatisfied counterparity (central to peripheral stability) potentially can be measured for entities in physical systems. Our hypothesis is that the very same range of ratio of SCP to -SCP will be characteristic of those entities on one level of the hierarchy which give rise to the next no matter what the specific nature of the CP or at what level the measurement is taken. Further, there is a good chance that this invariant ratio (or probably tight ratio range) would bear significant relationships to other invariant laws of our universe due to its role in generating hierarchies which are an important feature of our universe.

This invariant ratio we call "concrescence ratio", and since it arises naturally from the counterparities at each level of the metahierarchy, it is another candidate principal systems concept deserving study.

STEP FIVE:

CONCRESCENCE FORCES ARE ACTED ON BY BOUNDARY LIMITS RESULTING IN HETEROGENEITY WITHIN THE POTENTIAL FIELD AND BETWEEN POTENTIAL FIELDS

Albert Wilson states..."if in a system (given sufficient mass); (i) there exists a force of gravity (or an aggregating force), and (ii) there also exists in that system a "boundary" limiting the potential field, then when that system comes to equilibrium, it will be a modularly hierarchical structure," (Wilson, 1978). The most important feature of this statement is its mathematical equivalent. Although the aggregating force equation must take the form of the level of the hierarchy under study, the "boundary" equation, for astronomical systems, takes the form,

$$\frac{GM}{c^2R} < b$$

where G= gravity, M= mass, c^2= the velocity of light, R= radius, b= bounds, and ρ= density of object. As

$$M = \rho R^3$$

and

$$\frac{G}{c^2}\rho R^2 < b$$

then

$$\rho R^2 < b$$

which states that for matter at a given density, the size is bounded (or for a given size the density is bounded), and the boundary delimits essentially what we see as the cluster limits of the hierarchical level.

Although these observations have been developed primarily in the field of astronomy, they could profitably be extended to and tested in other hierarchical levels as the same dynamics exist in all following the above discussion. The gravitational forces active in astronomical systems should be considered a specific type of concrescence tendency typical of that level. The extension of the concept of concrescence to concrescence ratio and this to the root concepts of counterparities should provide a number of new "handles" to use in seeking relevant and measurable parameters at each level of the metahierarchy to apply the above equations, (or their generalized modifications). These kinds of studies will aid in understanding the mechanisms active at each level (so contributing to the special fields) while at the same time providing a basis for the unity of knowledge.

One key insight that emerges from defining the interrelationships of material aggregates (entities) and "potential spaces" is to recognize that they are the most primeveal and abstract counterparity from which all others arise. The two truly form each other given the emergent evolutionary process. Their interaction (material vs. space/time field) actually produces what we call energy at all levels, and the three taken together yield the heterogeneity we call hierarchies, as partially described in generalized versions of the above equations.

Potential spaces are new types of beasts for Western man to explore. He has all but entirely ignored them, but now they pop up all over...in atomic physics, in astronomy....wherever Western science finally gets down to fundamental questions. Potential spaces are so important that it is impossible to describe completely such basic concepts as material entities, natural system counterparities, energy or directional force, or hierarchical evolution without including them in the equations. This reminds us again of the indivisible unity or holistic nature of natural systems and brings us back full circle to the Yin/Yang philosophy with which we began. It is comforting that science and philosophy are indeed counterparities themselves and will be one again.

Steps Six and Seven will be explained more completely in future papers. Step Six is "NEWLY EMERGENT COMPLEXES GENERATE NEWLY EMERGENT COUNTERPARITIES: THE SELF-ORGANIZING, GENERATIVE CYCLE CONTINUES. Step Seven involves mathematical statements of the previous steps which are then related to several existing mathematical systems in an attempt at unification of several natural processes.

CONCLUSIONS

The following statements are suggested; (i) the continuous, self-referencing, and self-organizing origins of hierarchical levels can be explained in terms of one generalized natural process, (ii) the concepts of counterparity, concrescence, concrescence ratio, and potential spaces are fundamental abstractions true of so many diverse systems that they deserve recognition/study as principal systems concepts, (iii) systems evolution is a central process too long ignored by systems theorists, (iv) any one counterparity-type exists as a population and much of its functional significance derives from this fact, (v) counterparities and concrescence ratios have features which are amenable to measurement, which measurements once undertaken will sharpen our understanding of these concepts, the emergent evolutionary process in which they function, and will encourage the formation of testable and falsifiable predictions.

The metascientific (Troncale, 1977) and systems study of counterparity adds considerable dimension to the ancient concepts of dualism, &/or complementarity. The old conceptualizations generally do not link dualism to (a) the generation of hierarchies, (b) to stability/diversity mechanisms, (c) to measurables in real systems, (d) to populations of dualities, (e) to boundary limits and potential spaces, or (f) to processes of "emergence". This paper links counterparity to all of these phenomena.

POSTSCRIPT: A bubbling waterfall in a stream does not exist apart. Instant by instant it is remade by the constant flow of different waters over the same potential spaces of the rocks. Likewise hierarchies do not exist apart. They are continuously formed by the flow of things thru potential spaces. Trying to explain either will never be as beautiful or complete as the natural processes themselves.

TABLE ONE: EXAMPLES OF SUGGESTED COUNTERPARITIES FOR SEVERAL SYSTEMS

ASTRONOMICAL	PHYSICS	CHEMICAL	BIOLOGICAL	SOCIOLOGICAL	SYMBOLIC
*matter vs. anti-matter	*wave vs. particle complements	*L-forms vs. D-forms	*bilateral symmetry	*Yin/Yang	*word pairs in languages (good/evil; in/out,etc.)
*black hole vs. quasar cosmology	*opposite spins on electrons	*anabolic vs. catabolic reactions & networks	*ag-ab complexes (steric fit)	*thesis/antithesis	*duality theory in computer programming math.
*space vs. time	*energy vs. matter	*oxidation vs. reduction reactions	*male/female	*tonal vs. nagual	*holism vs. reductionism; analysis vs. synthesis
*gravitational attraction vs. size limits	*dual resonance hadrons	*positive vs. negative ions/charges	*complementary bases [illegible] DNA	*challenge vs response (or S/R)	*binary math
GENERAL (all levels)	*poles in magnetic fields	GENERAL (cont.)	*genetic palindromes	*worldview value cycles	*duality processes in Markovian proc.
*stability vs. variation	*continuous vs. discontinuous matter	*entropy vs. negentropy	*left/right brain hemisphere specializations	*goal vs. process orientations	*subjective vs. objective reality
*stability vs. diversity			*opposing muscle groups	*Eastern vs. Western philos.	*protagonist vs. antagonist in drama & mythology
*satisfies vs. unsatisfied counterparity			*compl. social calls in animal behavior (attraction vs. repulsion/ birds)	*conscious vs. subconscious	
			*post div. cell migrations		

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EVALUATION TECHNOLOGY: THE APPLICATION OF DECISION AND UTILITY THEORY TO PLANNING, OPERATING AND MANAGING COMPLEX SYSTEMS

TECHNOLOGICAL FORECASTING SUMMARY

Dr. Albert G. Wilson

January 26, 1973

PRESENTED BY

CONTINUING EDUCATION IN ENGINEERING AND SCIENCE
UNIVERSITY EXTENSION, UCLA

TECHNOLOGICAL FORECASTING GLOSSARY

FUTURISM: The philosophy that the future is continually defined and shaped by human imagination, choice, and planning rather than being deterministically governed by the past. Orientation toward anticipatory thinking and action based on forecasting and long range planning. The sociological phenomenon of concern with the future resulting in a professionalism and institutionism for guiding change.

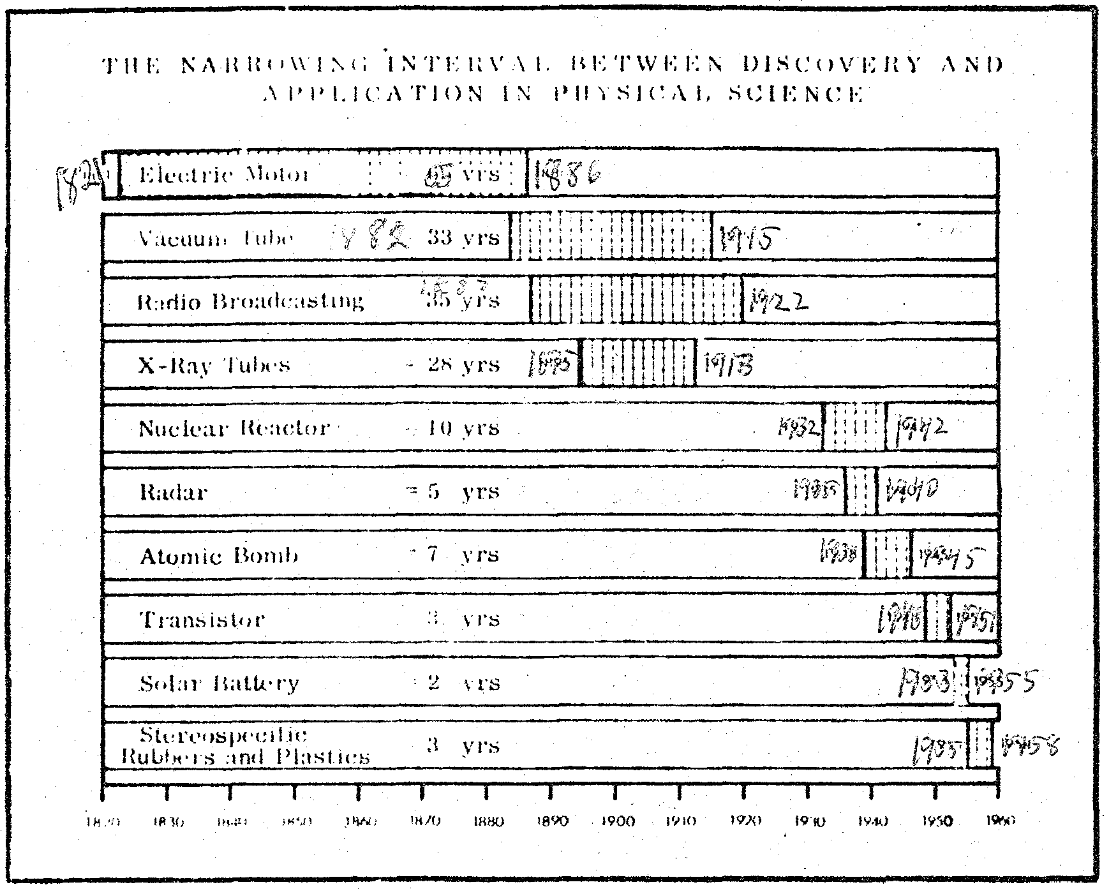
FUTURISTICS: The study of the probabilities and implications of alternative conceivable and possible futures. Specific images and scenarios of future possibilities, specific forecasts, assessments, and plans. The practice of any activity that generates images of the future, predicts or shapes the future.

FUTUROLOGY: The subject of how the future is studied. The dynamics of technological and social change; the roles of causality, finality, determinism, volition, and chance in the processes of change; the nature of time, the modeling of change; the design of methodologies for forecasting, imagining, assessing, and planning alternative futures.

FORECAST: A relatively high confidence level probabilistic statement concerning the future. Three basic types are common:

> Extrapolative: A forecast of the most probable future based on the unmodified continuation of existing trends.
>
> Exploratory: Forecasts of probable futures resulting from specified sets of alterations in existing trends.
>
> Normative: Forecasts of probable futures derived in accordance with alterations in existing trends as effected by specified goals.

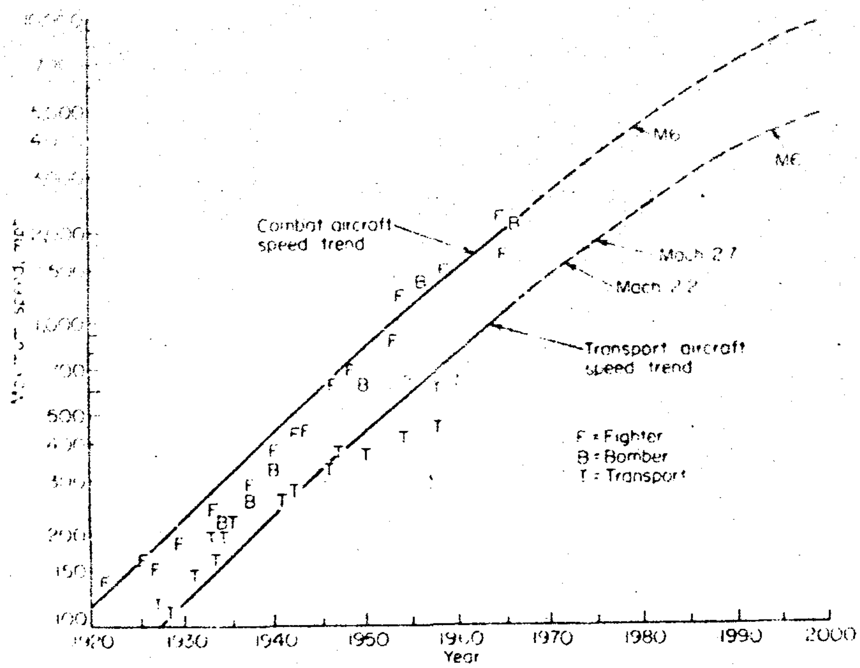
PLAN: A detailed and systematic formulation of a set of objectives together with a description of procedures and schedules for their realization.



Forecasting on the basis of science preceeding technology

(# Building metaphors: pump: blood circ. clock: solar system steam engine: thermodynamics gambling: probability games: game theory oil refineries: cybernetics solar system model: Bohr atom computer: ? hologram: ? laser ?

Figure 1 (Reference 4, p.60)



Forecasting on the basis of horizontal transfer of a technology

Speed trends of combat aircraft versus speed trends of transport aircraft, showing lead trend effect.

Figure 2 (Reference 5, p.119)

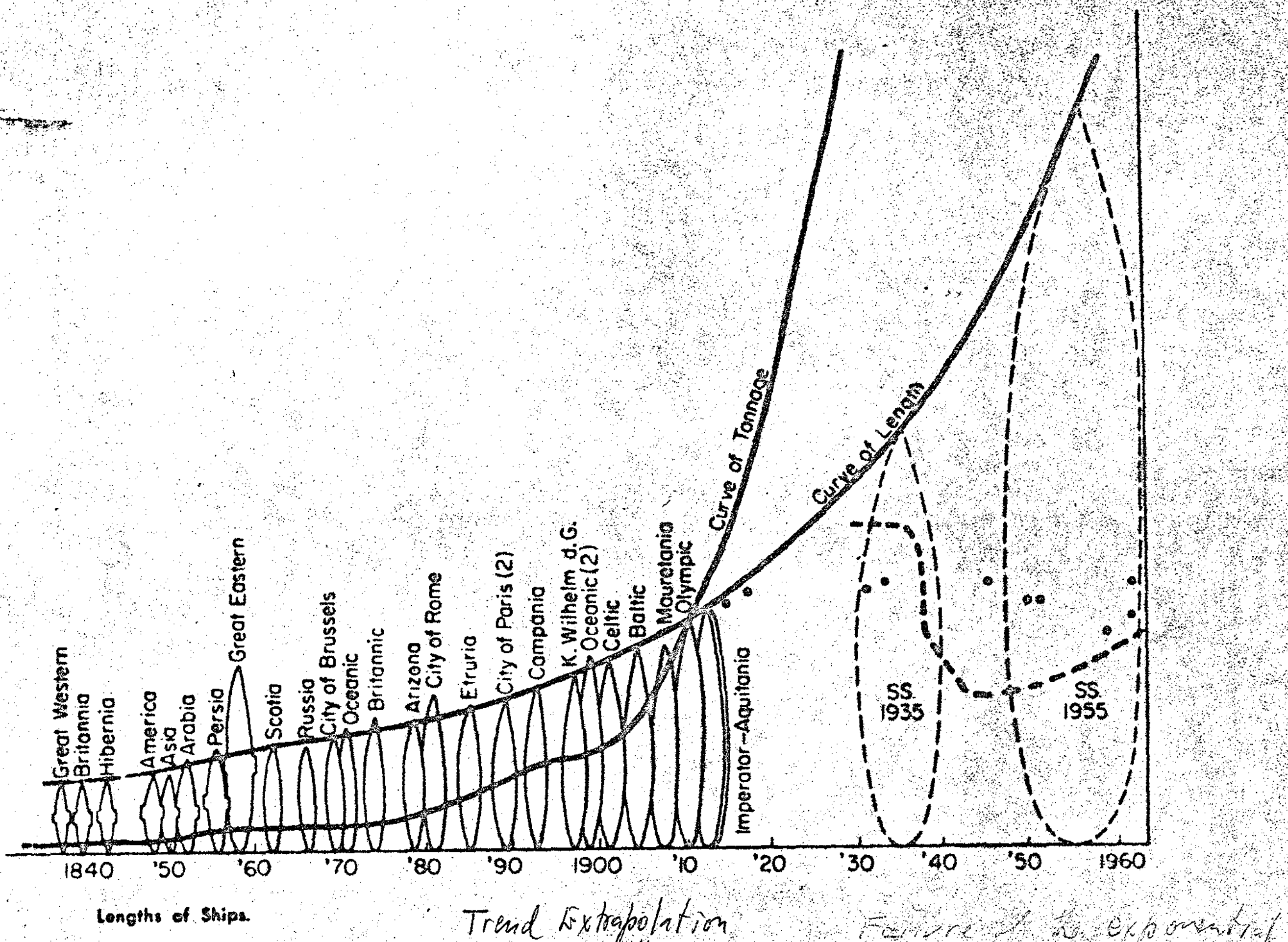
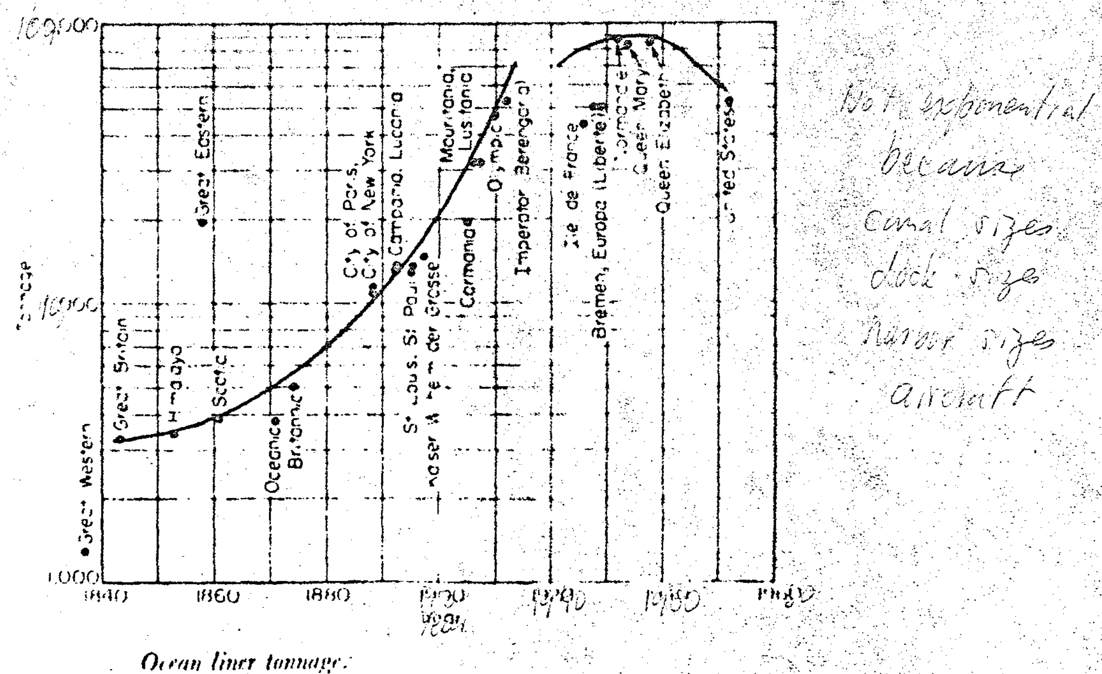
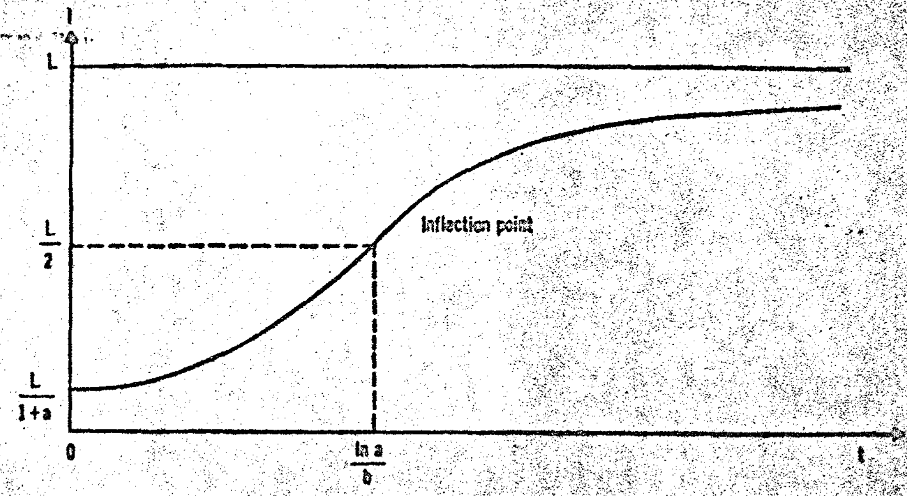


Figure 3 (Reference 17, p.22)



Ocean liner tonnage.

Figure 4 (Reference 5, p.25)

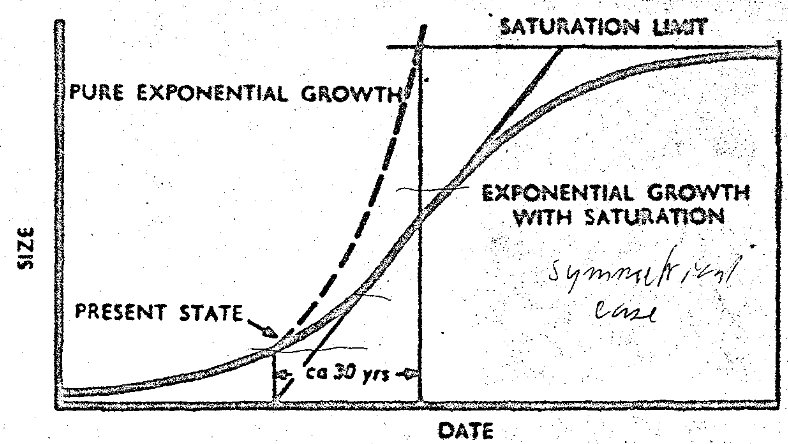


$$I = \frac{L}{1 + ae^{-bt}}$$

I = Accumulated information (state of knowledge) at time t.
L = Upper limit of information (due to constraints).
t = Time.
a = Constant, dimensionless.
b = Constant, per time unit.

Example of Growth of Knowledge

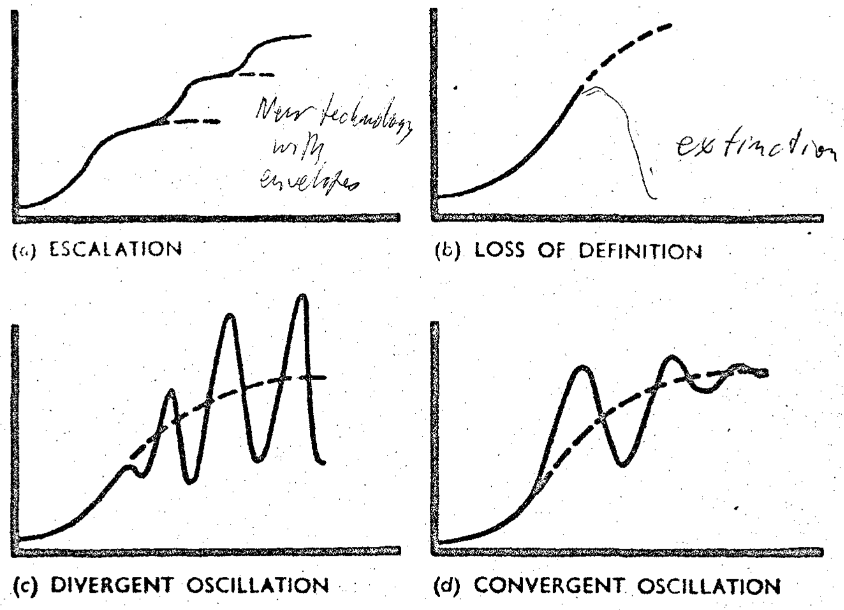
Figure 5 (Reference 1, p.151)



about 3 doubling period

Inhibitors
Finite Earth
parts wear out (hemd)
competition
Exhaustion of possibilities

Figure 6 (Reference 39, p.401)



Impact of the inflection point

How to go to zero growth

Figure 7 (Reference 39, p.381)

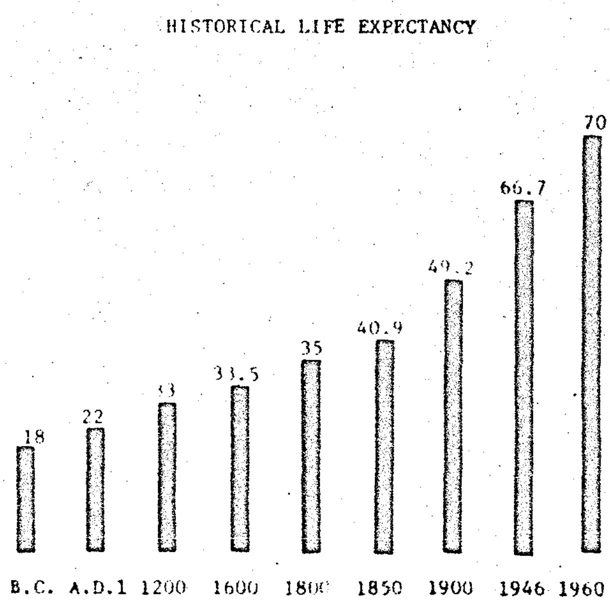


Figure 8 (Reference 4, p.85)

On the basis of extrapolation what might we expect:
exponentially
1975 – 80
1990 – 100
- - -
At some point, will live forever.
This is mean
But $\exists$ an upper limit c. 140yr. long known.
already dropping in U.S.

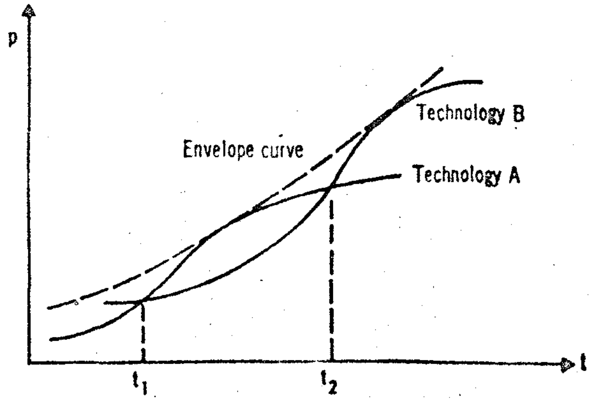
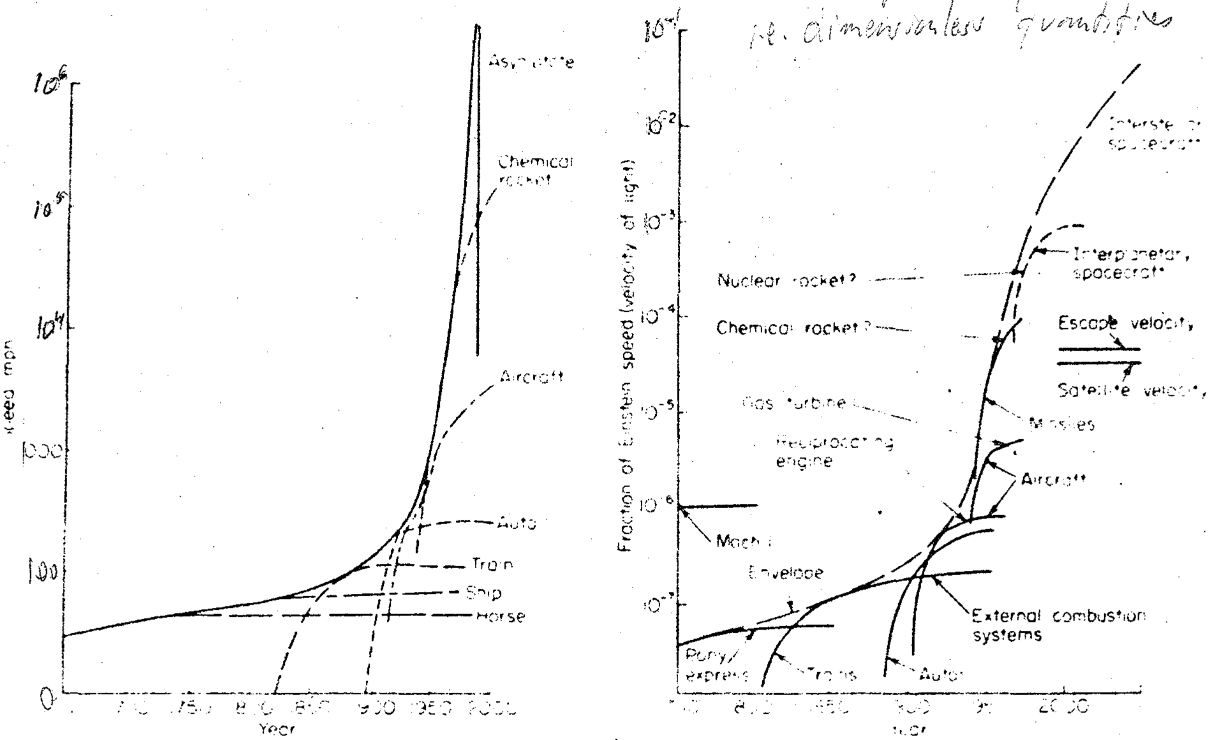


Figure 9 (Reference 1, p.165)

e.g. propellors - jets
steam - diesel

when to start a
new technology
timing
transistors, vacuum tube
innovators at t_1, Bandwagon
at t_2

Importance of right units
i.e. dimensionless quantities



Speed trend curve. *Speed trend curve.*

The same parameter is plotted in both graphs. The one on the left is extremely misleading because an inappropriate scale is used.

Figure 10 (Reference 5, p.21)

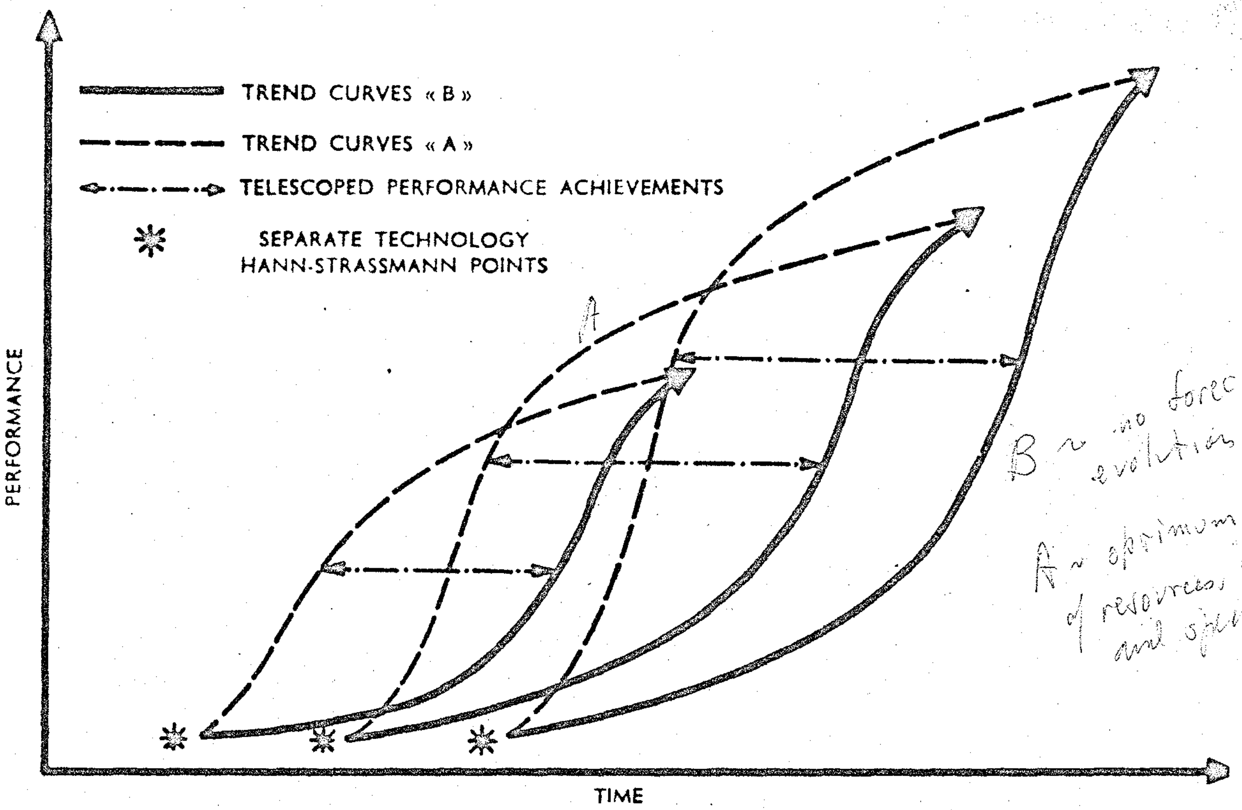
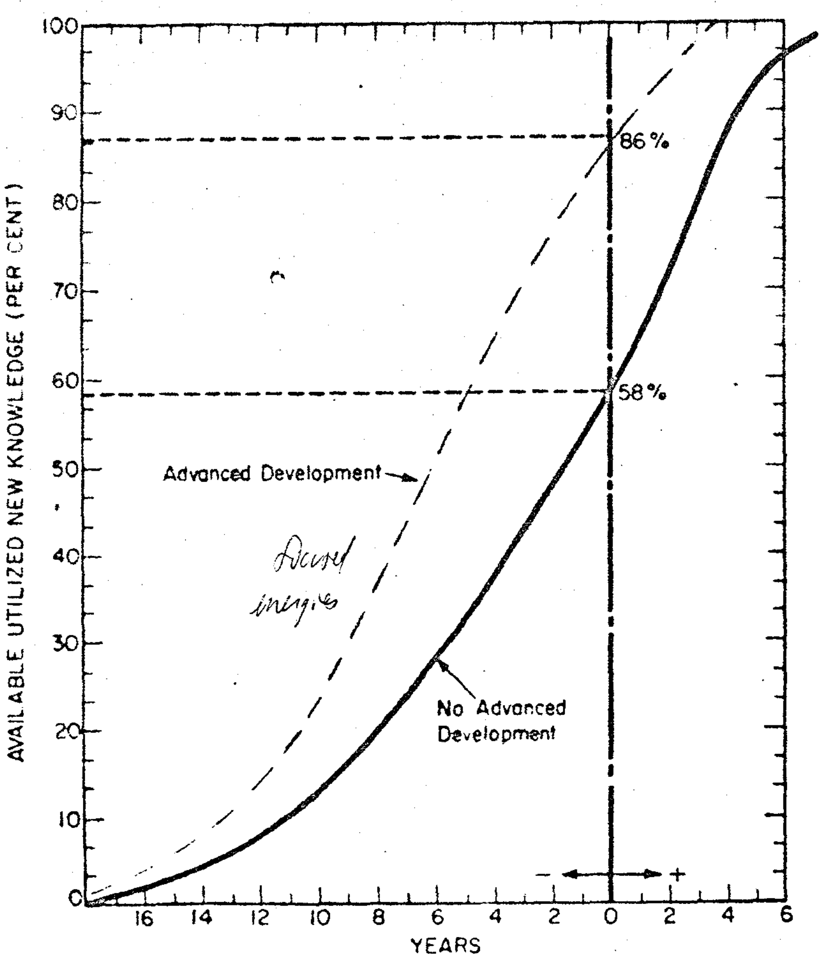


Figure 11 (Reference 39, p.502)

Height is not altered only slope by advanced development



Here we have two systems Those with pre-prototype development & those normally evolved

Figure 12 (Reference 17, p.43)

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FORECASTING

Lecture UCLA Engineering Executive Program. March 8, 1976

The subject will be divided into three parts:

I. Forecasting Foundations and Fundamentals
II. Forecasting Techniques
III. Technological Forecasting

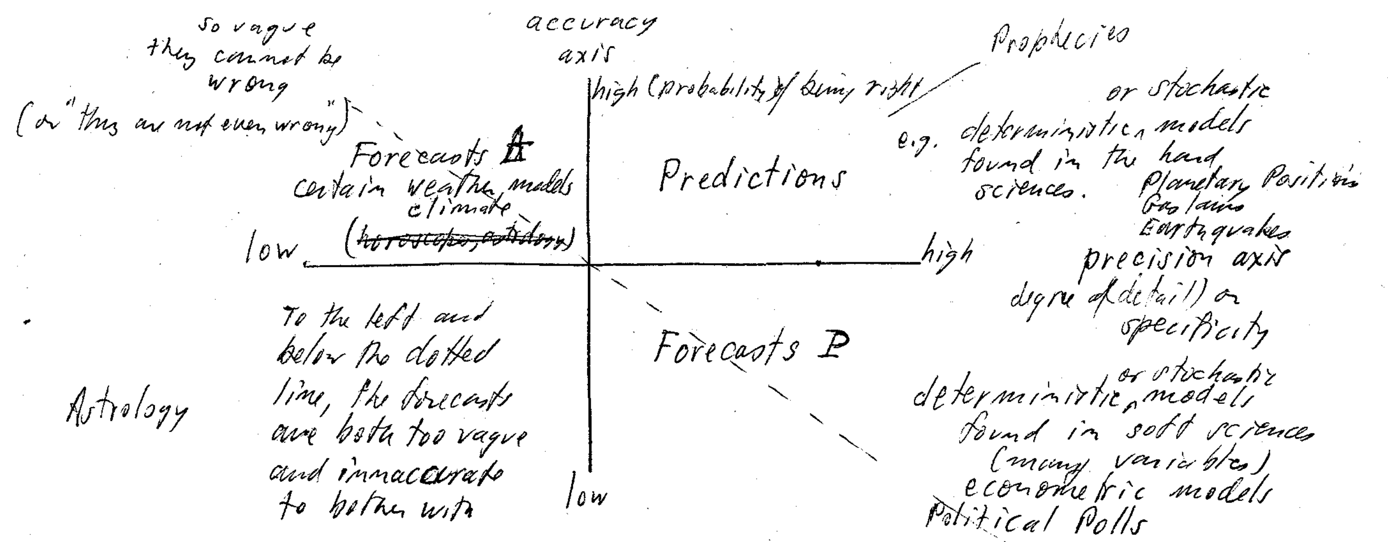
Part I. Forecasting Foundations and Fundamentals.

Many associate all statements about the future with tea leaves, astrology, mysticism or Jeanne Dickson. In talking about the future you are talking about something that does not exist, so anything you say is highly suspect. These people have a point, but

We all make statements about the future many times a day. The fact that verbs in most languages have a future tense shows how common talk about the future is and how important is our need to make statements about the future. We recognize many different kinds of statements about the future. There are statements of intention and expectation--I shall meet you for supper this evening, Joe will be home this weekend; Program statements--You will be required to submit a term paper in this course, A tour of the computer facility will take place following the final meeting. The bulk of futures statements, such as these ~~four~~, refer either to the immediate future or to some specific plan, usually about some rather small system under our direct control, such as a couple of individuals, a class, or a conference.

But there are more comprehensive ~~extensive~~ statements about the future, those refering to bigger systems, systems not under our direct control, or to longer range time intervals. There are statements we call prophecies--An important contender for the presidential nomination will die before August. There are statements we call predictions--There will be an annular eclipse of the sun on April 29th. And there are statements we call forecasts--The probability of rain will increase to 20% tonight with clearing and warmer tomorrow, The Dow will break 1100 before the November elections but will drop sharply before the end of the year. How do these three types of futures statements, prophecies, predictions and forecasts differ? and is it proper to group them with tea leaves, horoscopes and Jeanne Dickson?

First let us separate out prophecies. We must include them because they really exist, not because anyone can explain how they are made. Prophecies are highly specific statements about the real world. They are not probabilistic statements. They are not based on any model and they are either right or wrong. They are made before the event and are on public record before the event, (otherwise they are not prophecies). They are a real phenomenon related to what is being seriously ~~considered~~ researched these days--precognition. They challenge our present physical theories and our basic notions of ~~what~~ time, ~~is~~. To deny their existence is to put~~ting~~ our head in the sand. but To worry about them, unless you wish to research the field, is a waste of time. So for the record, they are there ~~and~~ but we will put them aside until some future date when something meaningful can be said about them.



Th~~is~~ Hatrick diagram displays the differences between forecasts and predictions. We see that ~~all~~ both of these are based on models, and are statements about the future states of the model rather than about the real world. There are good models and there are poor models. For a model to be good it should give both accurate and precise outputs. Most econometric models have precise outputs but they are usually inaccurate. Astrology, on the other hand, if it may be included at all, assuming a horoscope is a model, may make ~~accurate~~ statements ~~but~~ of such a vague nature that they ~~are~~ can not ~~even~~ be wrong.

so precise the indeterminacy principle requires them to be wrong

The term prediction is reserved for a futures statement that is both precise, i.e. possesses a high degree of specificity, and whose probability of being correct is close to unity, e.g. eclipse predictions. Predictions are the statements about the future made by the established sciences.

P sector forecasts include political polls, highly precise in the numerical value of their percentages, but likely to be inaccurate because of sampling errors and the susceptibility of certain voters to blow with the latest political breeze. Meteorology, on the other hand, --in the A sector-- possesses some good models which give accurately general circulation flows and weather change patterns, but not to the degree of specificity that most agronomists and week-end sports addicts would like. When a forecast is too vague to be useful, even when correct, or so likely to be wrong, even though specific, then it has little utility. As below the dotted diagonal

From all of this we see that a forecast to be useful enough to consider for decision making and planning purposes must be a "relatively high confidence probabilistic statement about the future" and this is the usual definition of what is meant by a forecast.

We usually have two questions about the future:

What is going to happen? and

What should we do?

The first question is the motive for forecasts; the second question is the motive for plans. We like to know what is going to happen so we will then know what to do. This all seems trivial enough, but it involves an important paradox. The first question is about a macrosystem, the second question is about a microsystem--a microsystem imbedded in the macrosystem.

The posing of these two questions as though separate and in the order in which they are usually posed ignores the feedback between the microsystem and the macrosystem. We ask the questions as though what is going to happen is independent of what we are going to do, although we clearly recognize that what we are going to do depends on what we <u>think</u> is going to happen to the macrosystem. Now the situation is no longer trivial. We recognize that the feedback of our participation--the role of our microsystem and that of many others influences the macrosystem in such a way that it becomes quite unlike the systems customarily researched in science which do not contain this feed back loops. In science the microsystems usually ~~have~~ play only the role of observer, not that of participant.

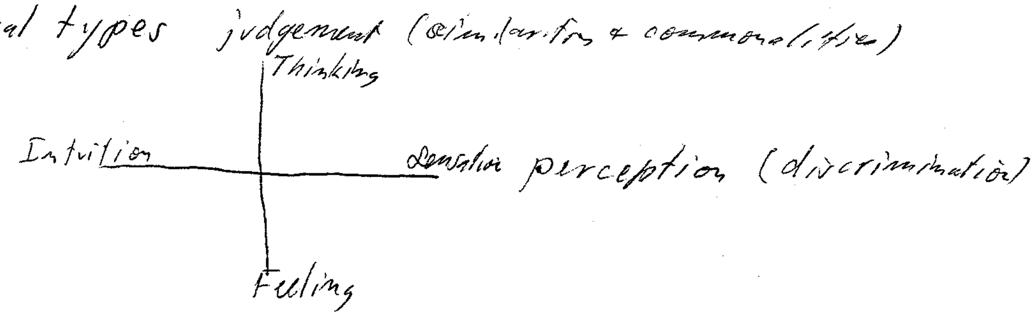
Another approach ~~to~~ arriving at the same destination; that science and the study of the future are different beasts, is by Boulding. He said that "All knowledge is about the past, all decisions are about the future". Thus the present constitutes a remarkable watershed and poses some curious dilemmas. What we say about the future in forecasts is properly considered to be different from <u>knowledge</u> and different from scientific knowledge in particular. Perhaps it is most accurate to label what we say in foredasts as <u>opinion</u>, but opinion of a very special kind.--opinion based on critical and logical processes, such as that used in the sciences (in many cases identical with the same as those used in the sciences), but none-the-less opinion because the usual canons of scientific verifiability (induction etc.) are not applicable except after the fact when the forecast is either fulfilled and the opinion then becomes knowledge or when the forecast fails and the opinion becomes garbage.

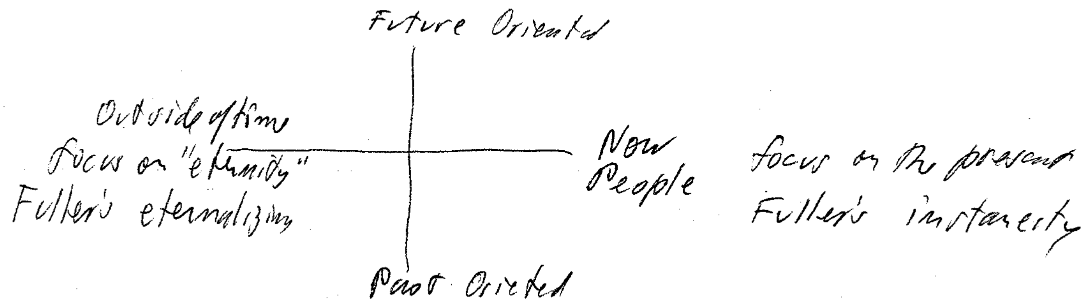
It is useful to understand some of the important differences between the discipline ~~we~~ now generally call <u>Futures</u> <u>Research</u> and Science.

		SCIENCE	FUTURES RESEARCH
(A)	o	Objective microsystems in the observational mode	Has a subjective dimension microsystems in the interventive or participation mode ~~(also cf. Jung's 4 types)~~
(A)	o	Value free	Value laden two types of future values: trends of present preferences, shoulds and oughts
(B)	o	Descriptive (the way it is) descriptive knowledge tells what the world is like. It is accumulative	Normative (the way we want it to be) Normative 'knowledge' tells what we ought to do. It is not accumulative, but revisable
	o	The Product knowledge conclusions	The Product praxis decisions
(B)	o	Bottom Up reductionistic	Top Down goal oriented (hopefully holistic)
		feasibility + opportunity ⇒ implementation can ⇒ should	
(B)	o	Predictive deterministic or stochastically determinative continuous	Decisionable open ended, teleological branches discontinuous catastrophes
	o	Focuses on The repeatable The ubiquitous The accessible The communicable	Must also take into account The unique The local
	o	Validation verification demonstration proof	Signification importance interest utility (value)
(A)	o	Purports to Operate on the object	Purports to Operate on the subject as well as the object What did you expect to get from the course New knowledge – or to be changed yourself?
(B)	o	Causalistic	Finalistic

What is generally termed the 'subjective dimension' has several components. These include: 1) intervention or participation, 2) value systems, 3) the intervenor or participator being himself changed by feedback or other, 4) psychological type. Psychological type expresses itself in futures research primarily in two attitudes: The attitude toward capital formation and the value of the discount rate usually assumed. (A)

Psychological types





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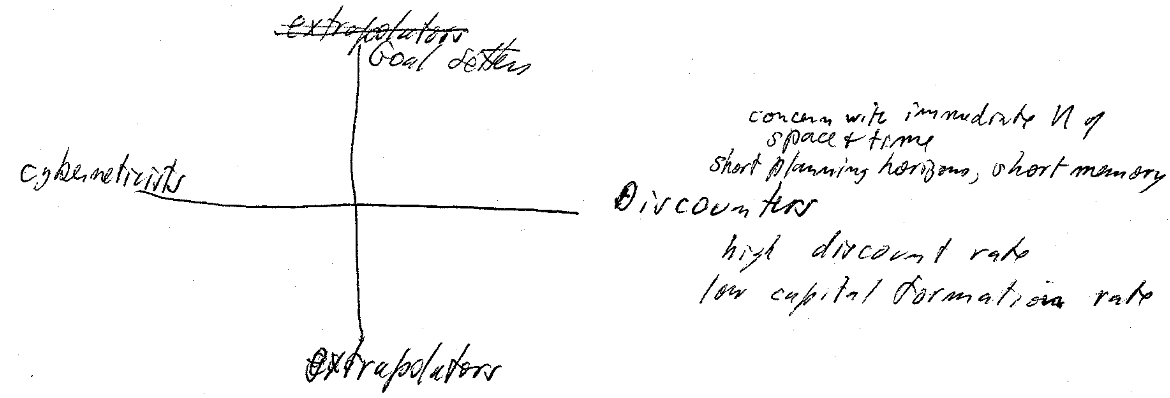

Discounting the Future

p the present value of the future

$$p_n = \frac{A_n}{(1+r)^n} \quad \text{or} \quad p = \sum_n \frac{A_n}{(1+r)^n}$$

$$\text{or} \quad P(r) = \int_0^\infty A(t)\, e^{-rt}\, dt$$

The larger r, the smaller P

Considered as a function of r

as $r\uparrow$, $P\downarrow$ Bearish

$r\downarrow$, $P\uparrow$ Bullish

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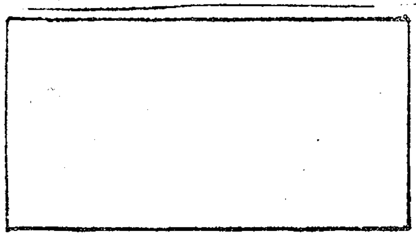
Table 4

PARADIGMS OF FUTURISTS

TYPE	PHILOSOPHY	TOOLS	CHARACTERISTICS

DISCOUNTERS

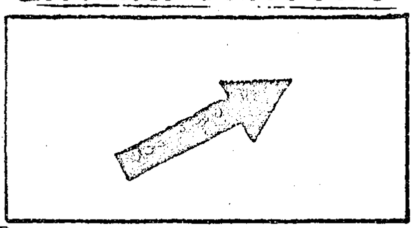


Philosophy: Interest only in near term problems

Tools:

Characteristics: Disinterest in forecasts; Improvisation; *Muddle Through*

EXTRAPOLATORS

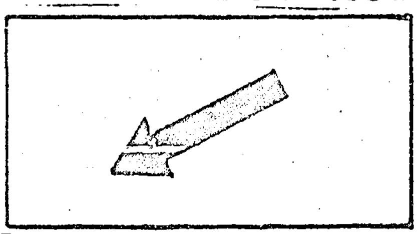


Philosophy: Future is extension of past

Tools:
- Trend extrapolation,
- Models based on past

Characteristics: Emphasis on data; Empiricism; Lockean I.S.

GOAL SETTERS

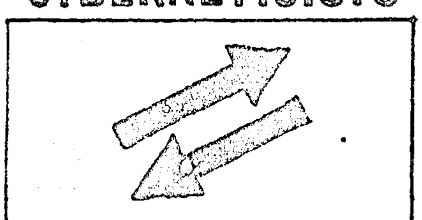


Philosophy: Idealism; Future can be created

Tools:
- Normative (needs) analyses
- Imagination, vision

Characteristics: Emphasis on values; Creation of new models; Leibnizian I.S.

CYBERNETICISTS



Philosophy: Combining of past and future creative approaches (feedback)

Tools:
- Interaction of exploratory and normative forecasting
- Use of multiple tools

Characteristics: Adaptive; Alternative futures; Singerian I.S.

I.S. = Inquiring Systems

(2)

From Linstone 4 Paradigms

5C

Table 1 - A Classification of Futurists

TYPE		ORGANIZATIONS Business Military	TECHNOLOGISTS	THEOLOGIANS	ECONOMISTS	ARTISTS
DISCOUNTERS	MOST OF THE PUBLIC	Unsophisticated businesses				
EXTRAPOLATORS	POPULARIZERS: Toffler, Jungk ENTREPRENEURS: Cetron, Gordon	Conventional business planners Utility industry Military agencies	Most technologists Lenz	Bell Gilfillan Kahn McHale	Most economists	"Year 2000" (Kahn-Wiener)
GOAL SETTERS		Creative marketing organizations Drucker Bennis Harman De Gaulle	Dubos Gabor Fuller Soleri Spilhaus	de Chardin Galtung Reich Skinner Saint Simon	Galbraith Theobald	Burgess Bradbury Capek Clarke Kafka Orwell most scifi
CYBERNETICISTS		Defense - RAND systems analysis groups	Ayres Forrester Jantsch Martino Turoff Gordon	Dalkey Michael Ozbekhan	Boulding Leontief	"Limits to Growth" (Club of Rome) De Jouvenel

Basic to all problems in futures research, whether the problem is one of forecasting, planning, assessing, decision making or alternatives generating, is the selection of the model of change. In science most models of change are either causal/deterministic or stochastic/deterministic. These models have been the most successful ones: celestial mechanics, continuum mechanics, elasticity, hydrodynamics, electrodynamics, thermodynamics, etc. How to model systems that are not purely determinative or stochastic but contain teleological or goal oriented modules is the problem of both the behavioral sciences and futures research.

The three basic modes of change are:

large scale	deterministic:	past shaping the future Laplace quote p. 6b
meso scale	goal oriented: or decisionable	image of the future influencing behavior in the present The concept of freedom, free will
small scale	probabilistic:	random transitions from earlier to later states

In futures research we must work with all three modes.

Forecasting depends primarily on the deterministic mode,
Planning depends on the goal orientation or finalistic mode,
while both are intimately affected by the probabilistic mode.

The problem is not which of these three is the correct mode by which the systems of the world ultimately operate--a philosophical question. The problem is where is the interface between the three--a pragmatic question. No wonder that the prayer of the futures researcher is:

GRANT US THE SERENITY TO ACCEPT THAT WHICH CANNOT BE CHANGED,
THE COURAGE TO CHANGE THAT WHICH CAN BE CHANGED,
AND THE GOOD SENSE TO KNOW ONE FROM THE OTHER.

A useful metaphor for illustrating the interface problem is that of a book:

to p 7

And it is in the exploration of the nature of change that we encounter deeper difficulties with the Weltanschauung of Science for the purposes of Futures Research. The futurist requires a different model of change and a different model of time than that which has successfully served the classical sciences. And in the study of change we are led to novel candidate ideas ~~of a novel nature~~ for the emerging world view.

Historically, there have been two polarized views of the essential nature of change. The first of these views has its scientific expression in the words of Laplace (Young p 305)

"Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it--an intelligence sufficiently vast to submit these data to analysis--it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it nothing would be uncertain and the future as the past would be present to its eyes."

This view also has a religious expression in the poem:

"What the first Morning of Creation Wrote,
the Last Dawn of Reckoning shall read."

This view of change, ~~based on~~ causal determinism or one of its modifications, is the philosophical base of all scientific prediction and of ~~or~~ any brand of prophesy that can foretell the future. (note that in this philosophy future is singular) ~~We may designate this tradition, (and it is an ancient one,--fatal~~ that includes ~~fatalism~~, predestination, etc. ~~that of the prophet.~~

At this point I would like to introduce a metaphor--perhaps suitable for illustrations in an after lunch talk, but not for the dialogue proper:

Let us think of all human experience as pre-written in a book. We are the readers of the book. Right now we are beginning to read on page 1976 of the latest volume. Pages already read and turned we call history, up-coming pages we call the future. The place where we are reading is called the present. From time to time there appears an individual with rare gifts who is able to read what is written on the yet unturned pages. He is the guy we have called a prophet. But the prophet is not to be confused with the maker of scientific predictions who deduces what will be on the next page from what he is reading in the present. His deductions usually are based on analogy with similar sequences that have repeatedly occurred on previous pages. It is essential to his function however that the book be written and that we be only readers, for otherwise there would not be scientific law.

But the second equally important classical theory of change -- teleological change alters the metaphor. In the terminology of our metaphor of the book, again human experience is written in the book, but is not pre-written. It is written as it happens and it is we who are the authors. The pages already turned are those on which we have written the record of history. The place where we are writing is the present; and the future consists of all of the unturned pages, which are blank, and upon which we shall be free to write as we please.

~~This tradition is also an ancient one.~~ ~~It~~ This is the ~~tradition~~ metaphor of the planner. It built the pyramids, laid out the streets of Persopolis, constructed all the roads that led to Rome. This tradition is very much alive in the world today. It is the view of the existentialist who believes we are free to reshape the world completely at every instant of time. It is the view of those who made it possible for man to place his footprint on the moon.

~~As I said~~ These two views of the nature of change are polar extremes and in recent years only occasionally does someone present a case for the out and out adoption of one view and the discarding of the other. Scientists, such as Rensch in his recent book, Biophilosophy, still hold for a totally deterministic universe. Humanists such as Sartre hold for the total freedom view.

F, R ~~We~~ must live with both the views ~~of the prophet and the view of the planner.~~ Science to form its predictive models must employ ~~causalism~~ determinism: the past shaping the future; society to plan and build its structures must operate with finalism: the future shaping the present.

This paradox on the nature of change is somewhat like the dilemma which confronted physicists concerning the nature of light. Light behaved in certain experiments like a wave and in other experiments like a particle. Neither view by itself could explain all of the observed properties of light. It was necessary to employ both. Only in the integrative synthesis of the quantum mechanics in the 1920's was this century old dilemma resolved.

The futures research workers in designing their methodologies and systematizing ways of studying the future have done with determinism/finalism what scientists did with the particle/wave dilemma. For purposes of forecasting, the world system is viewed as determinative, for purposes of planning the world is viewed as finalistic. But all the while a search has been going on for the "quantum mechanics" that will enable the contradictions to be integrated.

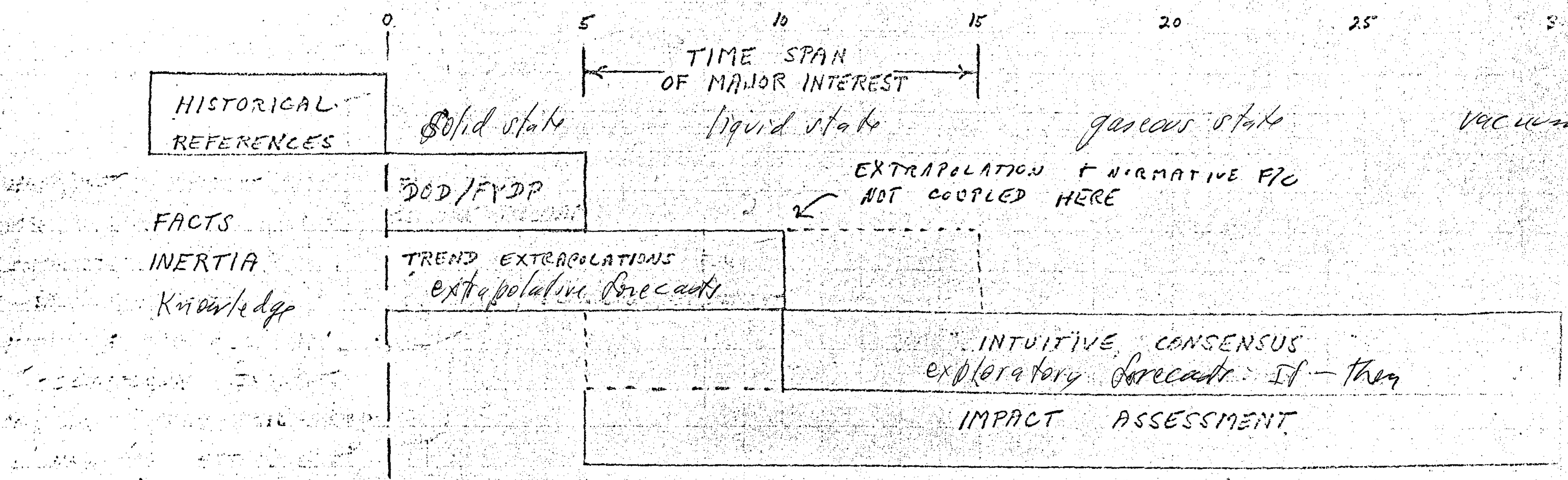
F. R.

Returning to our metaphor, the futurist has come to believe something like the following: First we agree with the planner, we are primarily writers in the book, not just readers. We write in the book at the moment of the present, but as we do so we simultaneously write on the ensuing pages, so the prophet is correct too. There is indeed something fixed to be read on the pages of the future, but we have written it there ourselves. In today's world as we turn each page we are finding that there is increasingly less blank space per page. Since the primary thrust of futures research is to generate sets of alternative passages from which we may select what we prefer to write in the book, it becomes a meaningless endeavor unless there is sufficient blank space for the inscription. The futurist recognizes this problem by stating that, while it is true that the next five or so pages are pretty well filled, there is ample blank space on the pages beyond. (But after 20 or so pages there is little or nothing for the prophet to read.) But this rough statement is barely more than an admission that this central problem exists.

Platt and others illustrate it the the following way

...ley
Model
Time Ranging

FORECASTING APPROACH



FACTS (Knowledge)

TECHNOLOGY ACHIEVEMENTS
BUDGETS
FORCES AND OPERATIONS
ENVIRONMENT

INERTIA

COMMITTED FUNDS AND HARDWARE
DEPLOYED FORCES
POLITICAL ATTITUDES
EXISTING PROGRAMS

EXTRAPOLATION

CURVE FITTING
SYSTEMS EVOLUTION

INTUITION

CONSENSUS OF EXPERT OPINION
RATIONALE MADE EXPLICIT

ASSESSMENT

CROSS-IMPACTS MADE EXPLICIT
ALTERNATIVE ENVIRONMENTS COMPARED

We must now go on to the other parts of our discussion, but allow me to mention in passing some of the levels of change:

Motion	inanimate systems	and above
Growth	bio systems	" "
Evolution	eco systems	" "
Intentional	sentient systems	" "
innovation — self change	conscious systems	

Comprehensive theories that can deal with all levels are lacking. The only good theories so far (good in the sense of accurate and precise prediction) are those based on the laws of motion. But we have not been able to generalize the laws of motion to subsume the higher ~~types~~ levels of change, as has been the desire of many bio and social scientists who are reductionistically inclined. The futures researcher and the general systems theorist have inverted the pyramid and have begun by considering the nature of intentional change ab initio. Later they will probably seek to reference their ~~models~~ theories to the other levels in their characteristic top down manner.

This ab initio approach has demanded new theories of change and even new theories of time. The concepts of time suitable for treating bodies rolling down inclined planes and most engineering applications are not adequate for treating the problems of futures research. Alternative constructs have been proposed, such as distinguishing the 'decker', the present, and the 'determinator'. Or a new viewpoint of the archetype as the fundamental unit of deterministic change. But these subjects lie outside the scope of today's discussion. But very hopeful is the new topological theory of René Thom, which he calls "Catastrophe Theory". This is the first rigorous mathematical theory that promises to do for systems involving branches and discontinuities what Newton's calculus did for continuous, non-branching systems. The first text in English on this revolutionary approach has just become available: "Structural Stability and Morphogenesis" Benjamin Inc. publishers.

Part. II. Forecasting Techniques.

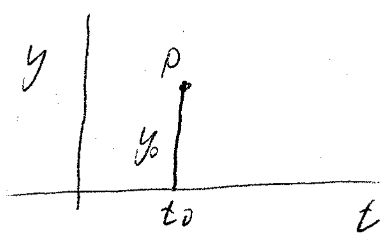
Corresponding to the modes of change, different types of forecasts are recognized

1) Extrapolative Forecasts

Based on the past. Generally use the same techniques used in science
Power Series. extrapolations –
Time Series extrapolations – cyclical phenomena
S – curves. (show some slides later) – syntropic phenomena

These are all based on the concept of continuity. (But all of what we call prediction – high precision, high accuracy – is up till now based on continuity. Thom's work promises prediction sans continuity.

We have for example, the Taylor Series approach



If at time t_0 the value of y and all its derivatives are known, and they are all continuous then, the future can be represented by the expression

$$y(t) = \sum_{n=0}^{\infty} y^{(n)}(t_0)\frac{(t-t_0)^n}{n!}$$

The basic predicate is:

In continuous change, knowledge of derivatives in the present can tell us all about the future.

No branching, no innovation
just continuous processes like growth

It is rather astonishing how much of the physical world can be treated predictively through the use of differential equations involving no higher derivative than the second. Forces D.Eq of Motion

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More general than extrapolative forecasts are exploratory forecasts, still past to future oriented. Extrapolative focuses on present trend. Exploratory introduces innovations, if-then events. Some of the techniques used in exploratory forecasts include:

From Linstone Survey of Technological Forecasting

a. DELPHI

~~Among forecasting methods we consider first the Delphi technique which is essentially intuitive.~~ Delphi, first developed at the RAND Corporation in the early 1960's, really constitutes a replacement for a group of experts assembled in conference to prepare the forecast. A panel is used with the members being in communication remotely through several rounds of questionnaires transmitted in writing or through a computer terminal. The results of each round are analyzed, integrated, and distributed to the panelists for their use in the next round. The method has several key advantages. First, it preserves anonymity so that one of the problems of a conference is solved: a dominant personality no longer can impose his ideas on the others. Second, the conference becomes much more structured: there are discrete steps, and changes can be tracked. Although convergence is often obtained in two or three rounds, there is no requirement for its occurrence; in fact, Delphi is an excellent mechanism to determine polarization and differences of view. The panelists may well use self ratings to indicate their expertise on a given question and the responses may then be weighted on the basis of the self-ratings. Analyses of Delphi studies have shown that the process is quite well ordered and behaves in a recognizable pattern. It is not chaotic; parallel panels on the same subject tend to produce similar results. The use of Delphi has mushroomed since its introduction in 1964 and has spread to industry, universities, and government. Its relative ease of use makes it particularly attractive.

ECHO

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b. Analogy

Another process of forecasting is that of analogy. We may, for example, use a known technology and its evolution as a base for forecasting a new technology. Much of the technological impact of the space program was foreshadowed by the impact of railroad technology on society in an earlier era. The introduction of detergents to replace soap in the United States was followed by a very similar substitution in Japan a decade later. Before we can use the analogy concept we must assure ourselves that the subject of the forecast and the reference "model" are really comparable. Such evaluation must involve technological, economic, political, social, cultural, ecological, intellectual, and ethical dimensions.

Monitoring

Systematic survey of technical journals, the New York Times, Christian Science Monitor, Wall Street Journal, Fortune, etc. with subjective filters ~~tuned~~ to importance of events, innovations etc. Specified monitoring is easy. Any clipping service can do this for you. Say you want to keep up with swimming pool technology. But Signification monitoring is difficult. What are the items most importantly ~~watched~~ followed? What innovations will bear watching? This takes trained futurists. Don't give this job to your secretary.

c. Growth curves.

Many technological changes exhibit the characteristic that the rate of change of the parameter which measures the technology is proportional to the parameter (exponential growth). To illustrate, the rate of introduction of black and white television sets after World War II was proportional to the number of sets in use. This growth rate means that the doubling time is

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a constant. It has long been assumed that many phenomena such as population and gross national product grow and should grow in this exponential fashion and it has recently come as a shock to many to recognize that nothing on this finite earth can keep on growing exponentially. The imposition of a limit changes the exponential to an S-shaped or logistic curve and this shape must be considered the most fundamental pattern for forecasting. Sometimes the curve is also known as a "substitution" curve: it represents the behavior when a new technology substitutes for an old one. Thus the substitution of synthetic for natural rubber, of margarine for natural butter, of water-based for oil-based house paints, of plastic for hardwood residence floors, and of detergents for natural soaps all exhibited this logistic behavior.

Normative Forecasts

We must divide the techniques of forecasting into two classes: exploratory and normative. With exploratory techniques we move from the past to the future as, for example, in trend extrapolation. In the normative approach, we first look at the future ("necessity is the mother of invention") and then move toward the present. An exploratory approach might be termed a "can do" forecast, while the normative one would indicate what we "ought to do". A useful forecast is the product of the interaction of both elements. We may start in an exploratory fashion and move to a normative mode, whereupon we combine the two (as with the atomic bomb); alternatively, we may start with the normative and then move to the exploratory approach (as with the ABM).

~~that from reciprocating to jet engines in the 1940's. Such a curve may be an envelope composed of a whole sequence of S-shape logistic curves each reflecting~~

e. Normative methods.

Methods such as trend extrapolations are clearly exploratory in nature. Let us briefly look at normative methods of forecasting. Market research provides many illustrations of normative forecasting. Among the newer techniques is the relevance tree or mission analysis. We consider the tasks or missions to be performed in the future and then look for all means or systems which can perform these missions. The systems, in turn, are broken down into subsystems, the subsystems into components, i.e., we create a hierarchy or relevance tree. If we have weightings of the missions at the top level, and place weights on the relationships connecting any two adjacent levels, we can

top down

compare the relative importance of the various items within any one of the lower levels. The result of such an analysis tells us what the relative significance of different systems or components is in view of the mission priorities. In other words, it tells us what may be needed most and needed least. It is obvious that this needs-analysis is quite useful in an organization which has to allocate its resources for research and development activities. Another normative technique centers on the development of alternative scenarios of the future. As with any environmental analysis we must include political, social, economic, cultural, ecological, and behavioral factors and consider the interactions among them to insure internal consistency. Here a technique called Morphology has proven useful for considering alternatives, alternate goals and alternate strategies.

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Finally f. Interactions.

Let us return for a moment to the Delphi method. We have described the procedure and found that in the usual operation a series of statements about the future is made by panelists and then subjected to feedback. A statement may represent a technological or social change. Nothing has been said about the possibility that different statements may, in fact, be related so that the occurrence of one may enhance or inhibit the occurrence of another event in the same list. To illustrate, consider forecasts concerning (a) improved accuracy of weather forecasts, and (b) improved farming efficiency and less crop losses due to weather. Most would agree that these two statements are related: if the first occurs the second increases in likelihood. We have now developed a procedure -- cross impact analysis -- for taking into account these interactions to arrive at an internally consistent set of forecasts. This approach is perhaps most indicative of our recognition of the complexity of systems and of the fact that in such systems nearly everything interacts with everything else. Properly discussed with Delphi

There are other important forecasting techniques used in making social forecasts.

What artists are doing

The young.

Life style of younger groups

Then there a techniques for changing the changers

World Game

Syncon

Delphi

"Experience" Conferences

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PART III

Technological Forecasting

List of Slides

1. Discovery - Application Interval — Figure 1.
2. Aircraft Speed, Military Civilian — Figure 2.
3. Ship Size - exponential — Figure 3
4. Ship Size - S Curve — Figure 4
5. Life Expectancy — Figure 8

Population → 5b

6. Diagram: Exp ~~w~~ S-Curve — Figure 6
7. Exhaustion of Possibilities
8. Logistics Curve — Figure 5
9. The General Growth Curve — (r = -1, +3, ∞)
10. Properties of the General Growth Curve
11. Four Inflection Point Responses — Figure 7
12. Envelopes — Figure 9
13. Two Speed Trend Curves — Figure 10
14. Advanced Development Curve — Figure 12
15. Hahn Strassman Points — Figure 11
16. Substitution, Steam for Sail
17. Annual production of electrical power
18. Incremental Advantage Competition
19. Percentage Advantage Competition
20. Air Travel costs ~~vs~~. year
21. Telephone Costs vs. year
22. Comparison of transportation + communication

Other Forecasting

Expansive - Contraction

23. Optimism and Pessimism in forecasts
24. Temporal Telescopes
25. World Game
26. Syncon
27. Future Shock - Bar Cartoon
28. Decisionable - Non Decisionable, Determination Teleological
29. Niebuhr's Prayer
30. Images - 3 quotes

E.Hechler

Modifying Inputs Necessary to Develop the H-A Soceity

The normative pressures required to minimize the forecast uncertainty and ameliorate the social anxiety reaction are:

- Very accelerated national investment in medical, biological, genetic, behavioral, econometric research.
- Major programs to develop truly scientific methods for the 'soft' quasi-sciences, bringing to bear all the analytical tools of the 'hard' sciences.
- Massive sensing efforts to generate valid data for model construction and social process study.
- Completely revised education process to create the orientation required for future adaptivity.
- Merger of specialist-scientists into macro-specialists by cross-fertilizing educational and research institutions.
- Complete revision of the communications media, especially the TV industry, by creating incentives for a major role in the public re-education for the future.
- Rapidly increasing strength and influence of public ad-hoc commissions to pressure for 'what ought to be' - right up to and including the operation of government and industry, private and public.

List of Transparencies

1. The Perception - Judgement Axis : The Functions
2. Thinking - S - F - I Quadrant Base : The Functions → The Types
3. Overlay: Likes
4. Overlay: Solutions Must
Ov. 5. Perception of time
6. Ov.: View of Change
7. Ov. Basic Anxiety
~~8. Dynamics~~
8. Ov. Dynamics (Motivation)
9. Idividuals to Institutions
10. Industrial Society

TENTATIVE OBSERVATIONAL CONFIRMATION OF DISCRETIZATION IN GALAXIES

A. G. Wilson

The RAND Corporation, Santa Monica, California

Paper Read AAS
Fairbanks, 1963, July 24

Abstract

The design of an observational test to corroborate the theoretical prediction that the diameters, r, of galaxies of low eccentricity* are proportional to an eigen-sequence:

$$[n(n+1)]^{\frac{1}{2}} \quad n = 1, 2, \ldots\ldots$$

must be approached initially in its epistemological aspects. The r specified by the theory as the diameter or semi-major axis of an ellipsoid determined by a surface upon which there exists a discontinuity in some component of the energy-momentum tensor, while well defined for theoretical purposes, is not in general identifiable with any observable feature of elliptical galaxies. In fact, there is question that such a discontinuity may even exist in any observable sense. Compounding the difficulty of correctly relating such a theoretical diameter r to a diameter defined on observables is the fact that the many operational definitions of diameter, whatever the detailed method of measuring, usually involve systematic errors not easily isolated or evaluated. Hence it is extremely difficult to assign meaningful numbers to the ratios of the diameters of elliptical galaxies of different sizes and different distances.

*In accord with present ideas concerning the morphology of galaxies, the only class of galaxies which have members with low eccentricities is the ellipticals. In this paper, therefore, galaxies will mean elliptical galaxies.

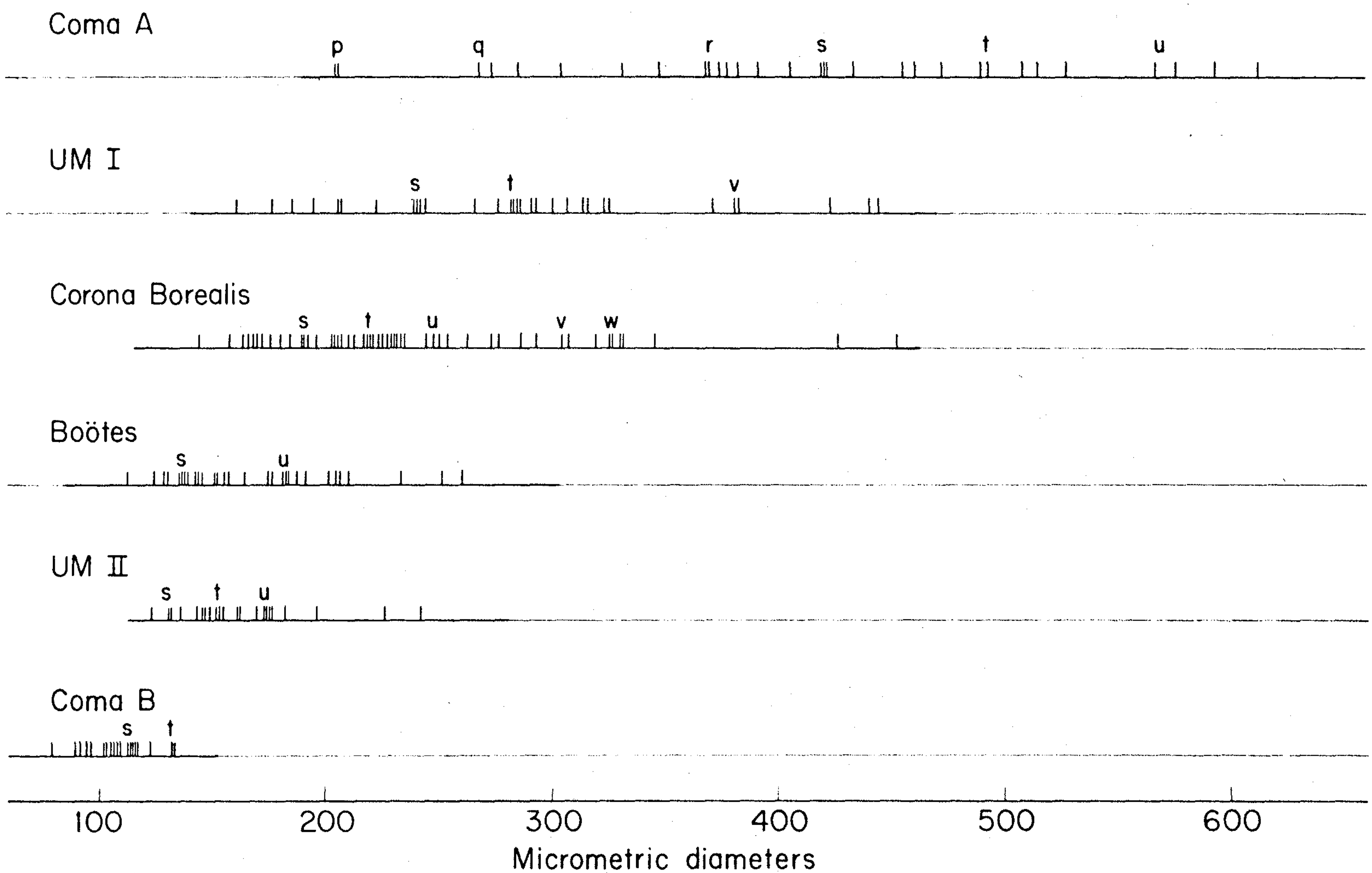
The procedure adopted in constructing the present test of the Edelen discretization hypothesis was to take several specified operational definitions of diameter all of which result in a set of measurements of linear dimensionality and convert these measurements into quantities which may be called proper diameters in the sense they possess the property, when angularly interpreted, of varying inversely with distance. This was accomplished by calibrating the measurements with red shifts, on the assumption of constant proportionality of red shift with distance.

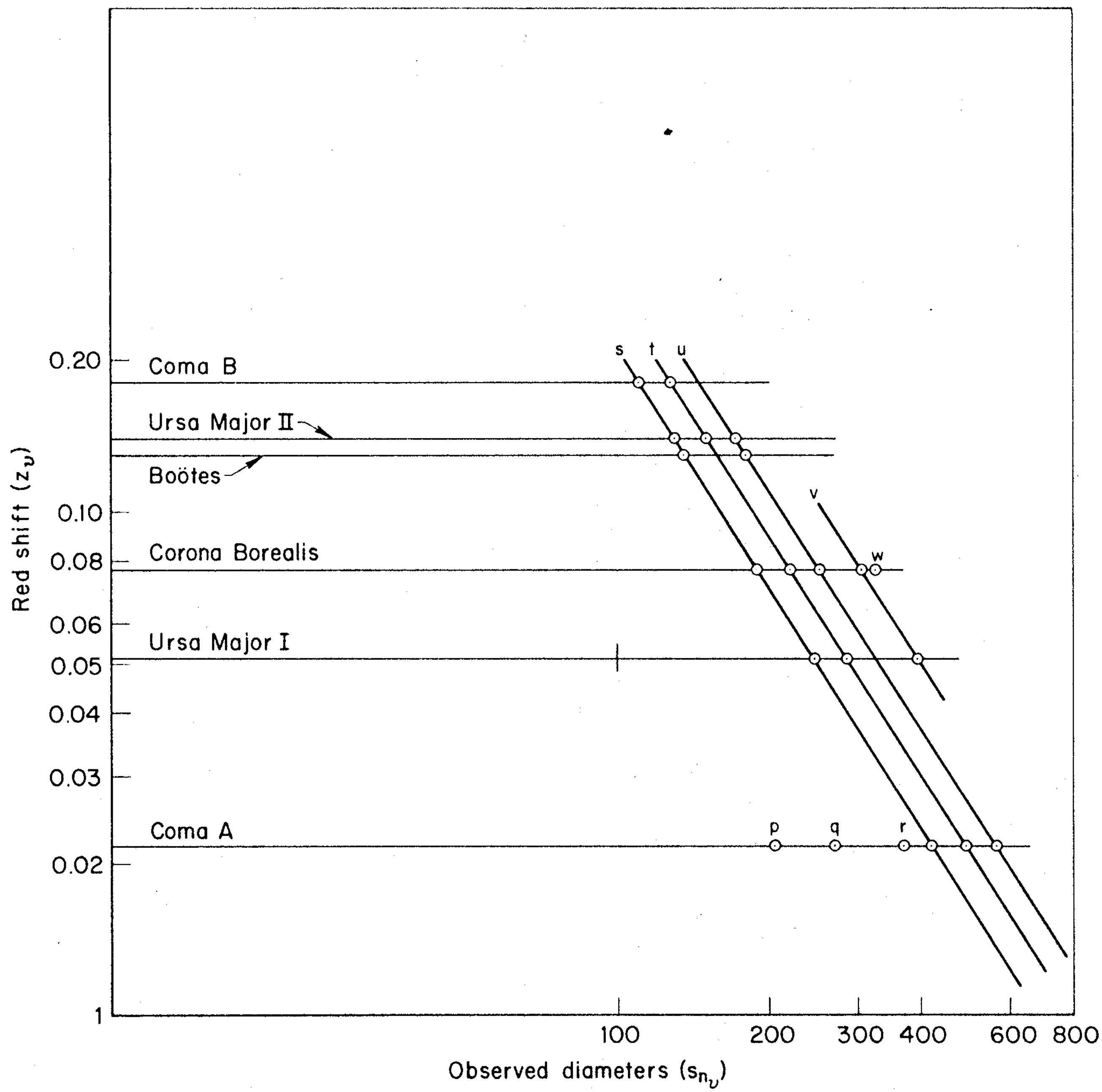
The operational procedure selected for reporting here is that of micrometric measurements. In Fig. 1 the measurements (s) made of images of galaxies on a homogeneous set of photographs of six clusters are shown. The plates were 30-minute exposures taken by Humason with the 200-inch telescope on 103a-0 emulsions. The sample of galaxies measured was selected from probable cluster members having apparent ellipticities of three or less.

Patterns were prescribed for discernment of "signals" which might correspond to the distributions expected from the discretization eigen functions. These patterns were defined by one or more criteria based on (1) condensations at roughly periodic intervals, (2) abrupt gaps on the lower edges of the condensations, and (3) only E0 galaxies at the "band heads" (so called for obvious reasons). The more sophisticated the pattern the rarer the event and the higher the level of noise through which discernment is possible. On the bases of identification of patterns according to these specifications, values of (s) were determined which were thought likely to correspond to a band head signal emerging from the general noise of the data.

The (s) values of these signals are shown plotted against the red shifts of the clusters in Fig. 2. The fact that a set of very closely parallel lines can be unequivocally constructed passing through the (s) values of the signals allows feedback to establish further confidence in the pattern identifications. The signals from each cluster lying on the same line are identified with a corresponding letter designation such as t, u, v, etc.

If the (s) measures are proper diameters, then they must possess the property of linear variation with distance (or some suitable

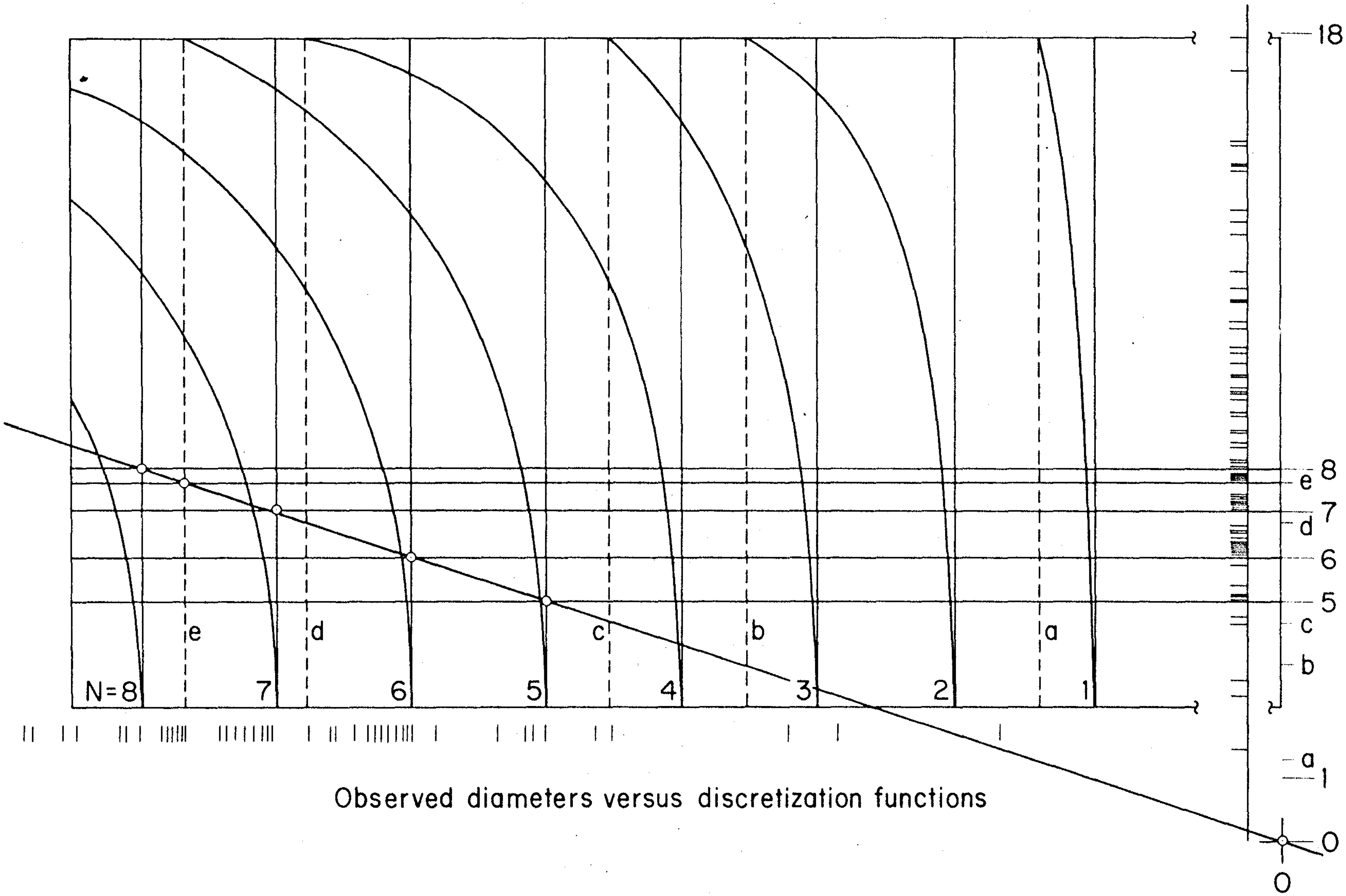

Coma A
p
q
r
s
t
u
UM I
s
t
v
Corona Borealis
s
t
u
v
w
Boötes
s
u
UM II
s
t
u
Coma B
s
t
100
200
300
400
500
600
Micrometric diameters


Coma B
Ursa Major II
Boötes
Corona Borealis
Ursa Major I
Coma A
s
t
u
v
w
p
q
r
0.20
0.10
0.08
0.06
0.05
0.04
0.03
0.02
1
100
200
300
400
600
800
Red shift (z_ν)
Observed diameters (s_{n_ν})

modification of this law) demanded by our restriction on all definitions of diameter. For proper diameters the slopes of the (s) versus red-shift lines should be equal to -1. The observed slopes of these lines are all approximately equal to -1.63. This may be interpreted to mean that all of the (s) measurements are subject to systematic errors which cause small galaxies to be measured as too large and large galaxies to be measured as too small. The observed slope of -1.63 can be used to correct for this systematic error and for any possible physical variations which are proportional to distance, such as possible factors of (1+z) or variations in the parameter ε, simply by raising each measurement to the 1.63 power. In other words if $\theta = s^{1.63}$, then the quantity θ may be considered to be a proper diameter.

The subset of all galaxies with observed ellipticities of one or less were then normalized to the distance of the Coma cluster by means of the red shift ratios, and the resulting distribution of the θ's are plotted in Fig. 3.

The distribution of observed diameters plotted on the right of Fig. 3 is seen to have a correspondence to an expected distribution of diameter sizes based on the eigen functions of the Edelen theory. A scale factor is assumed in Fig. 3 and a line drawn through the origin to demonstrate a possible correspondence of band heads, gaps, etc. The particular correspondence shown is <u>not</u> to be taken as the correct correspondence. It is for illustrative purposes only. Many alternate identifications are possible, and with the probable errors in the observed band heads being greater than the differences in the successive ratios of eigen numbers, no meaningful identification can be made on the basis of this data. All that is to be remarked is that the observations seem overall to be consistent with first-order effects predicted by the theory.



Observed diameters versus discretization functions

In conclusion, on the basis of this data, there appears to be no serious contradiction to the discretization prediction. The consistency of the observed results with regard to the distributions may be accepted as ample justification for initiating programs to investigate discretization phenomena, but should in nowise be considered a proof of the Edelen hypothesis. Hopefully, the present demonstration may prove to be the first of a series of demonstrations which can be used inductively to establish validity. A higher level of confidence can come both from further direct tests along the lines of the present one and through applications of other consequences of the theory. There is no question that if this theory proves true, as is presently indicated, it constitutes a major breakthrough in extra-galactic astronomy and cosmology.

Theory of Structures

A. G. Wilson
12/7/67

TRAFFIC DENSITY AND SYNAPSE DENSITY

It is suspected that there exists a bound to the ratio of the traffic density in the neighborhood of a synapse to the mean spatial density of the synapses themselves. Such a bound appears as the possible explanation of Zipf's Law and the Scott Effect, relating the brightest star in a galaxy to the number of members of the galaxy.

We shall assume a spherical aggregate of N spherical synapses, each of mass M and radius A. The radius of the aggregate will be taken as R. The mean spatial density of synapses will be

$$(1) \quad \bar{\rho} = \frac{3NM}{4\pi R^3}$$

There is assumed to exist a flow of traffic into or out of each synapse. This traffic may take the form of mass particles, energy packets, information packets, or field effects. For example, if the synapse is a city, the traffic may be aircraft, motor vehicles, or telephone messages. If the synapse is a star, the traffic may be material particles (protons, electrons.....), photons, neutrinos, or gravitons. If the synapse is neural, the traffic may be nerve impulses. This traffic is channeled by the nature of the nexus which connects the various synapses. For a city, the nexuses may be the highways, the rail lines, or the air routes leading into the city. In the nervous system the nexuses are the nerves themselves. For a star, the nexus is the field space surrounding the star. This may be ordinary Euclidean space with the nexus permitting a 4π solid angle or it may have more restrictive geometric and topological properties.

I. 4π Nexus

Let us assume that the energy packets may be represented by equivalent masses m. The flux F of these packets will be proportional to the number n crossing a surface of radius r in time T. If v is the velocity of the packets at the surface r, then the energy flux F per unit time per unit area will be,

$$(2) \quad F = \frac{n(mv^2)}{4\pi r^2 T}, \quad [F] = \left[\frac{M}{R^3}\right] \left[\frac{M}{T^3}\right]$$

From Equations (1) and (2) the ratio γ of the traffic density F to the synapse density ρ is

$$(3) \quad \gamma = \frac{F}{\rho} = \frac{n}{3N}\,\frac{m}{M}\,\frac{R^3}{r^2}\,\frac{v^2}{T} \quad \text{with } [\gamma] = \left[\frac{L^3}{T^3}\right]$$

i.e., the dimensionality of the ratio of densities is that of a velocity cubed. This dimensionality is bounded in relativistic physics by the quantity c. We therefore assume (4) $\gamma \leq c^3$.

Example:

The traffic is the radiation leaving a star. In this case the energy packet mv^2 becomes $h\nu$. Substituting in (3)

$$\gamma = \frac{nh\nu R^3}{3NMr^2T}$$

But the bolometric luminosity of a star, $L = nh\nu/T$, i.e., the total energy per unit time (take T = 1 sec.), hence

$$\gamma = \frac{L}{3NM}\frac{R^3}{r^2}$$

$\gamma = \frac{L}{4\pi r^2}\frac{1}{\bar\rho} < c^3$ $\quad L < 4\pi r^2 \bar\rho c^3$

or $l < \bar\rho c^3$?, apparent luminosity gives lower bound on density

But r is arbitrary so long as $r \geq A$. We may, therefore, take r as equal to A.

For a star $\frac{GM}{c^2A} < 1/2$. Thus setting $r = A$, *and multiplying* we obtain

$$\frac{2}{3}\frac{GL}{c^2N}\left(\frac{R}{A}\right)^3 < \gamma < c^3$$

or

$$(5) \quad L < \frac{3}{2} N \left(\frac{A}{R}\right)^3 \frac{c^5}{G}$$

It turns out that $\frac{A}{R} \doteq 5^{-1/2}$ giving $L \sim N$ ergs/sec where N is the no of stars in the univ.

The expression (5) says that the energy emitted per unit time is less than a constant times the ratio of the volume occupied by the synapses when close packed to the volume actually occupied.

The maximum value of the bound is when the synapses <u>are</u> close packed. In this case we get the maximum luminosity, $\hat{L}$,

(6) $\hat{L} < \frac{3}{2}\frac{c^5}{G}$ power bound

The right member of expression (5) can be evaluated. Assume the following values:

log N = 11.6 stars in a galaxy

log A = 10.84 in cm, radius of star

log R = 21.8 in cm, radius of galaxy

log c = 10.48 in cm/sec, velocity of light

log G = -7.16 c.g.s, gravitational constant

Giving log L < 38.46 ergs/sec.

Using the relation,

$$M_{bol} = M_{bol\,\odot} - 2.5 \log (L/L_\odot)$$

with $\log L_\odot = 33.59$ and $M_{bol\,\odot} = 4.72$

(3.90×10^{33} erg/sec) Allen p. 161

we get $M_{bol} = -7.45$

The maximum absolute magnitude of galactic novae is

$M_{pg} \sim -7.5$ (Allen p. 214)

why?

(using $\log L_\odot = 33.59$ and $M_B = 5.41$)

$M_B = -6.76$

Hence the bound given by the assumption (4) is in excellent agreement with the maximum value of absolute nagnitude observed in the galaxy. (Super giant stars have $M_{pg} = -6.8$.) Supernovae will be discussed separately.

It is of interest to evaluate the maximum possible luminosity of a radiating object under the assumption (4). This may be done in equation (6). Using the same values as before, we obtain

$$\log \hat{L} < 59.74 \text{ ergs/sec}$$

This is essentially the power value for quasars, according to the cosmic distance hypothesis (Hoyle and Fowler). We thus have as a consistent interpretation of equation (6), that whenever a set of stars are close packed (or one star not a member of any aggregate), that the luminosity can be a maximum and has the value $10^{59.74}$ ergs/sec. This does not permit the mass of the quasar to be derived, but it suggests that quasars may possess a wide range of masses all having essentially the same luminosities. It is accordingly their <u>lifetimes</u> that vary with mass not their luminosities.

Equation (6) may alternately be derived by setting $r = R$, the radius of a galaxy, and using

$$\frac{GNM}{c^2R} < 1/2$$

which gives (6). This would lead to the conclusion that quasars are ~ galactic mass.

Let us evaluate L in equation (5) under the same conditions of N, R, etc., but assume that A, the stellar radius is that of a giant star instead of a main sequence star, i.e., log A ~ $10^{13.2}$ cm

	$R_\odot$	cm
ζ Aur	190	$10^{13.12}$cm
32 Cyg	353	$10^{13.37}$cm

From equation (5) we get

$$L < 10^{45.5} \text{ ergs/sec}$$

or

$$M_{bol} \sim -24 \text{ or } -25$$

This corresponds approximately to the luminosities of <u>supernovae</u>. (The values of N and R sould be selected for other galaxies.) It thus appears that supernovae correspond to giant stars and novae to main sequence stars under assumption (4).

Equation (5) shows that for a fixed type of star (A fixed), that the maximum luminosity depends on the <u>density</u> of the galaxy in which it is located, such that the greater the density the brighter the maximum. However, since $2GM \sim c^2R$, the mass increases with R not with R^3. Hence for a given type star, i.e., A, M fixed, $\frac{N}{R^3} \sim \frac{1}{R^2}$. Hence the bigger the galaxies the less luminious their giants. This is consistent with the maximum population II stars being fainter than the population I stars and the elliptical galaxies being more massive than spirals.

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DIMENSIONLESS PHYSICAL CONSTANTS IN TERMS OF MATHEMATICAL CONSTANTS

It is of interest to note that the present empirical values of two basic dimensionless physical constants may be approximated to within experimental uncertainties by a simple logarithmic expression involving π. With the usual notations, the Sommerfeld fine structure constant $= 2\pi e^2/hc$, and the ratio of Coulomb to gravitational forces $S = e^2/Gm_p m_e$ are given by

$$\alpha = \frac{1}{2+w} \quad \text{and} \quad S = \frac{2^w}{2\pi^2}$$

Where $w = \pi^4 \log 4$ (natural logarithm), the numerical value of 2+w to nine digits is 137.037664. The present measured values [1] for α^{-1} are:

137.0388 ± 0.0006	Triebwasser, Dayhoff, Lamb
137.0370	Robiscoe
137.0352	Hyperfine splitting in Hydrogen
137.0388 ± 0.0013	Hyperfine splitting in Muonium
137.0381 ± 0.0032	Electron magnetic moment anomaly
137.0361	Hughes

The numerical value of $\log_{10} (2^w/2\pi^2)$ is 39.355058. The present indicated empirical value of $\log_{10} S$ lies between the three σ limits 39.357 and 39.355, the largest part of the uncertainty being in the value of G. The three σ limits of S are $2.27(01)\times10^{39}$ and $2.25(46)\times10^{39}$, whereas $2^w/2\pi^2 = 2.264947 \times 10^{39}$.

From these two relations a third numerical relation

$$G = \frac{8\pi^2}{2^{1/\alpha}} \frac{e^2}{m_p m_e}$$

may be derived. This equation, giving G in terms of other fundamental physical constants, is independent of W.

Although one may be reminded of relationships derived by the late Sir Arthur Eddington, the quantity W used here has no known physical basis and the approximations are quite possibly all fortuitous.

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THE DIMENSIONLESS PHYSICAL CONSTANTS AND
BASIC MATHEMATICAL CONSTANTS

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Eddington held that the dimensionless physical constants could be evaluated as simple mathematical expressions. His approach to this conjecture was through a construct established by purely rational arguments from which the values of the dimensionless physical constants could be derived solely by mathematical inference [1]. His success in proving his conjecture by means of the fundamental theory has been generally questioned. The difference, for example, between the derived 137 [2] and the observed 137.0388 [3] is considered by many to be unsatisfactory in view of the essential claim to derive the observed world from first principles. However, because of the philosophical implications which Eddington's conjecture has for the foundations of physics, it is important to know, regardless of the validity of Eddington's fundamental theory—or other theory—whether the conjecture is true. But apart from the context of a theory can the conjecture have a meaning?

Meaning may be given to the conjecture, without an explicit theory, if two specifications are agreed to. (1) A specification as to degree of fit between the observed value and the mathematical value, and (2) a definition of simple. The form of specification No. (1) which most physicists would insist on is that the fit be such that the difference between the mathematical and observed values be less than the experimental uncertainty in the observed value. As subsequent experiments improve the observed value, the difference must remain less than the new observational uncertainties. In this sense the mathematical value legitimately plays the role of a hypothesis, i.e., the hypothesis that a purely mathematical expression, M ≡ the value of the dimensionless physical constant. If refined observation shows the observed value does not converge to M, the hypothesis fails to make valid predictions and is discarded. So long as the observed value continues to converge to M, the hypothesis may be used as any conventional hypothesis derived from theory. This is quite conventional.

A satisfactory convention for specification No. (2) is more difficult to formulate. Any numerical quantity can be approximated to any degree of accuracy by sophisticated combinations of basic mathematical quantities. What one considers to be a simple expression is ultimately a matter of personal taste. To avoid these difficulties, we propose as a possible approach, to specification No. (2), the introduction of the requirement that the same mathematical expression occurs in at least two of the dimensionless physical constants. By this demand the aspects of simplicity and improbability of occurrence serve as checks on one another. An expression which begins to reach a level of complexity which exceeds the threshold of permissibility as simple, and therefore appears to be ad hoc, is at the same time reaching a level of improbability of simultaneous occurrence by chance in two or more cases. Hence involvement in two or more instances restores the expression to continued interest as arising from real, albeit unknown, relationships. The essential feature of meaningfulness—interpretability through theory—is deferred. The existence of sufficiently accurate replication of a phenomenological feature together with a sufficiently large improbability of this being a chance occurrence combine to create confidence in significance and ultimate interpretability by theory. Reasoning such as this has been implicit in the rationale for continuing interest by astronomers and physicists in observed, but inexplicable features, such as the Titius-Bode Law and the numerical coincidences which occur between certain atomic and cosmic measurements.

In this epistomological context, the following hypothesis "M" is proposed: In the usual notations, two dimensionless physical constants, the Sommerfeld fine structure constant

$$\alpha = \frac{2\pi e^2}{hc}$$

and the ratio of Coulomb to gravitational forces.

$$S = \frac{e^2}{Gm_p m_e}$$

are given by the following purely mathematical quantities

$$\alpha = \frac{1}{2 + \omega}$$

and

$$S = \frac{2^{\omega}}{2\pi^2}$$

where $\omega = \pi^4 \ln 4$ ([illegible] natural logarithm). The mathematical value of α^{-1} to nine significant digits is 137.037664. The present observed values [3] for α^{-1} are given in the table.

137.0388 ± 0.0006	Triebwasser, Dayhoff, Lamb
137.0370	Robiscoe
137.0352	Hyperfine splitting in Hydrogen
137.0388 ± 0.0013	Hyperfine splitting in Muonium
137.0381 ± 0.0032	Electron magnetic moment anomaly
137.0361	Hughes

For specification No. (1) mean values and "adopted values" are of less interest than the array of recent determinations given in the table.

The logarithm to the base 10 of the mathematical value of S is 39.355058, while the present observed value is close to 39.356. A more accurate observed value cannot be given until better determinations of the gravitational coupling constant G have been made.

The quantity $\omega = \pi^4 \ln 4$, appearing in the mathematical values of both α and S thus satisfies specifications No. (1) and No. (2). The occurrence of ω in both numbers reduces the likelihood of its being ad hoc, yet it is still a "simple expression involving only integers and the basic mathematical constants π and e. Granting the epistemological rationale of the two specifications, we conclude—until more refined observations contradict the mathematical values—that Eddington's Conjecture is true.

An immediate consequence of the truth of the conjecture is that the dimensionless constants α and S do not vary with time. This does not preclude the separate variation of G, h, etc., but requires any variation of fundamental constants with time to be such that

$$\frac{d}{dt}\left(\frac{2\pi e^2}{hc}\right) = 0 \text{ and } \frac{d}{dt}\left(\frac{e^2}{Gm_p m_e}\right) = 0 \ .$$

There is no known theoretical relation between G and the other fundamental constants of physics. ~~Consequently~~ Hence, a second interesting consequence of the mathematical formulae is a possible relation linking G and the charge to mass ratio of the electron:

$$G = \frac{8\pi^2}{2^{1/\alpha}} \frac{m_e}{m_p} \left(\frac{e}{m_e}\right)^2$$

This equation may have interesting implications for relativistic electrons.

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