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The Organizing Principle of Complex Living Systems

A scheme is outlined for a useful way to think about the complex biological organism, man. It is based on physiological findings that the regulating and control functions in the system make use of active processes, exhibiting oscillatory properties [1].[1] The resulting homeostatic regulation, which was the key concept proposed by Bernard, Sechenov, and Cannon for the living system [2], emerges from mediation of these oscillators. Because of its dynamic character, the scheme is renamed homeokinesis [3]. The concept may be extended to man's behavioral complex. In outline, it touches on all the time or frequency domains in life—that is, of the many episodes in man.

Instability and the Nature of Life

As a suitable engineering definition [4], we may provisionally define a life-like system as any compact system containing an order and distribution of sustaining nonlinear limit cycle oscillators, and a related system of algorithmic guide mechanisms, that is capable of regulating its interior conditions for a considerable range of ambient environmental conditions so as to permit its own satisfactory preservative operation; that is capable of performing these preservative functions for a long period of time commensurate with the "life" of its mechanical-physical-chemical elements; and that is capable of recreating its own internal systems, or being recreated, out of materials and equipment at hand in the ecological milieu.

An essential characteristic of a living system is its marginal instability. Its principal dynamic properties are that it hungers, feeds, and can move or creep so that it can continue to hunger, feed, and move or creep. At the right unfolding time, it couples and reproduces so that the newly formed unit can hunger, feed, and move about. Both the external and internal environment constantly present the organism with an impulsive (vicissitudinous) input against a background of the slowly searched, changing milieu. As a result, the motor systems of the organism are plunged into intermittent search modes to satisfy all of its hungers.

Similar to the character that we have identified with the entire complex organism, we incline to agree with Waddington that it is unlikely that anyone before Brian Goodwin conceived of or argued so forcefully that the biological cell too is an oscillator system [5].

Internally, there are many active biochemical chains organized around the emanations from cells [6]. These chains are parametrically unstable, and the changing internal milieu provides ever-present input excitation of their state. We use the term chain to stress that we are discussing causal chains of events and elements that are not absolutely fixed spatially. Many of these chains in fact have external links.

Functionally, at all levels, the key principle by which the living system is organized is dynamic regulation of its internal degrees of freedom (concentrations, potentials, fluxes). This is achieved by the mediation, mainly by inhibition or release from inhibition, of a manifold of oscillatory (or rhythmic) processes which make up the many biochemical chains in the organism. It is by a number of modulating schemes—generally asymmetric—that these processes change and regulate the mean parametric states. These regulating chains tend to be organized hierarchically at a sequence of temporal levels.

Structurally, what is common among the internal organs is organization of their actions into essentially closed chains of biochemical-mechanical-electrical nature, involving the solids, liquids, and gases in the body; e.g., the breathing, heart beat, voiding chain. The systems exhibit complexes of stable, rhythmic limit cycles, often passing through transitory stages as the organism is affected by changing contingencies in the external milieu.

The function of the central nervous system, with its memory, communications, computational, and learning capabilities, is to provide algorithmic content capable of mediating the stability of the internal chains, so that a satisfactory pattern of behavior emerges among the organism's many behavioral modalities (such as eating, voiding, sleeping), perhaps twenty in all in man. It modulates the systems into modes.

The scheme of regulation by which these oscillator systems are modulated through their nonlinear stable operating range we name homeokinesis. It is chosen to stress and extend the principle of homeostasis by which regulation of parameters in the internal watery milieu, independent of the vicissitudes of the external milieu, is the condition of life. In extension, it is only by the manipulation of kinetic variables of space and time—namely, by mediation of the limit cycles—that the scheme can be achieved.

What results is a behavioral patterning whose richness depends on the topology of the central nervous system rather than on its size, in which the successful organism threads its hungers so that the emergent patterns fit the ecological-ethological environment and the modalities of the system. Behavior is essentially periodic, episodic, and repetitious. Individual or species failure may be marked by patterning that saturates, or that goes into violent oscillations with regard to its hungers.

The motor-actuated living system unfolds its states, posture by moment. In each posture (the action of the body on the body), the system is temporarily locked into an orbital constellation of all of its oscillators. The psychological-physiological "moment" then changes from instant to instant. The biological spectrum emerges from the many oscillatory chains that enter into the constellation.

Salient characteristics of the system include, first, the turnover of material. Although form and function tend to be more fixed, the actual chemical constituents of the biological "factory" are all in flux. Second, there is a fixity of form and function which can be identified at three levels: (1) the *metabolic* high-frequency domain in which the operating chemical chains exhibit their character as modulations of a mean state; (2) the

[1] Numbers in brackets designate References at end of paper.

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epigenetic medium-frequency domain in which the fixed genetic coding unfolds with links that can only be formed from the content and experience derived from the external ecological milieu; and (3) the *genetic* frequency domain, which is rate governed with a long-time relaxation phase and a short escapement phase, in which chemical coding exists for the dynamic gating of catalysis by which structural-functional hereditary chains of reliable reproduction emerge.

The Spectroscopy of Man—Organization in Space and Time

Study of such a mobile dynamic factory may be tackled effectively by dynamic systems analysis. This requires a technical decision as to what processes are of concern at the shortest time and the smallest spatial element of interest. Within these limits, spectroscopic analysis of spatial and temporal effects can be attempted. The lower functional levels are illustrated by the distributed capillary bed in which near 10-micron free red cells interact with 1-micron capillary system walls; by the glomerulus;[2] and by the distributed communications unit in the local neural net. The time scale limit is about 0.03 sec. Extensive electroencephalography of the brain cannot find significant organized content below this limit.

At the upper limit, the isolated animal is our unit. Beyond lies the province of the social sciences, although behavior begins on the unit-to-unit interaction. The long-time limit is the single "relaxation" process that is a man's lifetime. More restrictively, it is the failure of one or more internal systems that marks the beginning of a degradation phase. The temporal spectrum of behavior is centered, grossly, much closer to 30 days than to a lifetime; yet the 15 years to adolescence must also lie within focus. However, it is necessary only to bring the family unit of mother-father-child and the peer group just barely onto the stage.

In addition to sustained spectral elements, at the gross organizational level there is a number of aperiodic flaring instabilities that govern the individual's history. These are determined by maturational cues to the central nervous system. The first is that of birth and the mother-child constellation. The mother teaches the child routines of living by whose repetitive patterning the child can survive. A plastic brain develops and encompasses a multidimensional image of the body—its interior and surface—and the external world. Guide rules emerge which lead to successful patterning of the rhythmic modes that are represented in the body image.

[2] A tuft of capillaries which normally passes a protein-free filtrate from the blood into the proximal convoluted tubule.

In a subsequent peer or chum stage, the youthful organisms play and practice routines until they are well adapted to the milieu. Interpersonal forces begin to develop the socializing constellations that are a condition for sustaining life. At the right time of epigenetically emergent adolescence, male-female constellations are formed that lead to reproduction.

At the macroscopic level, why individuals are bound into orbital constellations that make up the content of bio-, psycho-, socio-spectroscopy is a mystery. A model is suggestively found in the quantum mechanical system known as exchange forces. An individual projects his body image—totally or in part—into the other object's shell. This image and the physical image are internally compared, for their complementarity or congruent character. From this exchange of body image arises empathy, antipathy, indifference, all the shadings possible of interpersonal force. It is a binding to be likened to the analogous quantum process that binds atom to atom as a shared electron c oud.

At the atomistic (high frequency, small spatial field) level of the biological system, the cellular level and its emanations, the essential processes are the genetic coding and replication, the energy-releasing chemical reactions, and the complex of catalytic reactions, essentially enzymatic, that lead to synthesis of materials for both structural form and function. The unit processes involved are, typically, transport, conduction, convection, diffusion, bipolar stress, and chemical linking. However, the mechanisms of oscillating biochemical reactions have not yet been determined [6].

The spectrum of such biochemical chains is not continuous, nor even densely populated. Instead, it appears that there is a rather limited time fracturing (or time locking) around which processes tend to form and be cooperatively involved. There apparently exists a rather limited finite matrix of regulated elements. Its columns are elements given by the metabolic reaction (fuel, oxygen, water, carbon dioxide), some other chemical constituent streams, typically electrolytes; its rows are time scales. There seem to be regulating chains that fit many of the temporal intersections. Not all animal species use exactly the same chains or time scales, but the density is similar.[3]

Within the space and time domain that represents the individual, his characteristics can be presented as a spectrum, Fig. 1. It is the analog of spectroscopy for atomic or molecule structure.

[3] While this covers the functional portion of the matrix, it neglects the structural portion of the matrix, in which many steps of synthesis take place by which structural form and functional specificity are assured.

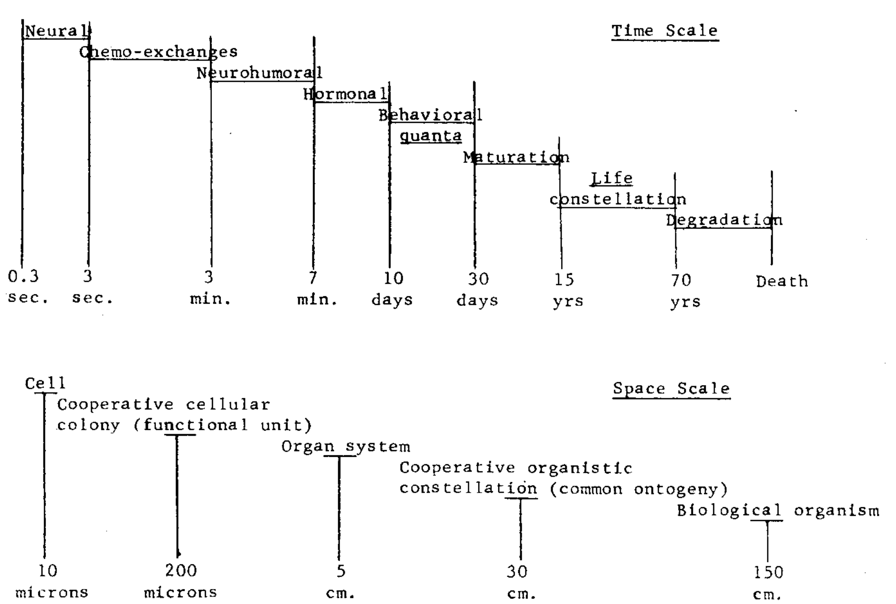

Fig. 1 Dynamic spectrum for man

(The schematic figures grossly specify the essential regimes.)

The High-Frequency Biochemical and Electrical Foundations

An introduction to regulation and control in the complex biological system may be usefully viewed in terms of a series of polar concepts. The hierarchical control systems are chemical and electrical. In the main, control is exercised through an electrically sensitive structure—the membrane. Roughly speaking, chemo-electrical mediation of the membrane controls electrochemical processes within the membrane. The two major coordinating membane systems are: the capillary membranes, controlling chemical flux exchange of the capillary; and the nerve membrane, controlling "informational" flux exchange (of electrochemical nature).

Communication in the organism goes by two channels: "to whom it may concern" messages go by hormones in the blood—i.e., by chemical signals; and specific messages to particular places go by nervous impulses—i.e., by electrical signals. The latter, so far as housekeeping controls are concerned, are mediated by the antagonist autonomic systems, both of which use acetylcholine in intermediate relays; but only one, the parasympathetic system, like the motor nerve, uses it in the target organ. The other sympathetic system uses it peripherally in two ways: one locally, in the target organ, and the other by throwing it from the adrenals into the blood stream, like a hormone—which has a circulation delay of some seconds before it reaches its target and, typically, a release time of several minutes. Together, these half-systems control vasoconstriction and dilation. Their principal central controls reside in the hypothalamic and deep centroencephalic structures.

As a rudimentary description at this level, signals received from the milieu—both internal and external—excite the nervous system into transient states. Its chemo-electrical communications signals modify the stability of chemical chains via the endocrines or neuroendocrines. Follower characteristics to the nervous system state emerge to support the motor excitation that provides the system's movement. In longer term, it is actually likely the persistence of chemical signalling—starting from conception—that forms the algorithmic content of the nervous system's transient response which is identified as behavior.

Without the nervous system mediating the biochemical chains, their predominantly unstable characteristic would show up. The nervous system is thus the mediator between information—a measure of contingencies in the surrounding milieu, both internal and external—received as sensory input, and the unstable motor and glandular systems. The resulting pattern is a controlled synchronization in which most systems are regulated in a limited oscillatory range by repression or inhibition, while some are released from inhibition and spring into orbit. System motion proceeds by the scheduling of these orbits in time, unfolding its repertoire of behavior moment by moment.

While higher frequency rhythms—including the brain "waves" of the cortex, as well as the aperiodic pulses and trains of pulse-like potentials associated with nervous paths—are sometimes overlooked in considering the large-scale and long-time integrative action of the system, they are always present. They involve chemo-electrical escapements. They utilize mechanical and hydraulic links. Their presence makes it impossible to view the system, at any level, as static. However, conversely, they are not the communications language of the system. Their buzz is not the information flux, only an indication that the system is dynamically in flux. Decoding the internal communications and transport fluxes is a difficult matter.

The informational influx arrives from about 10^8 transducers for electromagnetic waves and about 10^6 for chemical and mechanical reception. Some of these have short delays before initiating millisecond pulses in the first input neuron, but it is trains of about 7 or more impulses in each of several parallel neurons that constitute its signals to subsequent neurons. Hence the spectrum begin at about 100 Hz. The fastest closed loop through the muscle and brain takes twice as long. Cortical tasks, like locating a spot of light, require a moment of about 0.1 sec. Similar informational fluxes from internal transducers course through the nervous system so that some of the subsystems of the brain, notably the hypothalamus, are informed by these signals from the heart, lungs, gut, arteries, both baro- and chemoreceptors, as well as the body's muscles and joints. These informational winds of the milieu, external and internal, coursing through the brain, update its model of the body and the external world at approximately 10 Hz. Posture and movements induced by muscular activity are reported by the electrical coupling from mechanical, hydraulic, and perhaps electrical or chemical receptors. Information is yielded in two ways: tremors furnish the information as to posture; and, in movement, the information is derived from the motion apparently accompanied by an inhibition of the tremor.

The hypothalamus is the highest automatic regulator of the potential state variables in internal organs, glands, and the blood vessels. It patterns the response of autonomic systems at a medium-cycle time scale of minutes. This includes hormonal control through the pituitary portal system, forming a switchboard that operates in a ring oscillator mode, cycling through its affector variables. It acts as a slow follower on chemical signals produced within those various internal systems.

A most significant signal is the socially conditioned high-speed adrenalin signal, generally seen in the anger, fear, fight, flight autonomic response from the adrenals. One component of this adrenergic response of the nervous system, high-speed production of adrenalin at nerve ends, outlines the system at the one-tenth second level. This is used as an "arousing" signal or "groping" signal for what the instantaneous properties or status of the system is, and what may likely be the fact of the external world. As a sustained small-signal excitation, it helps keep the internal systems sufficiently regulated to face the motor system demands that may be placed on it by the command system, and to ready the system for follower action.

It is the reticular core furnishing discrete informative signals to the rest of the nervous system—in the 0.1 to 0.3-sec range—that provides the sustained grouping signal. The adrenals furnish large-scale regularizing or follower signals throughout the blood system at the 1–2 min level. The hypothalamus then provides follower action at the 5–10 min level.

It is generally accepted that the reticular formation likely is the large-scale arousal system in the brain. As a parallel core system throughout the neuraxis and midbrain, it has connections to all levels of the nervous system. Acting as a probabilistic computer based on all internal and sensory inputs, it controls the arousal of the system with regard to the direction and level of attention and of motor activity.

The most meaningful hypothesis is that signals from all sources run up and down the reticular core which contains the potential command system to commit the organism as a whole.

High-frequency behavior has characteristics that can be readily seen by watching any animal. The system is basically unstable. If you put the organism down, it will soon start to move. If it exhibits extensive motion, in time it will stop. Whatever the inputs, whether nearly constant, or changing, the system changes. It changes its postural dynamics. Furthermore, men do this routinely at a rate of approximately 10 per minute. These changes can occur within a few nervous "beats"—"moments" of up to 0.3 sec. Once developed, whether by learning or otherwise, these responses are subcortical. (In the response of the body to the external world, they may retain and require a cortical contribution, as illustrated in speech.)

Illustrative of postural elements are: postural attitudes of parts (head, feet, body, hands); dynamics of parts (e.g., scanning for movement); characteristic movements (yawn, stretch, rapid eye movement, laugh); insecurity stereotypes (tics, twitches, scratches); sweat response; saliva response; voice pitch.

At high speed, the reticular system can act on displacement, velocity, or acceleration inputs within 0.1, 0.2, or 0.3 sec. Its core can obtain information and provide the command for about 15–20 kinds of actions. Logically, the reticular core operates as an abductive system (in the Aristotelian sense). It commits the system. It questions whether an information state is a case under one rule or another and takes a decisive action that actuates the controllers of controllers; i.e., it is a command system. In doing so, it may or may not consult the cortex.

The subcortical dynamic postural elements make up a manifold of responses. A classification of the chemical foundations of those response elements, for example, among the endocrine systems involved, does not exist as yet.

The subcortex sets various internal systems into orbital paths. The three large slower follower systems seem to be:

(*a*) The adrenalin-blood system. A major follower element seems to be the oxygen flow available to the tissue (as marked by the red blood cells) through the capillaries. The flux wave, involving concomitantly other metabolic elements—sugar, carbon dioxide, water, lactate, heat production—in dynamic cycles, likely represents the "escapement" for the thermodynamic power cycle of the system. (The physical view of organized energy transfer is the task of thermodynamics. Such transfer involves a sustained temporal process and, thus, an escapement, unless tied uniquely to cues such as light-dark, or seasonal changes. Simpler biological systems that are tied only to cues may exist. The complex human, homeokinetically operating, is freed from the vicissitudes of the milieu. Thus it must be self-timed.)

(*b*) The hypothalamus (at the minutes level, with a connection to the pituitary system as the master regulatory endocrine gland).

(*c*) The pituitary gland.

In the lower animals, the reticular system contains the entire executive logic of arousal and shutdown of function. In the higher animal, the reticular core assigns the (phylogenetically) newly emergent role of induction to the cortex. If the input pattern is not a case that is fitted by standard analog patterns immediately available from the basal ganglia, the case is referred quickly (e.g., within 0.1 sec) to the cortex. The cortical memory (whose storage place is as yet unknown) is an analog memory of many past cases. Presented now with external patterned "facts," it "guesses" at a law (i.e., it wires together a network response that excites the motor oscillators into action). The cortex "takes" habits. Once these are set up on the motor side, the cortex is often no longer involved and the solution analog may be transferred or formed within the basal ganglia.

In primates, the cortex is very busy with optical signals. This is the "price" the biological system pays for a precise invariant field. (Other fields are not outlined with such detailed precision and consistency.) In man, it is also quite busy with verbal signals. There are well defined regions associated with speech.

To attempt to adequately describe the central nervous and endocrine system components, and the currently known or suspected functions of the divisions of the brain and endocrines, is beyond our present task.

The Medium-Frequency Range of Behavior

We now approach the medium time of behavior—the 1 to 1000-hr time domain. This is the time to go on vacation, get drunk, fall in love, take a job, get an important idea, get married, menstruate, commit suicide. Its unit of cueing will have a time constant of the order of the female menstrual period.

Common in philosophic-pyschological speculations are aspects of the mind-body problem, such as the distinction between responses that may be closely coupled and "wired" from input to output by an interposed, mechanistic, indeterministic system. Much of the argument can be avoided if it is recognized that our present concern is the result of changes in the state of the internal inputs to the central nervous system, rather than to external inputs, for in this time scale one day is much like another, and one week like another.

Behavior is drawn as patterns, it seems, from the concurrent connected internal states of the biological system given in Table 1. They may be identified as dynamic action modes of the system, such as "The system sleeps."

Table 1

Action modes	Percent of time
Sleeps	30
Eats	5
Drinks	1
Voids	1
Sexes	3
Works	25
Rests (no motor activity, indifferent internal sensory flux)	3
Talks	5
Attends (indifferent motor activity, involved sensory activity)	4
Motor practices (runs, walks, plays, etc.)	4
Angers	1
Escapes (negligible motor and sensory input)	1
"Anxious-es"	2
"Euphorics"	2
Laughs	1
Aggresses	1
Fears, fights, flights	1
Interpersonally attends (body, verbal or sensory contact)	8
Envies	1
Greeds	1
Total	100% ± 20% of time involvement

An essential characteristic in this longer time domain is the instability of the nervous system. The animal tends to develop an internal rhythm dominated mainly by endocrine chains arising from changing threshold cues; the actual performance is conducted largely at a subcortical level. Social activity and intellectual activity all are ritualistic past the minor originating cues.

A most significant element in the organization of behavior is the use of cues. (What should be noted is the large number of geographic, social cues.) In case of a temporally or spatially cued input, the animal will develop a ritualized behavior. (By definition, a patterned response which is stereotyped.[4]) It likely follows from the system instability. An animal cannot maintain undischarged nervous excitation energy, but must seek to release it by releasing the inhibition on some motor response system so as to unstabilize it into orbital action.

What is particularly noteworthy in the biological system is the patterning of behavior that runs it through a repertoire of performances. Psychology of higher animals should be regarded as a "pattern" psychology. Since the patterns are not rigidly fixed, they are not deterministically preprogrammed and not rigidly cued; they can only be self-actuated, and thus must arise from internal instability, so that the system goes into "motor-sensory-internal organ" motion. However, the orbital synchronous patterns that arise must thread, in an ergodic sense, all of the "needed" systems responses. These "needed" responses must be regarded as "hungers," metabolic for individual survival, and genetic for species survival. This temporal threading must fit the cues, or the cues must have been fashioned or adjusted or adapted to fit the species. Then it can exist.

A species must be "comfortable" in its pattern fitting into the time space. The first nonlinear role of behavior (likely for higher cortical species) is that a noncortical routine of patterns must be achieved that fits the cue space with small integral cycle numbers.

[4] The stereotypes of behavior may be taught by the mother. In rough approximation, they recapitulate the phylogenetic progress up to the particular species (Gesell).

Then processes—the hungers, particularly—come off on time and the system is not in sustained stress.

For such compatibility to be arrived at, there must be a sustained effort, by orbits, to bring the existing set of body images toward some optimum. It is some optimal view of reality that the mother and father or their surrogates attempt to develop in the child. It is a view of "which way is up"!

What is really basic to the plastic higher brain is the alternation in state between two essential roles of inward behavior; for want of a better name, an anxious or dysphoric state and the euphoric state. In the higher animal, it is the cooperative impact of all signalling interfaces that produces the longer time scales. The periodicities may be in the few per day to one per 2 to 3-week time scale.

The Low-Frequency Range—Life's Foci

At the longer time scale, the predominant note is the great flaring maturational instabilities. The first is that of birth itself. In this phase, the newborn infant faces the development of a routine of rhythms whereby its greatest sensory interface—the oral interface—is encompassed within a "satisfying" schedule. This develops in the brain as a dual mother (or surrogate)-child "symbiotic" oscillator system, a constellation. Anxiety follows upon euphoria; motor patterns stuffed with ritual fill develop. The unfolding maturing nervous system brings new sensory interfaces (anal, gastrointestinal and urethral, motor, visual, kinesthetic, etc.) into the field. The plastic brain encompasses these. Priorities and patterns emerge.

The second lesser flare occurs when the system "masters" its primitive routines. There is spare computational capacity. As an integrated "Gestalt," the system grasps its freedom from the immediate "mother-child" milieu. The system seeks out its own kind, its mirror images, its chums. It plays [7].

The third great flare is the adolescent sexual maturation. The genital interface explodes on the scene. The system is now chemically and biologically prepared for reproduction.

The fourth lesser flare is then the integration into a "Gestalt" (a view) of comfortable orbit with a sexual partner. It doesn't have to be, but in many species and all mammals, it is the pattern that insures a continuation of the species by protection of the unprepared-young system.

These great flaring instabilities all cast light on the orbital configurations that represent a large segment of the behavioral foci. What are the other foci—in particular, the other long-range foci for the complex human animal? The following speculative schema is proposed:

At one or more times within the child-chum-adolescent-young adult stages, there arise particularly favorable orbital configurations—"experiences"—that are "attractive" or "pleasurable" to the individual. A regular pattern grouping of internal and external oscillators occurs—neural, sensory, organistic, motor chain—that are attractive and non-anxiety producing. These make an impression. They are learned as analogs. The system forms preferred paths.

Within a complex of possible patterns, the motions gradually become smoother, more practiced; the system encompasses these into a more determinate pattern of orbital paths that then make up the "life" postures. The system begins to lock into a more permanent, more characteristic pattern. These paths circulate around the foci of the system; i.e., there exists a focal imperative. The system does not drift through life aimlessly. It is unstable. It seeks to entrain, it selects both foci of behavior and orbits. These "suit" the individual. They involve more and more routines that become subcortical. They begin to form a patterned field in the brain. Man becomes doctor, drunkard, woman-chaser, intellectual, politician.

A fundamental observation to make about the content of behavior is that externally it does not appear to have a strong metric, whereas internally it may have. What this proposed principle means is that, internally, in the heterarchy of oscillator chains, there is a parity of measure by which the priority of effects and probable sequencing[5] of oscillator states has some deterministic but weak connectivity. Externally, the response to input sequences is "irrational," i.e., not highly ordered in regular sequence, for the individual. He may get mad at a trivial input; he may disregard obviously near-infinite forces; he will run uphill; adore the indifferent; be swept into step by the outrageous; mistrust his most certain guides. His "tastes" and "fancies" have traditionally defied accountability. Yet, internally, there is a psychologic of sorts. We thereby most often know our man.

Here then is the central theme of a man's behavior—a choice of his life's focal pattern that fits or becomes part of his slowly changing image ideal.

In the present context, the image ideal is a very primitive integrated pattern of internal operative states, involving the many body images that are projected into the brain, which provides a satisfying state for the total organism (e.g., involving surface temperature, pressure, sound field, light field, interpersonal constellations, etc.). "Satisfying" states are those that were likely associated with early satisfying physiological experiences. The image ideal is not a "valued" pattern, but an abstract pattern.

It emerges in essential form in man by age three. It develops for the first two years of life within the mother-child constellation (the toddler stages), and during the third year within the mother-father-child constellation (as the child becomes an active motor system). This image ideal pattern lasts through all life. Its subsequent more socialized development simply represents a veneer on the basic structure. The basic structure remains the patterned response in the endocrine system that the nervous system has been adapted to produce.

Longer term behavior may be represented by the continued effort to shift the internal state patterns so as to attempt to bring them into concordance with the image ideal.

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[5] The sequencing is more diffusive than rigorously wave-like, and more probabilistic like a Markov chain than rigidly deterministic.

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