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Sensory Processing and Systems Science: There Is More Than Meets the Eye

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Abstract

Background: Perplexing questions exist regarding the reliability of human eyewitnesses and form the purpose for this study: why two observers can have different recollections of the same event and simultaneously be both wrong? *Material/Method:* Public domain records, related to sensory processing and perception, have been studied; selection emphasis has been on the most recent publications. Systems Science and Dynamic Systems Model methodologies were used in this study. They offer a complementary perspective on examining sensory input, processing, and output of biologic entities while searching for meaning. *Results/Conclusions:* Sensory processing depends on "*movement*" and "*intensity*" of any environmental change; sensory perception depends on "*memory*" and "*rhythm*" within neuro-net oscillations; both processing and perception involve massive data filtration and compression at various strategic nodes within the connectome; brain and muscles are closely linked in their basic metabolic needs and functions that maintain the life-sustaining process of a biologic system with alternating "*activity*" and "*recovery;*" the "*internal dialog*" of cognition is the language of the mind and functions as the Rosetta Stone for translating the electro-chemical signals of sensory processing into an understandable mother tongue of sensory perception. The conflicting observations by eyewitnesses are related not to their differing sensory processing but to their variable sensory perception; systems science offers a path to elucidate the details.

Keywords

Senses, Sensory Processing, Perception, Systems Science, Reality, Relationships, Phases of Life

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1. Introduction

What is this, fundamentally? What is its nature and substance, its reason for being? Marcus Aurelius [121-180 AD] [1]

The Earth is a living planet where every entity is engaged in relationships, receiving output of others through its sensory receptors, and shares its own; this capacity to interact is a common denominator for all biologic entities but the similarity ends there. This is because any sensory processing is restricted to the range of its sensitivity and specificity which varies greatly. Sensory perception/interpretation is even more limited as it is biased, subjected to a variable encoding of input, often based on what is needed from the data, what is considered relevant, and what is separated/ignored as noise; no amount of computing power or the sophistication of any algorithm will either compensate for this shortcoming or will it continue to stay relevant; time marches on and biologic systems inevitably change. Systems science, evolving its principles from biologic observations, however, offers a framework for interpretation of living/changing phenomena thus see what the eyes alone cannot. [2]

It is only vaguely relevant how much data/information is "out there," from megabytes to exabytes, as most of it seldom reaches our awareness; selecting, from the remainder, the most appropriate attractor, an item of interest (people, places, events, etc.), depends mostly on the level of the functional

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complexity of a given biologic system. For example, astronomers recently found the farthest galaxy: 13.1 billion light-years from Earth; computers/mathematicians can assign a number to this distance but human cognition has no idea what it means and how far the galaxy really is. The one negative aspect of having access to mega-data is that it is often confused/substituted for having mega-knowledge; data and knowledge seldom have parallel connection as increasing knowledge can only be generated by evolving cognition of an optimized biologic system.

Change in the external or internal environment of a biologic system triggers specific senses; this contact generates sensory processing, which filters and compresses the data/information representing the change, and culminates with producing some form of awareness within corresponding neuro-net; the entire process may end there or an awareness is selected and becomes an attractor for the system by engaging memory or a desire for pleasure; decisions/choices are subsequently formulated and the next path for the biologic system is determined, for better or worse.

Our knowledge of *Self,* our own biologic system, and the world around us, which gives us our world view/paradigm, depends on our ability to extract, process, and make sense of whatever fraction of the *infinite* our biologic system captures. Intuitively, some cultures instill this notion in their aphorisms:

(One's attitude [paradigm] determines how one sees things) ~ Chinese proverb

Art is known to put a mirror to societal trends. The poet E.E. Cummings, along with James Joyce, Henri Matisse, Pablo Picasso, and others, as Susan Cheever writes, *All were trying to slow down the seemingly inexorable rush of the world, to force people to notice their own lives [as] we are all inundated with information and given no time to wonder what it means or where it came from. Access without understanding and facts without context have become our daily diet*. [3]

This research study utilizes observations from biology that have been formulated into systems science, as well as the Dynamic Systems Model, capable to examine *function and structure* of systems; this approach allows for analysis of data/information in terms of their compliance with the principles of systems science in order to arrive at a highly predictive perception of what the data/information likely means. Perception attempts to set up contextuality, assimilate memories, synchronize with cycles, etc., a process of a complex integration into the rhythm of Life.

It is the relationships, interactions that we have with our own epigenome, metabolome, microbiome, and connectome that define each of our biologic systems and our capacity for sensory interpretation. It is, however, our memories that delimit who we actually are; without memories, our existence loses its meaning and could even end; though senses may still respond to a specific input, all the richness of it gets lost somewhere in the cognition hierarchy of consciousness or the methylation sequences of the genes. The memories in the hippocampus have a tendency to be unreliable though, as their initial development and any subsequent recall, are two distinctly separate steps within the connectome's neuro-net. Sensory processing is a one-way street; what we consider a recall is not a reverse engineering of a previous input into a new output but an attempt of the synaptic neuro-net at its recreation with likely a significant tradeoff; this is similar to a painter looking at a vista and then painting it; sometimes there is a resemblance and sometimes there is just an abstraction. Zimbardo and Boyd make a point that *the brain that created the memory is not the same one that recalls them*. [4]

The memories of the epigenome, however, are very reliable; genes get UP/DOWN regulated, mostly by our decisions/lifestyle choices, and remain in such a state until our decisions change the mosaic and thus, eventually, the morphologic phenotype.

Human memories are primarily visual and provide a framework for how we see the world, how we live, and relate to others, a paradigm of complexity that arises from the character of relationships of a given biologic system. About 80 percent of the input, through vision, is triggered by a certain level of *movement* and *intensity* of the input, interpreted as *change* that is outside of the usual comfort zone, the pseudo-equilibrium of the senses and the neuro-net, in order to generate a meaningful response; otherwise, this comfort zone degrades over time and, as a consequence, diminishes both the *muscle and the brain*.

Motion perception in animals appears to have evolved long before color vision; perceiving motion is one of the most ancient and primitive forms of vision. Visual perception goes far beyond our retinal images, which provide only partial sensory information. We use our knowledge and expectations of the world to fill in the gaps. Visual object recognition thus involves two stages: a bottom-up inputting of perceptual information, and a top-down memory stage in which perceptual information is matched with an object's stored representation; illusions teach us that perception goes far beyond the information picked up by our senses. Perception is an indirect, interpretive top-down process that is not driven simply by stimulus patterns, but is instead a dynamic, active search for the best interpretation of the available sensory data. [5]

Both sensory processing and memory creation are energy and information dependent, exhaustible factors in need of periodic renewal which underscores the need for cycles of activity and recovery. In contradistinction to electronic sensors, whose processing energy has been standardized to the flow of electrons with the capacity for almost inexhaustible and continuous availability, the energy for biologic systems is orthogonally different: it is not standardized, is source-quality dependent, and very much temporary as it relies on our choices of intake and compliance with metabolic requirements. Unhealthy diet, for example, creates unhealthy gut microbiome which creates sub-optimal neurotransmitters that are ferried to the synaptic neuro-net and unfavorably impact its functioning, including sensory perception; any memory, created from sensory input under such a scenario, is suboptimal and likely very different from those created by an optimized system; the variability of testimonies by eye witnesses serve as an example. It is also likely that a suboptimal cognition returns, in a feedback loop, to affect which senses are subsequently activated or deactivated, what is either intercepted or neglected, selected or deselected, from any new data/information available as an input; such a loop of inter-related influences continues, sometime through multiple generations, as the modifications of the neuro-net also implies modifications of the epigenome and the ensuing, though slower, morphogenesis. Sensory perception and memories provide the context within which we understand the past, present, and create a framework for the future, provided that we are an optimized system. A recent New York Times article documents the often encountered dilemma of which recollection of eyewitnesses is correct, if any: *Two people who saw a police encounter on Wednesday reported different details; surveillance videotape showed that both of them were wrong.* [6]

Any operational paradigm, the summary of a system's functional complexity, leaves a pattern that is often readily observable, including its inconsistencies and ironies which affect the interpretation of sensory processing; a pattern reveals a great degree about the internal dynamics of engaged relationships. Consider the following observations that are well known and available in the public domain*: we are trying to discover other livable planets in the Universe, with our technologically-expanded senses, while we can hardly take care of the one we have*; *we are trying to find cure for the epidemic of neurodegenerative diseases while we know that degenerating function of the neuro-net is greatly facilitated by a long-term lessening and misdirection of sensory input, level of physical activity, type of food intake, etc. with the inevitable outcome of a failing function that will diminish structure*.

This current study differentiates sensory processing from sensory perception: the first is considered to be engaged in the translation of changes in the environment into electro-chemical signals of the sensory network and is, to a large degree, automatic; the second, the sensory perception, attempts to create meaning from such signals and thus is strongly context-based on situational awareness and is under the control of cognition; the sequence then would be: from pre-set processing to conditional perception, from signals to meaning. When cognition is engaged, it begins with the end-result of sensory processing and opens the door to sensory perception, for better or worse, and, in a feedback loop, decides what senses will start processing the next change. The concept of "from processing to perception" touches on a fundamental existential question: what is "reality?" We will return to this question below.

Systems science suggests that a discussion about the variability of sensory perception, within the same cluster of biologic systems, should not begin by examining senses, as similar species have basically the same ones, but to look at the decisions that followed previous sensory processing. Such a starting point sheds light on the "internal dialog," the language of cognition, a system-specific Rosetta Stone, which translates and assigns linguistic terms to the electro-chemical signals between the prefrontal cortex and the hippocampus in response to sensory processing. This cognitive conversation, which may or may not remain internalized, broadly reflects the overall state of a biologic system: its function, structure, the character of its complexity and the ensuing emergence, its output, all in a *mother tongue*. When a biologic system is optimized and operates in the Health Territory of the Dynamic Systems Model (discussed below), the input interpretation will more than likely be accurate and the system will *adapt and evolve* with the change almost regardless of its nature; this scenario, however, will be vastly different when the system in question is in zones of Chaos or Entropy of the same Model.

Memory influences our choices; these processes involve the hippocampus, and the ventromedial prefrontal cortex, a decision-making region [for] memory-based decisions. [7]

It is the sensory processing that generates our awareness (e.g. of light, sound, etc.) but it is the cognition, the chatter either between the hippocampus and the prefrontal cortex or the *reward center* of the caudate nucleus, which selects what it considers an attractor, a point of interest from the pool of all existing awareness points or even one that is far removed from what senses are recording; the fatality rate of distracted drivers illustrates this point. The character of a system complexity and its history of previously selected attractors, also determines in which direction the senses will likely be oriented next in order to capture fresh input.

Observing another biologic system's function, structure, language/words, etc. gives valuable and predictive clues as to where the system is within the Dynamic Systems Model; in turn, this step allows an estimate of the quality and reliability of its sensory perception. The following observation, by a well-known rapper, is illustrative of the preceding points: *All he had were his eyes, taking in everything, and the words inside him.* [8]

The goal of sensory processing-perception sequence is to provide an accurate representation of encountered changes in the environment; this goal, however, is seldom reached. The objective of this study is to improve the odds.

Systems science offers a relational framework of study, applicable to all engaged systems, through which to assess the interplay of data/information among all participants in order to reach pragmatic knowledge; this method gives pre-eminence to fully integrated sensory processing and perception, which jointly register, evaluate, and most optimally generate its own output/change but it also identifies points at which this sequence is simply bypassed; in many instances, biologic systems are on both sides of such an interplay.

This study touches on many seemingly divergent topics, from fitness to epigenome to "reality" and language; all themes are, from the author's point of view, very much related to the topic of sensory processing but are refocused from the perspective of systems science which is always searching for the meaning during sensory perception.

To clarify the connotation of some, possibly unfamiliar concepts or terms, metaphors and grouping of clarifying words are used in this text; also, graphics are presented in order to achieve better understanding.

Brain is conducting an internal simulation as a way to understand the metaphor. [9]

This research is based on observations of others, as I understand them, as well as my own. Biologic principles, as systems science tries to emulate, are, as biology itself, still incompletely understood and always changing. Any observed principles are only transient, even if the transition spans a very long time. None the less, there is an endless learning in the subject as we are just a part of the same biology that we study.

This research also represents personal understanding of systems science derived from hands-on engagement with human health and illness, observations of biology as well as perspectives derived from other researchers, business and management fields. Due to the scope of the research topic and the diversity of material used, some annotated highlights of reference material are also used in the text to concurrently expand and clarify presented information for the reader as any observed event or reported finding may have different meaning for different observers; if that is the case with this study - readers' exploration of data, information, knowledge reported in the text - it would support the validity of this contribution. It is hoped that this study will provide a stimulus for further discussion and scholarship, as change of biologic systems never ceases and our knowledge will always be a step behind.

Research question: Why two observers can have different recollections of a single event and simultaneously be both wrong? This research provides an explanatory path.

2. Materials

Public domain records, related to sensory processing and perception, have been studied in the context of systems science, the dynamic systems model, and various cycles.

The time period from 1960s to the present has been selected because it incorporates unprecedented scientific developments within the span of only two generational cohorts.

Taking research findings from various, even seemingly unrelated fields of study, is encouraged by systems science in order to look for isomorphism, answers that some fields already have while others are still searching for them or are just formulating questions; it supports the premise that various systems theories resonate and can be found in numerous, outwardly unconnected fields.

In addition to scientific articles, general public domain publications were also selected, especially ones describing characteristics of the larger societal system. The collected information was grouped by similarities or dissimilarities with systems science principles. For example, for entropy, reports of decline and diminishing functionalities were extracted; for chaos, publications highlighting exponential excess of unmitigated cellular growth, were mined. For systems in health territory, descriptions of optimal adaptation and evolution were also examined.

3. Method

Systems Science and Dynamic Systems Model methodologies were used in this study. They offer a complementary perspective on examining sensory input of biologic entities.

Systems science is pertinent to this study because it describes the characteristics of living systems: Systems have *components/sub-systems*, from cells to societies, which should be *numerous and variable* but with a high degree of

shared decision rationality. Systems have *relationships with feedback loops* which, in healthy systems, express reciprocity, fairness, cognition-dependent empathy, and trust. Relationships create functional *complexity* which produces eventual outcome, system's *emergence*. When some of the above-listed features are absent, the gaps serve as a warning of potential instability and fragility of such a system. [Fig. 1a-c]

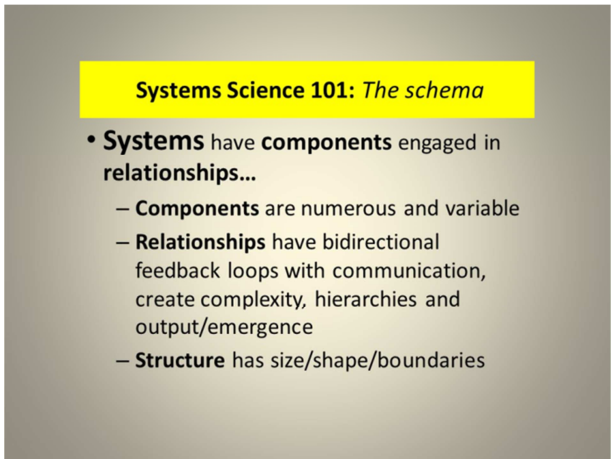

Fig. 1a. Schema of a system.

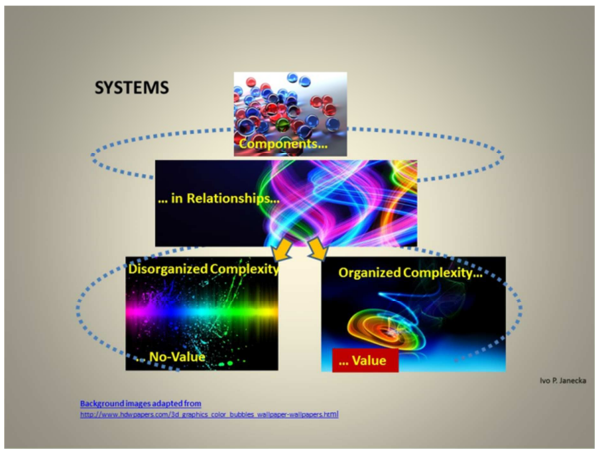

Fig. 1b. A system in images.

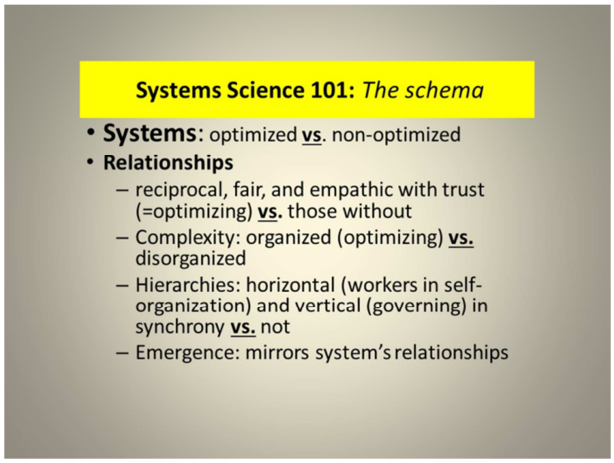

Fig. 1c. Systems's relationships.

Systems science differentiate between healthy and unhealthy systems, those with the highest capacity to extract meaning from sensory input, and those with the least. Utilizing systems science for evaluation of *change* that triggers senses transforms the traditional methodology of establishing linear probability of outcome into a multidimensional/non-linear/fractal contextuality. Such an approach offers different and likely more robust interpretation of what is happening and how best to respond.

The term, *complex adaptive system*, summarizes the positive attributes of a healthy system that is capable of producing value, its emergence, through organized complexity. Any disharmony in relationships has the capacity to change organized into disorganized complexity and the likely consequential absence of value creation, a portrait of an unhealthy system. Complexity has a major impact on the system's capacity to manage change. The significance of maintaining a state of health of any system is *prima facii*. Healthy human body is the best known complex adaptive system composed of numerous smaller sub-systems, all the way to cells, microorganisms, viruses, etc. Complex adaptive systems cannot be micromanaged and successfully live; they have to be optimized through complementary self-organization of components and governing hierarchy in order to achieve organized complexity.

Gradient flow of energy and information, within a function-defined size, shape and boundary, is essential to the survival of any biologic system. It refers to the *intake-throughput-output* sequence that creates a directional and proportionate cascading balance from intake to output; energy as well as information intake (*what* and *when*) have to be managed to maintain such a flow; unfiltered intake of information overwhelms the throughput making rational output/decisions difficult.

System's boundary needs to be semipermeable and dynamic; systems' size should reflect balance between *function and structure*, one that allows for oscillation with cycles. Systems should demonstrate system-within-a-system patterns of *self-affinity* and *self-similarity* of smaller and larger systems; fractal patterns that such systems generate can be considered a reflection of *adaptation and evolution*.

Complexity, arising from optimizing relationships, incorporates processes of self-organization within horizontal hierarchy ("people/components in the trenches") and governing vertical hierarchy (which creates rules, laws, their enforcement, institutions, tariffs, etc.). Organized/optimizing complexity gives rise to collective intelligence of a system that encompasses collective rationality and responsibility; a potential for creating value/its emergence, is present; such a system is robust enough to express high degree of resiliency

and functional redundancy. Lack of organized complexity, expressed as disorganized complexity, leads to absence of value creation and cognitive dissonance/stress.

Every well-functioning system, regardless of its size, needs semipermeable boundary, a filter, for incoming data/information as well as energy in order to provide manageable input. A system boundary is a reflection of the complexity character of a given system that is enclosed/protected but with ongoing intra- and inter-systems relationships, such as blood-brain barrier, intestinal lining, as well as those that are cognition-based, such as boundaries with parents, teachers, society, etc.; those systems that are in the Health Territory will have optimizing, only selectively transgressible boundaries; the non-optimizing systems have boundaries that are either too rigid or too loose, either severely filtering any input (think of the history of the "iron curtain" or arteriosclerosis depriving tissue of oxygen) or an indiscriminate input that is overwhelming the system (think of cancer invasion or obesity).

Dynamic Systems Model complements Systems Science because it places, the system that gave origin to the environmental change and any contextually-related/receiving systems, in a multi-dimensional assessment pattern. Such a mosaic allows for a more accurate creation of meaning from the change because it varies with system's position within the Model. [10]

The Model defines three zones based on their functionality: The Health Territory indicates optimal functioning, a healthy system. This zone dynamically spans the boundaries of two neighboring zones, the outer core of Entropy and the inner edge of Chaos. Extremes, the outliers in this Model, include the outer edge of Chaos and the inner core of Entropy. Each classification within this Model reflects, on one hand, the degree of system's capacity for organized complexity - adaptation and evolution - as well as the ability to produce positive emergence/value; on the other hand, the Model also reveals the high likelihood of random events or system entropic end-phase. Health Territory produces evolutionary changes; Chaos generates revolutionary changes; Entropy generates no new life-supporting changes. [Fig. 2a-f]

When a system is in Health Territory, random events are rare; most randomness is absorbed/dealt with proactively by a system that is fit; because of infrequency of randomness, it is possible to anticipate it only as an unlikely event; the interpretation of sensory input has the highest probability of being meaningful.

When a system is in Chaos, randomness is the norm and the time frame for resolution is short. Events in Chaos may lead to anarchy (summation of randomness and asynchronous cycles); abnormal DNA methylation can be observed and measured, demonstrating rapid cellular aging.

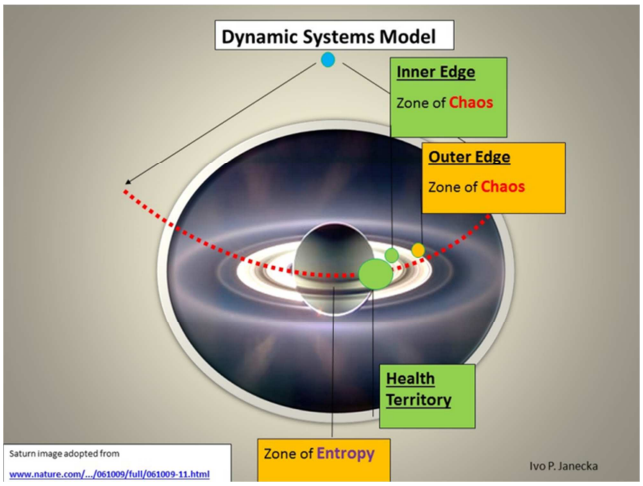

Fig. 2a. Schema of Dynamic Systems Model illustrating the transitional origin of Health Territory which straddles the Inner Edge of Chaos and the Outer Core of Entropy.

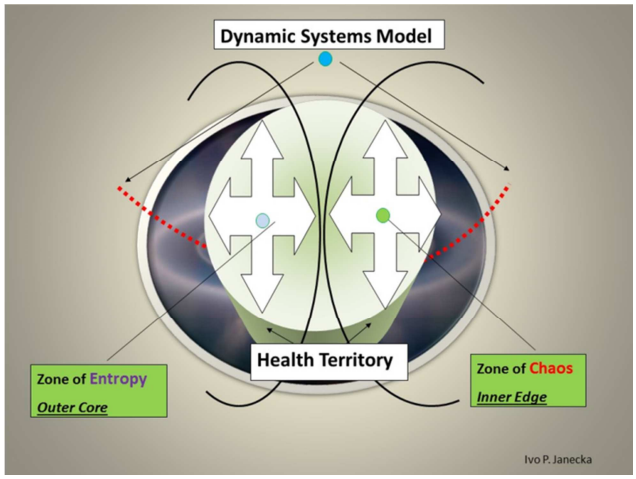

Fig. 2b. Details of Health Territory composition: overlapping border zones of Chaos (Inner Edge) and Entropy (Outer Core).

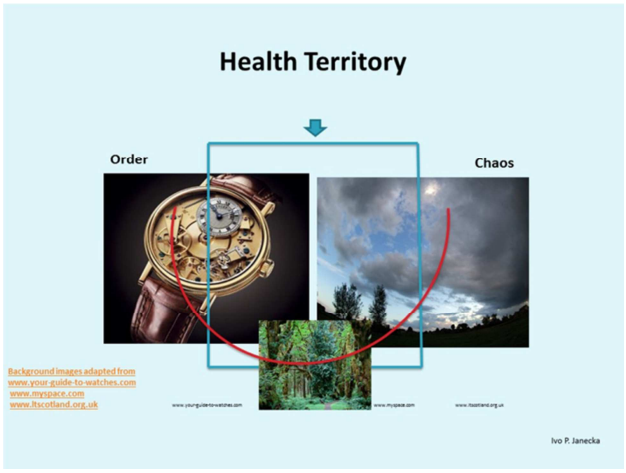

Fig. 2c. Dynamic Systems Model in images: Health Territory, exemplified as a rain forest, constantly incorporates and discards the characteristics of the outer core of zone of Order (exemplified as an analogue watch) with an ongoing pull toward Entropy, and the inner edge of Chaos (exemplified as weather turbulence) with pull toward complete randomness.

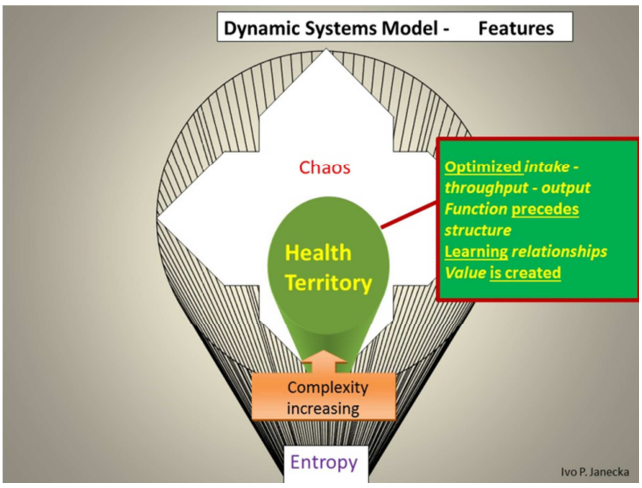

Fig. 2d. Key features of biologic systems in Health Territory of Dynamic Systems Model.

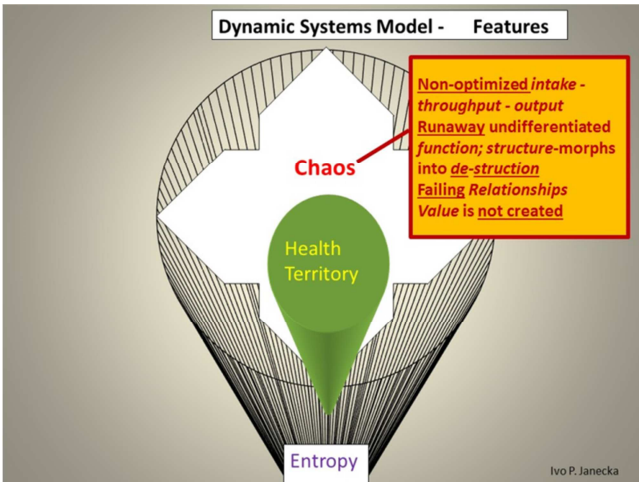

Fig. 2e. Key features of biologic systems in Chaos of Model.

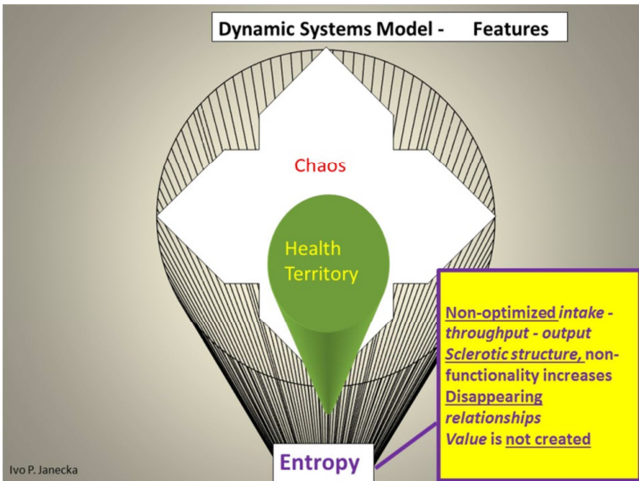

Fig. 2f. Key features of biologic systems in Entropy of Model.

The state of a system, either healthy or unhealthy, in Health Territory or not, can be determined with a great degree of accuracy, by also looking at the type of past and present relationships as well as the historic and current outputs that have been generated; this insight offers advanced knowledge of what can be anticipated from any new sensory input prior to sensory perception. [Fig. 3]

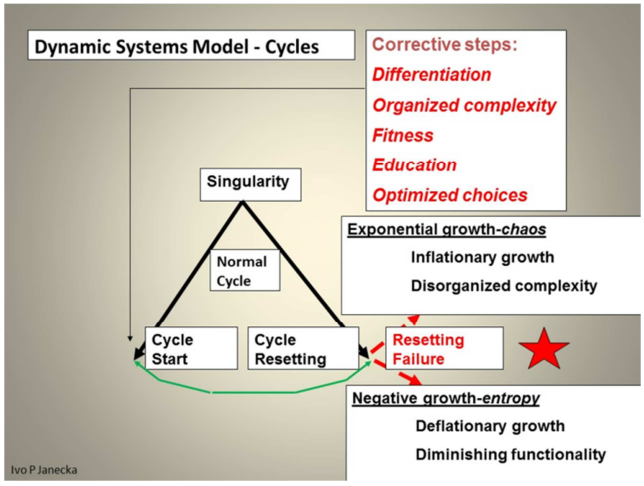

Fig. 3. Schema of oscillating biologic systems and end-state features of chaos and entropy when cycle resetting fails; feasible corrective steps are included.

4. Discussion

The goal of this study has been not just to *process* but also to *perceive*, not just to *see* but also to *understand,* what meaning there is when our senses are triggered; a multidimensional systems science, based on biologic principles, offers the framework for such a journey. It accomplishes that by examining the *state of a system* of both the originator as well as the recipient of environmental change; specifically, it looks at both systems' level of functional complexity, a proxy derived from their relationships. This approach significantly narrows the gap between the wide range of possibilities that may be encompassed in change and the actual probability of correctly reading the meaning of incoming data/information.

Sensory processing and perception resemble a never-ending and always evolving dynamic spiral; one follows the other but feedback loops exist; what is processed will be perceived, in principle; the details, however, may be dramatically different as identical processing may enter sometimes orthogonally different level of perception; there are several key "forks in the road" during processing of data/information as well as energy; the basic one concerns the path to the prefrontal cortex: is the signal going through or bypassing the hippocampus by way of the "reward center" of caudate nucleus?; for energy, it is a question of what the intake does to the normalized insulin levels. The other, not just a "fork" but a "cliff," is regarding the state of the prefrontal cortex: is it optimized or not? A malfunctioning prefrontal cortex is considered to represent a dysexecutive syndromic state which implies that learning from past errors does not take place.

Biologic systems are open systems with numerous

relationships. They share common principles acquired during evolution. Regardless of how small or large open systems are, i.e. cells or societies, they all sustain *Life* in following three basic phases: input – throughput – output, while handling both food/energy and data/information as well as recycling/removing detritus.

Healthy biologic systems comply with innate rhythm/cycles which are in synch with the following: the master circadian oscillations, the metabolic cycle, and the dopamine cycle; each one can strongly influence the other and the compliance of a biologic system with these cycles is under a great degree of control by our decisions/choices.

Function leads structure but only in healthy biologic systems, those in Health Territory, defined by the Dynamic Systems Model. In Chaos, the runaway function does not allow differentiated structure to follow (e.g. in cancer, there is only cell multiplication of immature cells without differentiation and, as a consequence, only destruction follows). In Entropy, there is accumulation of non-functionality (e.g. beta amyloid and Tau proteins in Alzheimer's neurodegeneration); when a system is in this zone, only sclerotic structures remain and interfere with function (e.g. arteriosclerosis diminishes blood flow and oxygen delivery to tissues which negatively cascades through cognition, muscles and all receptors).

Senses are an essential part of any biologic system and respond principally to *movement and intensity*; they are part of the many Life-sustaining characteristics that emerged during evolution with a central role given to relationships; among the existing ones, the one with *Self* (with own epigenome, metabolome, microbiome, and connectome) is the most fundamental one because without it, no optimizing relationships with others are likely to exist; this process can reverberate through generations.

Sensory processing is only activated in response to change in the environment and delivers any data/information to the neuro-net; there is no value judgment along that path; it is the cognition that can differentiate such change into a risk, quantifiable by a prism containing senses and cognition, or uncertainty, which is unquantifiable; this differentiating capacity, however, varies greatly from one biologic system to another as it relies on the character of its complexity; healthy systems have no problem reading the prism. [11]

Eyes can start processing visual input seemingly at the speed of light but meaning creation runs up against a cognitive threshold and all slows down. Cognitive threshold is simply a filter at the end of sensory processing and the beginning of sensory perception; it is a point at which the electro-chemical signals of the neuro-net are translated into words, numbers, or musical notes of the mother tongue.

The available data/information that is reaching the senses, has ballooned now to mega-data status. The processing technology that is being used on a large scale, is still based on the linearity of "0s" and "1s" and should be used only to augment human primary senses and not be used to make algorithmic decisions. Knowledge/meaning creation, from the data/information, lies in the domain of non-linear cognition which is far from uniform in terms of quality and temporality even in the same biologic system; cognition struggles within the variable functionality of the hippocampus-prefrontal cortex axis and any associated structures. Data/information is not knowledge; regardless how much data (mega-data) and the processing speed (super-computers) is available, without knowledge it all represents an incomplete approach to interaction with change where the goal should be the extraction of meaning.

Healthy biologic systems have their needs encoded into the semipermeable filtering boundaries/thresholds at each of connectome's nodes. The first barrier to entry for incoming data/information is represented by sensory receptors that are limited in number, have minimum-maximum range of sensitivity and specificity; the cellular connecting nerve fibers soon merge into clusters and undergo further compression/reduction along the processing path. In spite of that, there is still massive amount of data/information that is available to cognition. Within the neuro-net, it is the relative and inverse balance, a form of a relationship, between excitatory and inhibitory neurotransmitters at synaptic junctions that alters their transmission threshold; lower inhibition, for example, results in greater transmission but poses a threat to the cognitive threshold.

Inhibitory neurotransmitters, released in the synapse raise the threshold for neuronal firing, critical to the sensory perceptions of sound and sight; inhibitory neurons increase the signal-to-noise ratio [threshold] of brain activity; excessive excitation, for example, in the olfactory cortex, is associated with epilepsy [which] can be seen as an abnormality of inhibitory neurons. [12]

In humans, the cognitive threshold, navigating through multitude of synapses, is estimated to be somewhere between 25-120 bits per second; generally, human speech is comprehensible at about 60 bits per second. Our cognitive internal speech/chatter, which translates for us what is happening following an input, is probably around that number as well, 60 bits per second. Any daily experience will tell us that we can listen to and understand if one person is speaking to us but ask two people to talk to you simultaneously and your cognitive threshold is overwhelmed and your understanding of either person is greatly diminished. The cognitive threshold is a biologic phenomenon that is dependent upon the levels of

neurotransmitters, both excitatory and inhibitory ones, which are exhaustible commodities that require production, transport, activity, and recovery. If the threshold gets overwhelmed with "noise" of sensory processing (e.g. watching TV for 5 hours per day), any amount of additional data/information will not make it intact through the saturated threshold and subsequent decisions will carry that negative impact.

When an environmental change occurs, there are likely to be as many interpretations of such a sensory input as there are differing biologic entities. Systems science can identify optimizing and non-optimizing biologic systems and categorize them into three broad zones, mentioned above, within the Dynamic Systems Model: The first is the Health Territory where systems express strong capacity for adaptation and evolution, and for the extraction of meaning from sensory input; the second category is the Zone of Chaos where mostly multiplication of system components takes place but without differentiation; randomness prevails; the third is the Zone of Entropy where increasing accumulation of non-functionality dominates affecting any remaining function and structure.

Biologic systems either are or are not healthy, as measured by the Model; this observation has corresponding impact on their sensory processing and perception; the Model determines the degree of capacity that any of the systems have, not only to extract meaning from input, but also the capacity to generate an optimizing output themselves that others may perceive.

Systems science

Systems science is not an abstraction; it is a dynamic method which is adapting and evolving through new observations in biology and is also capable to triage new changes that trigger our senses. Similarly to the light spectrum of colors, revealing themselves after passing through a prism, systems science is such a prism for meaning extraction from encountered change.

Any alteration in the external or internal environment of a biologic system leaves its imprint which can be "made visible" through answering the following questions: is the change detectable with primary or enhanced senses and thus can be categorized as either a risk or an uncertainty? Has the change already triggered our awareness and will it likely become our attractor thus starting a cascade of events in the neuro-net all the way to final decisions? (Attractors may be considered people, places, events, ideas, incentives, etc. that we establish a strong relationship with.) Further questions are: Has the change originated from a healthy system and thus be reasonably expected to be an optimizing one or vice versa? Are we a healthy/fit system with a high degree of adaptation and evolution? Are our processing filters set/trained to retain key bits of information and filter out the "white noise"? Is our executive prefrontal cortex working well with hippocampal memory or is it using a detour through the "reward center" of the caudate nucleus? Do we have a record of value creation as our emergence?

Relationships

With still dominant paradigm of linearity in sciences and cultures, *Life* is widely considered to be a straight line, from a birth certificate to a death certificate, exemplified with bracketing Life and individuals' co-morbidities within segments of time, such as "age-associated diseases," etc. On one hand, statistical modeling indeed shows that many illnesses can be put in time brackets but this finding is likely due, not to the causation by "time" *per se* influencing health, but to the clustering of cultural lifestyle factors by many individuals which may be characterized as "how we live the time," paraphrasing a colloquial expression, sometime ascribed to Abraham Lincoln. On the other hand, as a contrast to the linearity of time, systems science is non-linear and mostly deals with relational patterns which reflect health or illness.

Biologic systems, as open systems, are guided by their needs to support Life through stages of *Intake – Processing/ Metabolism – Output*. These are sequential but independent steps that should be in synch among themselves as well as with various external and internal cycles. As light and darkness oscillate, so must biologic systems, e.g. engage in activity and rest/recovery; intake of energy and information also needs to oscillate and be in paralleling rhythm with light and darkness as should be the metabolic, energy-generating phase, and the sensory processing of data/information; the final step of a biologic system's life-needs is its output/ emergence; it reflects all the decisions and lifestyle behaviors that the system has been engages in; it may or may not represent value.

There exists critical inter-relatedness of all subsystems that are part of a larger biologic system, e.g. organs, tissues, etc.; any gaps or hyper-/hypo- activity among them disturbs the larger system. Examples: intake that far exceeds the output, or is non-optimizing for the throughput/metabolism, will cascades down to the gut and cause the microbiome, through the production of many neurotransmitters, to affect the synapses of the neuro-net; thus primed, the neuro-net is then set to influence sensory perception, the decision-making process, and the knowledge creation from any sensory input; furthermore, this type of neuro-net, determines a new cycle of sensory processing and perception by influencing what is captured as a new input by senses and what type of perception the new cycle will encounter.

It may seem contradictory, in the current sea of mega-data and ever-expanding "Internet friends" that there is very little expansion of actual human relationships as conceptualized by systems science; what is expanded here is more or less network noise, caused by geometrically expanding social network which goes way beyond a sustainable oscillation/rhythm among inter-related systems (e.g. "friends"). Systems with optimized relationships generate output/emergence as value encompassing features of efficiency, effectiveness, risk management, and proportionate cost.

For centuries, Physics was associated with certainty of the physical reality. Splitting the atom was a great achievement but likely signified the end of "*certainty in linearity*" as subsequent discoveries opened the door to only "*potentialities*" as the new reality of Quantum Physics. Now, even astrophysicists/cosmologists, also after centuries of discovering more and more planets, stars, galaxies, etc. are still unable to find the "Adam and Eve" of the Universe, the "one and only particle;" instead, they are encountering only the "*rhythm of the Universe*" and postulating *Dark Matter* and *Dark Energy*, neither of which can be currently detected but only inferred, which likely represent just possibilities of the Quantum Universe.

We live in a very peculiar universe—one that is dominated by dark matter and dark energy—the true nature of both of these remains elusive. Dark matter does not emit radiation in any wavelength and its presence is inferred by its gravitational influence on the motions of stars and gas in its vicinity. Dark Energy, discovered in 1998, meanwhile is believed to be powering the accelerated expansion of the universe. The dark matter direct detection experiments have not found anything [as] all these experiments are reaching the limits of their sensitivity; something is still fundamentally off and possibly awry in our understanding; is a fundamentally new theory of gravity that's needed, or is it a complete rethink of some aspects of particle physics that are needed? [13]

Biology, especially human beings, are still, to a large extent, and in spite of the overwhelming evidence, seen as mechanical/physical devices. In physics, the transit to quantum world was only assisted by mechanical sensors because it was the cognition of some scientists who asked the right questions and simply pointed the sensors in that direction and a new paradigm was born. A similar redirection of sensors would greatly benefit furthering of our knowledge in biology; there is no "atom" in biology waiting to be split but relationships to be explored in the cycles of the dynamic connectomes that represent the "rhythm of life," a paradigm of "possibilities."

Relationship is a form of communication, exchanging words, gestures, items, etc. in order to reach a desired goal. But, as George Bernard Shaw stated, *The biggest problem with communication is the illusion that it has taken place.* The most fundamental question should always be in the forefront: how will it be understood? This conundrum exists because the recipients of our communication process the signals via their neuro-net, not ours.

Cycles

Cycles are part of relationships: one with the Universe (Earth's heliocentricity gives us seasons), Earth's rotations around its axis give us day/night circadian oscillations; the metabolic intraday cycles are related to the choice and timing of food/energy intake that engages insulin. Both the circadian and the metabolic clocks can affect each other, with positive consequence for our system from synchrony, and a jetlag effect from asynchrony, even if time zones were not breached, simply from eating at the wrong time.

The way you feel while jet-lagged exactly reflects what your nervous system is experiencing: a profound loss of synchrony. [14]

Biological clocks work in tandem with [gut] bacteria; [they] vary their activities over the course of the day; mice and humans with disrupted daily wake-sleep patterns exhibit changes in the composition and function of their gut bacteria; [microbiome functions] as an extra "organ" [a system with] wide-ranging impact on our health. [15]

There is a clock inside every mammalian cell made of genes and proteins linked in mutually controlling feedback loops; the cellular clock regulates both itself and multiple circadian processes, including secretion, protein synthesis, and response to stress. The whole-body clock that governs our sleep–wake cycle and is entrained by exposure to light is built upon the cellular clock. [16]

The circadian clock controls rhythms in behavior, physiology, and metabolism in all living organisms, including methylation of the epigenome; the coherence in the circadian network arises from integration [of] neurons of both the molecular clock and information derived from circadian-relevant neurons. [17]

Sleep is an essential component of the circadian rhythm. Sleep loss as well as alcohol degrade the executive functions of the prefrontal cortex (a dysexecutive syndrome) and the overall system's capacity for adaptation and evolution; such a system is operating outside of the Health Territory and is in the Zone of Entropy; (after three sleepless days, the cognitive state is analogous to alcohol intoxication).

Sleep loss affects critical aspects of decision making. Investigations into the Chernobyl nuclear power plant

meltdown in Ukraine, the grounding of the Exxon Valdez oil tanker and the explosion of the space shuttle Challenger, all concluded that sleep-deprived operators played a role in causing the accidents; sleep loss degrades attention, decision making [and the capacity for] adapting to changing circumstances. [18]

Dysfunction in dopamine signaling profoundly changes the activity level of about 2,000 genes in the prefrontal cortex [creating a dysexecutive syndrome] and may be an underlying cause of certain complex neuropsychiatric disorders, such as schizophrenia. Genes previously linked to schizophrenia seem to be dependent on the controlled release of dopamine at specific locations in the brain. The altered dopamine levels can modify gene activity through epigenetic mechanisms. Dopamine, a neurotransmitter helps [to] manage functions ranging from movement to emotion. [19]

Biologic systems have memories that are stored in the hippocampus, the epigenome, and the microbiome; in the hippocampus, the memories are quite unreliable but the other two are quite stable as they closely follow/mirror our decisions. In general, following the mutual engagement of hippocampus and the prefrontal cortex, lifestyle choices are made and are considered an output of cognition; in a return feedback loop, they affect all memories in an ongoing process.

Our ability to decide, in spite of the presumed always-present free will, does vary greatly depending upon where we or any observers/assessors of sensory input are in the "life journey" which can be broadly divided into three time periods, termed the Phases of Life:

Phase 1: Ancestral Phase runs from conception to young adulthood (about 25+ years); the dominant influence during this phase comes from: a) the transgenerational epigenetically UP/DOWN regulated genes from parents and older direct lineage; the pertinent Health Territory, Chaos or Entropy states of those biologic systems can manifest through several generations; b) microbiome received from mother via vaginal delivery and/or breast feeding following birth.

[Intracellular] centrioles ensure that chromosomes are properly passed on to the new daughter cells; female egg donates most of the cell organelles, such as mitochondria; the centrioles come from the male's sperm, bringing with them any malfunctions to the first embryo cells. Passing information across generations [was demonstrated in laboratory experiments where], a study focused on the C. elegans; the paternally contributed centriole proteins can actually persist up to ten cell generations [and] could effectively be a non-genetic information carrier; malfunctioning centrioles can pass directly from the father and well into the life of the embryo; centrioles could be the means of a unidirectional inheritance of information; mutations in the proteins that make them up can cause a broad range of diseases, including developmental abnormalities, respiratory conditions, male sterility and cancer. [20]

A parent can pass silenced genes to its offspring [via] epigenetic inheritance; this silencing could persist for multiple generations -- more than 25 (in C. elegans); dsRNA (double-stranded RNA) can travel from body cells into germ cells and silence genes within the germ cells. [21]

Epigenetic patterns change dramatically during development; these early events are biologically programmed and necessary. Selective maintenance of DNA methylation at specific loci is essential for controlling differential expression of the paternal and maternal alleles in mammals, known as genomic imprinting. [22]

In general, the features of time periods Phases 2 and 3 are cultural expressions of specific cohorts and not a temporal determinism.

Phase 2: Phase of Decisions spans from young adulthood to early seniority (about 50+ years); dominant influence, on *Self* and others, comes from: a) current/recent behavioral/lifestyle choices/decisions which may epigenetically either rebalance or worsen inherited set of gene functions or make new alterations; b) dietary decisions affecting the microbiome which generates either optimizing or non-optimizing neurotransmitters for the neuro-net; c) the fitness level of the biologic system and its coping strategies for dealing with stress; d) ability to share the existing features of epi- and micro- biomes with any new offspring, thus expressing a transgenerational influence.

The impact of choices on the epigenome is well illustrated by the study of identical twins in Finland; they were initially raised together but, in adult life, during their Phase of Decisions, diverged in terms of the level of exercise:

This divergence was eventually reflected in different bodies and brains, in spite of identical genes. The sedentary twins had lower endurance capacities, higher body fat percentages, and signs of insulin resistance, signaling the onset of metabolic problems; the twins tended to have very similar diets. The active twins had significantly more grey matter than the sedentary twins, especially in areas of the brain involved in motor control and coordination. Overall, among healthy adult male twins in their mid-30s, a greater level of physical activity [was] associated with improved glucose homeostasis and modulation of striatum and prefrontal cortex gray matter volume, independent of genetic background. [23]

The human genome is epigenetically regulated through

methyl groups [that] attach to the DNA. [24]

Phase 3: Phase of Consequences extends from early to late seniority (about 75+ years); dominant influence comes from the already "created" epigenome and microbiomes during the Phase of Decisions. Better physical fitness in middle age, the second Life Phase, Phase of Decisions, is reported to be associated with reduced cancer risk as well as mortality from cancer and cardiovascular disease after the age of 65.

Cognitive function at age 65 or older appears to be inversely associated with CVD [cardio-vascular disease] overall, but also with cancer mortality. [25]

Chronologic time is not variable, and is related to the unchanging number of Earth's revolutions along its axis since birth. Biologic time is quite variable, and currently can be estimated from the level of methylation of the epigenome as well as the length of the chromosomal telomeres; both are highly dependent on lifestyle choices, including diet, exercise, and stress management, and may or may not overlap with chronologic time.

Methylation changes to DNA take place over a lifetime, and can help predict an individual's [biologic] age. People whose biological age was greater than their true [chronologic] age were more likely to die sooner than those whose biological and actual ages were the same. [26]

Sub-systems

Epigenome

Epigenome of a biologic entity that is endowed with cognition, reflects the owner's decisions and the type of relationships that have taken place; they mirror the character of its system's complexity. As long as you are alive, your body, your morphogenic phenotype, is being constructed by your epigenome, and is always waiting for your instructions, literally, from minute to minute. When we are born, no one is starting with a pristine, *de novo*, genome, but with one that "has a long history," for better or worse, from previous generations. The biology of *Life* indicates that genes are functionally modifiable by system's decisions, and any system's phenotype has been constructed "per directives."

We communicate our decisions (indecisions, uncertainties, fears, exercise, etc.) to our epigenome via methyl groups which need to be obtained from diet; its availability, diversity, etc. contributes to hypo-, hyper- or optimal epigenome methylation.

Endurance training alters the epigenetic pattern in the human skeletal muscle [with] strong links [to] the activity in genes controlling improved metabolism and inflammation; genomic regions in which methylation levels increased, were involved in skeletal muscle adaptation and carbohydrate metabolism, while a decreasing degree of methylation occurred in regions associated to inflammation. [27]

Microbiome

Neuro-net also includes its anatomical location in the gut where overall energy is obtained. The "neuro-net diet" needs to be pro-health, protecting the hippocampus – prefrontal cortex bond, with appropriate quality and quantity in order to avoid, at all cost, the dysexecutive syndrome and the loss of 3-D memory storage capacity of the hippocampus; otherwise, neuro-net dysfunction and neurodegeneration are likely to follow.

Gut microbiome is growing on a substrate provided by diet, healthy or unhealthy; it affects the neuro-net, positively or negatively, via neurotransmitters that include serotonin, dopamine, melatonin, gamma amino butyric acid (GABA), among others.

There are two known pathways to reach the central synaptic neuro-net: One is via blood circulation but an intact blood-brain barrier represents a semipermeable boundary; the second pathway is via the retrograde axonal transport within the vagus nerve, bringing neurotransmitters from gut bacteria to the neuro-net.

The gut [houses] about 1,000 trillion bacteria; [it also] contains around 100 million neurons which use serotonin to signal back to the brain - and 95 percent of all serotonin in the body is in the gut. About 90 percent of the fibers in the primary visceral nerve, the vagus, carry information from the gut to the brain; this communication between the gastrointestinal tract with its microbiome and the central nervous system is bidirectional; stress, [for example] can change the composition of the microbiota. [28]

Connectome

Connectome is a functional as well as a structural network that broadly refers to all that is linked via synapses and neuromuscular endplates within a single biologic system. Input into the connectome is carried out by senses which are essential for life as eyes, for example, allow for resetting of the vital circadian rhythm. Vision is our primary sensory organ, with one third of cerebral cortex devoted to vision, and is capable of recording the most of what is perceivable from any encountered environmental change; it normally creates multi-dimensional memory. Vision may also reflect evolutionary need for processing efficiency as sight allows understanding of the proverbial modification - "1,000 words in 1 picture."

Neuro-net

Neuro-net can be conceptualized as a large complex system with many clustered sub-systems. From systems science

perspective, we can identify many variable components, their relationships and communication, as well as the overall input – throughput – and output (termed system's emergence). The nuances of this concept also include boundaries, function and structure, cycles, etc.

Healthy neuro-net develops and sustains its structure through function; this is made possible by synapses where actual droplets/liquid/vesicles of neurotransmitters are exchanged and carry the signal; cease their production and the entire multidimensional structure implodes.

There is no function without byproducts even within the neuro-net and their accumulation hinders both function and structure. A process, which may simply be described as "de-cluttering," is ongoing in all healthy systems because, without it, it is very consequential and the state of Entropy (e.g. neurodegeneration) is its end appearance; exercising muscles offer a great help to this de-cluttering process as muscles, for example, clear stress-induced cytokines from the blood. The "cluttering" process (think of forest without termites and lichen) may begin in earnest in the second Phase of Life, the Phase of Decisions, with cognitive dominance for "accumulation" and "rewards" often leading to chronic metabolic inflammation, obesity, etc.; the Phase of Consequences, however, is not far away. A few pertinent observations of a societal system from The New York Times:

We're overwhelmed by the intangible detritus of 21st-century life: unreturned emails; unprinted family photos; the ceaseless ticker of other people's lives on Facebook; the heightened demands of parenting; and the suspicion that we'll be checking our phones every 15 minutes, forever, [with the feeling] that the joy of ditching all of our stuff is just as illusory as the joy of acquiring it all was. [29]

Physical exercise [can] prevent the brain from being damaged during stress; exercise induces changes in skeletal muscle that can purge the blood of a substance that accumulates during stress, and is harmful to the brain. [30]

A nerve cell (membrane) is normally electrically polarized, but a nerve impulse triggers depolarization to travel along the nerve cell. When it hits the synapse, the depolarization causes the opening of voltage-gated calcium channels (VGCCs) that traverse the membrane, allowing calcium ions to flood into the neuron. This sudden pulse of calcium ions in turn triggers the release of neurotransmitters [and causes] neurotransmitter vesicles to fuse with the synaptic membrane; these VGCCs are not only present on the synaptic membrane of cells, but also in the membranes of cellular bodies called lysosomes, where they play a critical role in the cellular "garbage disposal" processes of lysosomal fusion and autophagy [e.g. "de-cluttering" of neuro-net]. Lysosomes within cells contain proteins that can digest cellular waste and release processed waste for feeding the cell, acting as "recycling" centers. Cellular waste is first captured by a double membrane structure called the autophagosome and delivered into the lysosome through membrane fusion. Malfunction of the lysosome is highly problematic for the neuron because lysosomes are long lived and cannot renew their contents. As a result, the cellular waste accumulates inside until it kills the neuron. [31]

Prefrontal cortex

Prefrontal cortex [is] performing executive functions [such as] identifying goals, predicting the future consequences of actions, delaying gratification, balancing future rewards against present desires; Emotions deal with the present, thinking prepares for the future. [4]

The importance of the prefrontal cortex, in the creation of meaning and decision-making, following sensory processing and perception, is well summarized in the following quote:

Prefrontal cortex [is] the seat of logic, analysis, problem solving, exercising good judgment, planning for the future, and decision-making. Extensive two-way connections [exist] between the prefrontal cortex and virtually every other region of the brain [but] most of the connections are inhibitory [which] provides [for] impulse control and, the ability to delay gratification; the prefrontal cortex doesn't fully develop in humans until after age twenty. When the prefrontal cortex becomes damaged it leads to dysexecutive syndrome [which is analogous to alcohol intoxication and the "dark side" of oxytocin] [where people] get stuck in the present, unable to place events in the correct temporal order, a loss of insight. Alcohol interferes with the ability of prefrontal cortex neurons to communicate with one another, by disrupting dopamine receptors. [32]

It is the medial prefrontal cortex that continues to monitor the overall awareness domain and, when it is functioning well, it compares its searches to the currently engaged attractor, the current focus, while always looking for better strategies. When the prefrontal cortex as a whole is in a dysexecutive state, this critical exploration of other/better pathways is absent.

The medial prefrontal cortex [is] involved in monitoring what is happening outside one's current focus of attention and shifting focus from a successful strategy to one that is even better. The brain has evolved mechanisms that filter information that is useful for the task that you are doing. A disadvantage: you might miss out on important information that is outside your current focus. [33]

The baseline estimate for the worldwide incidence of a probable dysexecutive prefrontal cortex, can be inferred, for example, from the number of people who already have been

diagnosed with alcohol disorders; it is about a quarter of a billion; the total number is probably substantially higher as other alcohol users are not included in this number; this is unfortunate as these societal groups will unlikely contribute to the collective intelligence, rationality and responsibility of social clusters. [34]

The lateral prefrontal cortex filters visual information in order to create focus, e.g. select a point of strong interest from all that is available and stay with it. This function is suboptimal in diseases such as attention deficit disorder, autism, epilepsy, and schizophrenia where a malfunctioning filter in the thalamus is also suspected. [35]

Caudate nucleus

The pleasure/reward center of the brain, the caudate nucleus, uses dopamine neurons. When this structure, and not the hippocampus, is employed for processing sensory input, it starves the hippocampus of stimuli necessary for the ongoing development of its memory network thus degrading its capacity.

Thalamus

Sensory information must also pass through a neuronal gate, the thalamus, which filters innumerable stimuli competing for our awareness before reaching the cortex and the hippocampus; it regulates the level of consciousness, from wakefulness to sleep; absence/malfunctioning of this filter allows disorganized/unfiltered sensory input to reach higher cognitive levels leading to the accumulation of non-functionality, a state of Entropy, suspected in Schizophrenia and other attention deficit disorders. [36]

Hippocampus

When hippocampus is optimized, it is capable of creating a multidimensional mosaic of firing neurons which forms a framework for memory.

Every time you make a memory, somewhere in your brain dendritic spines reach out from one neuron and form an electrochemical connection to a neighboring neuron. Alterations in dendritic spines are associated with many neurological and developmental disorders, such as autism, Alzheimer's disease and Down Syndrome. When dendritic filaments make contact with one of the axons, it begins to adhere and to develop into a spine. The axon and spine form the two halves of a synaptic junction. New connections like this form the basis for memory formation and storage. Autism has been associated with immature spines, which do not connect properly with axons to form new synaptic junctions. However, a reduction in spines is characteristic of the early stages of Alzheimer's disease [typified by having] trouble forming new memories. [37]

Vagus nerve

The course of the vagus nerve, from the cranium to the gut and other organs, is a critical part of the connectome; it provides input to the neuro-net from the internal environment and likewise delivers an output from the more proximal neuro-net; in the gut, the microbiome generates neurotransmitters which are ferried, by the vagus nerve in retrograde fashion, to the synaptic neuro-net with either a positive or negative impact.

[A] gut instinct [is a systemic] response to fear, influenced by signals sent [from the gut via vagus nerve] to the brain. A loss of [such] signals from the abdomen [via vagus nerve after an experimental section] changes the production of certain neurotransmitters [and] complex behavioural patterns. [38]

Synapses

It is the dynamic, literally fluid connection within synapses that keeps the neuro-net open to function which in turn creates a temporary structural integrity. Synapses accomplish this task with synaptic vesicles, starting their existence with intracellular protein synthesis and ending as the synaptic intermediary; they need to be recycled/renewed and this process takes place mostly during sleep. Not all synapses are alike and those with similar cells have the strongest bonds and they cluster; weaker bonds do exist as if waiting for the need to adapt and evolve as part of neuro-net plasticity.

Individual neurons communicate with one another via their synapses [using] synaptic vesicles; an “average” synapse [is] displaying [about] 300,000 proteins. The numbers of proteins involved in the synaptic vesicle recycling correlate closely. [39]

Neurons [have] links with many others, but the strongest bonds form between the few cells most similar to each other; not all synaptic connections are equal. The few strong connections from neurons with similar functions exert the strongest influence on the activity of their partners. If neurons need to change their behavior, weak connections are already in place to be strengthened, perhaps ensuring rapid plasticity in the brain. As a result, the brain could quickly adapt to changes in the environment. [40]

Hormones - Neurotransmitters

Oxytocin, a neuro-hormone that promotes feeling of “love, connection and social bonding,” also has a potentially devious effect, the “me only reward, and I want it now,” which is cloaked in fake empathy and trust, suppression of the prefrontal executive cortex and through delegating the social consequences of any action/feeling to the background; this is a way that is not dissimilar to how alcohol creates the dysexecutive syndrome. Human touch, which generates

oxytocin, is not a straight path to "love, connection and social bonding" then; there are personalities that already have preferentially engaged the reward center of the caudate nucleus, e.g. hedonistic-narcissistic personalities, for their sensory processing and by ignoring the memories of the hippocampus. The dark side of oxytocin allows people to reach Maslow's "*sense of belonging*" level on the pyramid of needs at any cost. [41, 42]

[What appears as an attempt at] understanding another person's plight, empathy, [engages] both hormones and neurotransmitters oxytocin and vasopressin [but it may be an expression of aggression] on behalf of others. [43]

The "*Present in excess*" time perspective, ["I want it now"], robs you of your ability to learn from the past and plan for the future; [you] take risk [and] act without fully anticipating consequences; [you are] unable to delay gratification [and thus] compromise health. Emotions rather than reason tend to drive the behavior of people who have poor impulse control. [4]

Output

System's emergence, its output, is a product of system's functional complexity; healthy systems are engaged in organized complexity and generate output that represents value while its senses are looking for similar attractors in the sea of available awareness; such a paradigm is compliant with systems science principles and results in successful adaptation and evolution during the lifetime of the biologic system; deviations encounter randomness and dissonance.

Output as *Value*, in this context, represents *Efficiency* (it follows the law of parsimony), *Effectiveness* (it maintains or reestablishes organized complexity via systems science-based relationships), manages *Risk* (by avoiding cognitive dissonance), and ultimately represents *Proportionate cost* (by sustaining a gradient flow of energy and information through the system that is proportionate to its throughput and outflow).

Neuro-muscular junctions

What is good for your muscles is also good for your brain (and vice versa).

Within biologic systems, significant similarities exist between, what can be broadly categorized as "*muscle*" and "*brain*" - they both use great amount of oxygen and carbohydrates for their metabolism (e.g. brain represents only 2% of body weight but consumes 20% of body energy); both muscle and brain are critically dependent on sensory input: as healthy function determines healthy structure, exercise provides the primary sensory input for the muscle, and sensory processing provides the critical input for the neuro-net. For both, the muscle and the brain, to continue to adapt and evolve, the required input-output flow, in movement and intensity, needs to be outside of the colloquial "comfort zone"; the "comfort" state does not create new muscle fibers or new neuro-muscular connectivity, both essential elements of a healthy biologic system. *Status quo*, is a form of pseudo-equilibrium, which is unsustainable within an open biologic system; as such, any equilibrium-seeking path would result in the disintegration of both muscle (loss of muscle mass) and the related synaptic neuro-net (i.e. degeneration of neuromuscular end-plates and the larger neuro-net); such a state is visible in frailty. The term exercise simply refers to some degree of movement; fitness, however, is an achieved and measurable state containing features of endurance, speed, strength and flexibility; exercise may contribute toward fitness but only if it is carried out outside of the comfort zone.

Intensity of a biologic system's movement is important throughout all three life phases; usually, it is greatly accelerated in the first phase and greatly decelerated in the last, paralleling concomitant decline of cognition; bodily fitness usually matches cognitive fitness. [44]

Physical fitness can be measured through cardio-vascular performance which, when it is high, is accompanied by elasticity of brain arteries, a factor that enhances cognition and leads to low probability of neuro-degeneration.

Lifetime of fitness provides measurable benefits for the function and structure of human body. [45]

Physical fitness also translates into improved cognition and the connecting white matter tracks in the brain (visible on scans) that are engaged in attention and memory; per study of 9-10 year old children. [46]

Movement/Intensity rhythm

Vision is the primary sensory gateway for humans and most other biologic systems. Eyes represent a physical extension of the brain and form an integral part of the neuro-net structure; their functional and physical status often approximates what is happening in the more proximal neuro-net. Eyes respond primarily to "movement" and "intensity" of environmental change which tune up the memory framework of the hippocampus, as a foundation of future decisions/executive functions. Muscle also grows in response to movement and intensity. However, when movement and intensity of input achieve a degree of stability/plateau, our eyes lose interest in the scenery and delegate it to the background of cognition causing muscle function and structure to level off.

Loss of cells in the retina (retinal thinning) is one of the earliest signs of frontotemporal dementia; retina acts as a type of 'window to the brain'. [47]

Cognition

Observing the variable decisions that biologic systems make in response to the same stimulus, the question always is: "why the difference?" Systems science offers insight: it all depends on where the biologic system is within the Dynamic Systems Model; being in the Health Territory, Chaos, or Entropy has a dramatic influence on where the system's focus lies, what is selected, how it is processed and perceived, and what decisions are made.

There is an infinite and incomprehensible amount of reality/existence that we just have no idea about. In a schematic way, what is commonly referred to as "reality," a comprehensible one to us, is what remains from the initial sensory processing and perception after most of it was simply filtered out; this reality generates a paradigm, a world-view for such a system that sets up filters for future sensory perception. This concept offers understanding as to why identical input generates differing meanings; also, knowing in advance the state of each engaged biologic system, its "reality," greatly assists in categorizing the incoming change; those in Health Territory, Chaos or Entropy do entirely different "filtering" and their output, as a consequence, varies greatly.

During processing, there is selection and compression of signals; selection is related not only to the pre-programmed sensory range but also to the decision to focus the senses in that direction; the signal compression is determined by the number of sensory cells available to receive the signal (a limited number), the number of available nerve connections to each group of sensory cells (even smaller number), etc.; the next path for signal is to go through either the hippocampal memory database, which may or may not be appropriately programed in 3-D, or a route through the reward center of caudate nucleus before reaching the variable state of the prefrontal executive cortex. As we choose the input, (e.g. watching Fox News only), we, to a large extent, create/restrict the "reality" in which we live; our output that follows is likely similar.

Sensory perception, our cognitive filter/decision-maker, determines what new sensory processing it will encompass and what "reality" is to be processed; this sequence seems counterintuitive as the "end" (cognition) determines the "beginning" (the processing); in order to get some approximation of the scale of options that are available to our senses, consider the entire spectrum of light, described in a metaphor, as a distance from New York City to Los Angeles; the visible spectrum to us/humans would then be only a dime, and that is the best scenario. [48]

If one then adds the additional filters and compressions of the sensory processing as well as the variable cognitive levels of biologic systems, the outcome, between what is out there, potentially reachable, and what fragments are actually perceived, is hard to even imagine.

Senses share many common properties among many biologic systems, cognition connects with just a few.

Crows have the brain power to solve higher-order, relational-matching tasks, and they can do so spontaneously, [have one-to-one correspondence; patterned relationships]--without explicit training; crows join humans, apes and monkeys in exhibiting advanced relational thinking; they can remember faces, use tools and communicate in sophisticated ways. [49]

The motor output that controls bird song (adult Bengalese finch) is dictated not only by firing rate but also by firing pattern and the information inherent in those patterns greatly exceeds the information available in simple spike counts. The basic unit of a bird's song is a note; one or more notes are combined to make a syllable, syllables are repeated to form a motif, and motifs together make a song. [50]

Intelligence is an ability to solve problems previously not encountered; it is the dominant function of an optimized prefrontal cortex or equivalent within a healthy neuro-net; it is organized, which implies that it has the ability to establish a hierarchy for specific attractors/focus within the overall awareness of changes. Collective intelligence, which leads to collective rationality and responsibility, is an amalgamation of existing intellect among societal members who function as optimized biologic systems and make decisions based on commonly accepted scientific facts; intelligence can arise in healthy systems, those in the Health Territory of the Dynamic Systems Model, where a well-functioning prefrontal cortex is cooperating with hippocampus that stores the memory of core knowledge; other systems, those in Chaos or Entropy, will not generate individual or collective intelligence; such a state is quite consequential and likely reflects a dysexecutive prefrontal cortex and sensory processing that bypasses the hippocampus via the reward center; collective intelligence, through this path, is hardly if ever achieved and would be an expression of randomness.

Complex psychological processes that enable people to solve problems [is] popularly understood as 'intelligence'; [a] skill to covert information into useful knowledge. [51]

Intelligence, mostly understood in terms of cognitive abilities and often the execution of bodily dexterity, should also be applied to the *not seen but vital* biologic system's internal intelligence, its immune competence; both the cognitive and the immune intelligence concepts emerge from systems science view of biologic health. Healthy systems clear pathogens quickly, have high capacity for repair/regeneration as well as adaptation and evolution; the opposite, however, is true as well.

Our language is linear, one word at a time, while the incoming sensory input is multidimensional and recorded in memory as such; the cognitive internal dialog, the *chatter*, is the language that only we hear; it translates the sensory processing into understandable perception but in a linear sequence usually of words which significantly restricts the recall potential of any sensory input; registering an input through multiple senses would enhance the recall; if the internal language/chatter is already engaged in an unrelated monolog, sensory input is all but ignored. Also, the internal chatter must respect the overall cognitive threshold and gets triggered at the speed of about 60 bits per second.

How do biologic systems make sense of the world? There are certain brain cells that are the equivalent of a satellite-navigation system (GPS) and tell us how we know where we are in space; it is one of the most fundamental issues for survival. Researchers, Edvard Moser, May-Britt Moser and John O'Keefe received the 2014 Nobel Prize in Physiology or Medicine for answering this question.

The brain seems to have its own operating languages — a bewildering set of codes hidden in the rates and timing with which neurons fire as well as the rhythmic electrical activities that oscillate through brain circuits. These neural codes for cognition [are] how the brain generates behaviour [and] allow the brain to represent features of the external world — such as sound, light, smell and position in space — in a language that it can understand and compute.

The pattern constitutes a neural code [a matrix]. The early stages of Alzheimer's disease [in animal model] affect the entorhinal cortex (EC) [that functions] as a hub for memory and navigation. The EC is the main interface between the hippocampus and neocortex; one of the first symptoms is losing one's way. The disease goes on to devastate the hippocampus, stripping sufferers of their memories. [52]

There are 'place' cells (fire only when an animal is in a particular place, creating a map of the environment). [53]

In the hippocampus [there are] 'grid' cells [creating] a near-perfect hexagon lattice, like a honeycomb. The hexagonal pattern [for] spatial navigation [was studied] in the entorhinal cortex. [54]

In neurodegeneration, such as the Alzheimer's disease, there is a progressive degradation of the capacity for three-dimensional orientation in space that senses provide, such as smell, and others, followed by loss of horizontal orientation map; the outcome is that the neuro-net matrix degenerates from 3-D to fragments of 2-D. A healthy hippocampus is capable of constructing a 3-D matrix from received sensory input which, however, needs to be multi-dimensional. Engaging TV or other "face-time" activities, as the dominant daily sensory input, will likely prevent the matrix to be formed.

Failing of function - structure

A well-known observation of the bidirectional *function – structure* relationship, among biologic systems, is the difference between chronologic and biologic age: on one hand, the chronologic age is only related to the number of Earth's revolutions from birth up to a certain calendar date; biologic age, on the other hand, is primarily related to the lifestyle choices, as all decisions have an opportunity cost, which have been made primarily in the second Phase of Life; in a healthy system, the biologic age can measure to be substantially younger than the chronologic age.

A major contributor, to the observed features that are associated with the health decline in chronologic aging (generally referred to as "age-related"), is the dominance of Entropy, an accumulation of non-functionality; a large body of evidence already exists about the benefits of exercising *muscle and brain* on healthy life and longevity via *movement and intensity* which is outside of the comfort zone; this process optimizes the UP/DOWN regulation of the epigenome; the influence of exercise is especially critical during the second phase of life, the Phase of Decisions, when most behavioral choices affecting the epigenome are made and sustained for the third phase of life, the Phase of Consequences, when they dominate the morphologic phenotype. Another critical reason to pay attention to health in the second phase of life is that the epigenome, originally received during conception, already modified by forefathers, can now be "re-tuned" to health and carried as such to future generations; opposite scenarios are detrimental to all. Only functional epigenetic data/information, however, are transferred to an offspring, not judgement; that requires memory/hippocampus and the executive functions of the prefrontal cortex, which both await the lifestyle choices of the offspring as it goes through Phases of Life.

A biologic system is programmed, through inherent genetic clock in the suprachiasmatic nuclei, to be in synch with day/night (circadian) cycle of Earth's rotations. Biologic systems with cognition, however, also have "will", an ability to make decision that often are quite contrary to the rhythm of the circadian cycle and such disharmony cascades through the entire system, all the way down to the genome which is then epigenetically misregulated.

Chronological age, after adolescence, becomes a less reliable predictor of motivation, thought process, and emotional response. [4]

Dynamic Systems Model

Health Territory

Dynamic Systems Model is predictive regarding the character of system's relationships and everything that flows from it, e.g. complexity-Emergence-Health-Chaos-Entropy.

The existence of all biologic systems is conditional, principally on relationships with *Self* and others; optimized relationships, as conceptualized in this Model to be present in the Health Territory, express an aggregate of features of *reciprocity, fairness, empathy, and trust* which provide the optimal milieu for sensory perception; lack of any feature creates dissonance manifesting as stress and destabilizes all engaged systems; within such a scenario, sensory perception has random outcome.

Neuro-net as a system in its own right, can retain some of its functions in any of the three categories of the Model; in the Health Territory, there is a broad balance between excitatory and inhibitory synaptic neurotransmitters. Entities in the Zone of Chaos are deficient in GABA inhibitory neurotransmitters, while in Entropy the accumulation of non-functionality dominates.

A dysfunctional system, one in Chaos or Entropy, is highly unlikely to have operational framework that is capable of *adapting and evolving*, features that are characteristic of a robust and resilient system in Health Territory.

Entropy

The inability to fully conceptualize time, the past, the present, and the future, as part of Entropy, is similar to the characteristics of hedonistic personality (disorder), where only "now" is somehow viewed as the only time frame; relationships are severely impacted by the following: inability to express empathy, insistence on severe entitlement, and avoidance of trust. [4]

Even a large societal system can operate outside of the Health Territory. For example, there is visible evidence of the lack of "fitness" of system components, e.g. societal members on a large scale, placing them outside of the Health Territory; this amounts to a major instability for the entire system.

The majority of individuals in the United States are not eligible to donate a kidney, even if they wanted to, because 55 percent of the population would not meet criteria to donate, mostly because of preventable health conditions. [55]

71 percent of recruits, 17-24 year olds, do not qualified to enter military due to obesity, low education, and crime history. [56]

Four out of five firefighters, nationwide, are overweight or obese, and roughly half of all firefighters who die in the line of duty each year are killed by heart attacks. [57]

Obesity affects nearly 1 in 3 Americans. Obesity increases the risk of several chronic diseases but probably has the greatest effect on type 2 diabetes. [58]

Aging

The general concept of aging can be used as a well-known example of Entropy, where progressive accumulation of non-functionality is visible externally, including frailty and cognitive decline; in contrast stand the examples of fitness and ongoing cognitive intelligence, regardless of age.

System science would anticipate that it is the loss of function that precedes the loss of structure, e.g. sarcopenia, loss of muscle mass and strength; the dysfunction of neuromuscular junctions is followed by the decline in the number of motor neurons and muscle fibers thus impairing the communication within the connectome; such a sequence of events reaches beyond just muscles to other senses, including vision.

Age-related declines in intelligence are strongly related to declines of visual perception speed (making correct decisions based on brief visual impressions). [59]

Aging degrades reasoning, [especially] the hippocampus [which] is involved in relational reasoning ability, how we reason by analogy. [60]

Neurodegeneration

Alzheimer's disease is a neurodegenerative disorder characterized by progressive cognitive decline and dementia. [Pathognomonic are] changes in synaptic plasticity, neuronal disarray and cell death. [61]

Simulations/"face-time" and memory

Virtual reality/simulation, the future existential hope of many, provides vastly inferior input to the neuro-net which needs to create its own space-mapping framework; a "flat screen" input might lead to a "flat hippocampus."

The enormous amount of "screen time" that the current generational cohorts are engaged in, has potentially a significant negative impact on our individual neuro-net/memory, as the most recent laboratory recordings from hippocampus indicate (see above); "screen time" provides infinitely inferior sensory input into the neuro-net which appears to lack recallable memory patterns and represents disorganization; screen time often delegates learning/memory to some hard drive or a cloud server and not the hippocampus; without recallable integrated patterns of core knowledge within the neuro-net, new brilliance/discoveries will likely be harder to formulate. Simulation/screen time, regardless how seductive, is not Life; teaching, learning must primarily engage Life.

The pattern of activity in a brain region involved in spatial learning in the virtual world is completely different than in the real world when the hippocampal neurons become

selectively active, providing a "cognitive map" of the environment. In the virtual world in a laboratory, rats' hippocampal neurons seemed to fire completely randomly, as if the neurons had no idea where the rat was -- even though the rats seemed to behave perfectly normally in the real and virtual world. The original real world 'map', recorded with electrodes, disappeared completely. The neuron activity was a random function of the rat's position in the virtual world. The hippocampal neurons were highly active in the real-world environment but more than half of those neurons shut down in the virtual space. The virtual world used in the study was very similar to the virtual reality environments used by humans, and neurons in a rat's brain would be very hard to distinguish from neurons in the human brain. Complex rhythms of neurons are crucial for learning and memory; they are using two entirely different languages: one is based on rhythm [movement]; the other is based on intensity. Every neuron in the hippocampus speaks the two languages simultaneously and those neurons involved in memory have to be perfectly synchronized. [62]

Devout video gamers may develop more efficient visual attention but it is likely that the path from senses to cognition bypasses the hippocampus and travels instead through the reward center of caudate nucleus; as, indeed, videogames are driven by "rewards."

It is estimated that the average young [video gamer] will have spent some 10,000 hours gaming by the time they are 21. They may exhibit more efficient visual attention but more likely use navigation strategies that rely on the brain's reward system (caudate nucleus) and not on the brain's spatial memory system of the hippocampus. People who use caudate nucleus-dependent navigation strategies have decreased grey matter and lower functional brain activity in the hippocampus and may have reduced hippocampal integrity, which is associated with an increased risk of neurological disorders such as Alzheimer's disease. [63]

5. Results, Conclusions

Sensory processing is primarily an electro-chemical transfer of a signal from triggered receptors that is transmitted into the higher levels of the neuro-net; it is significantly conflated in terms of breadth and depth, while retaining some resemblance to the initial input; this sequence is judgment free.

Sensory perception, however, reflects the overall operational paradigm of a given biologic system which replicates the level of compliance with systems science principles from the past, the present, and in an outlook for the future; it may have no resemblance to the initial sensory input as this sequence is not judgment free.

The answer to the research question of why two observers can have different recollections of a single event and simultaneously be both wrong is as follows: It is due to the differing perceptional paradigm of biologic systems. Systems science offers a predictable path to parse the bias and to find meaning in sensory processing-perception sequence.

Epithet: to reach the most optimal sensory processing and perception, both of these functions must be under the guidance of a healthy biologic system, where structure follows function; this implies an inherent potential for adaptation and evolution of a given morphogenic phenotype through its relationships. Such a system has known needs and variables: the need for optimized relationships, the need for synchrony with external and internal cycles as well as the ongoing resetting of activities and recovery periods. Sensory processing and perception are the primary determinants of the "*reality*" of a biologic system, though always far away from the richness that lies beyond. It is not with the ever-increasing accumulation of data/information that we gain knowledge during sensory perception but in greatly enhancing intelligent multi-level filtering and "de-cluttering"; the gamma amino butyric acid (GABA)-synaptic inhibitory function of the neuro-net is the key to maintaining a sustainable balance between intake and output; furthermore, memories are created by rhythm, and rhythm is more important than rate, thus too much input suppresses rhythm.

Key dependencies: sensory processing depends on "*movement*" and "*intensity*" of an environmental change; sensory perception depends on "*memory*" and "*rhythm*" within neuro-net oscillations; both processing and perception involve massive data filtration and compression at various strategic nodes; brain and muscles are closely linked in their basic metabolic needs and functions in order to sustain the process of alternating activity with recovery; the "*internal dialog*" of cognition, is the language of the mind and functions as the Rosetta Stone for translating the electro-chemical signals of sensory processing into an understandable mother tongue (should allow for maximum creativity and not rigid conformity with endless rules); knowing other people's language offers clues as to their internal dialog, for that impacts the creation of their reality.

Prominent features in a life of a biologic system that beg for *reflections*:

- The daily questions - what you take in, how you process it, and what you do with what is left.
- There is no escape from fundamentals: We are our memories.
- Decisions do affect the epigenome, metabolome, microbiome, and connectome.
- Cognitive threshold allows the extraction of meaning up to

certain speed of internal dialog; it is very limited and degradable.

- Efficacy of the executive prefrontal cortex exists within a narrow and a labile state.
- De-cluttering process must be ongoing on all system's levels.
- Fitness enhances both sensory processing and perception.
- Choose, as your mother tongue, one that allows the greatest innovation/flexibility of expression and then become eloquent in it; this will maximize your cognitive capture from the processed signals.
- The choice of "*reality*" emanates from a chosen sensory input and biased perception.

Perils to be avoided:

Dysfunctional prefrontal cortex, a dysexecutive syndrome, which is analogous to and can be created by alcohol intoxication or sleep deprivation, has known negative consequences on meaning creation from sensory input and subsequent decisions.

Neurodegeneration that can schematically be visualized as an implosion of neuro-net following a long history of dysexecutive syndrome. This function-structure collapse is often preceded by shunting sensory input to the prefrontal cortex via the "reward center" of caudate nucleus while bypassing/neglecting the hippocampus. These steps are related to the decisions usually made during adult life, the Phase of Decisions, regarding non-optimizing intake-output of energy and information that are all consequential for Self and pertinent cluster.

"*Flattening*" of hippocampus with "face time"? Electronic simulation does not create the needed 3-D memory pattern/framework in the hippocampus.

The "*never forget*" points:

Encountering new change by our senses and invoking sensory processing, should always raise two existential questions to be considered by our cognition. The first question is: Where am I, my biologic system, within the Dynamic Systems Model, is it in Health Territory, Chaos or Entropy? The second question is: where is the other system, within the same Model, which originated the change that I am now meeting?

The Health Territory, identified by the Model as a fitness state of a biologic system, can facilitate the achievement of a very high degree of relevant/contextual meaning from sensory processing and perception.

Steps for "tomorrow:"

Learn how to "*see*" in 3-D to grasp the inter-connectivity of information in order to develop true knowledge. Life is non-linear; studying/engaging it with linear approaches leaves too many large gaps.

Teach "*imagination*" in all its dimensions as the logic of linearity can be seductively deceiving in its simplicity but mostly misses its mark.

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