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Duality/Complementarity As a General Systems Isomorphy

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ABSTRACT: This paper begins with a short discussion of the need for a methodology designed specifically for proving that the same Isomorphy exists across several disciplines. It then continues with a detailed case study evaluating the proposal that duality/complimentarity be considered a systems-level isomorphy. A prototype methodology is used to answer the question, "how can duality be demonstrated to exist in virtually all disciplines?" The several common synonyms for duality used by different disciplines (discinymys) are juxtaposed, compared, and critiqued. Twenty-four empirically researched examples of duality in biological systems are then presented ranging across such levels of organizational complexity as the molecular-, cellular, organellar, organismic, population, and ecosystemic. The cases of duality in biological systems are generalized to yield a set of criteria or characteristics which could be used to recognize the putative isomorphy "duality" in any discipline. These same criteria are submitted as a definition of the general systems level isomorphy duality. Analysis of the widely recognized empirical facts implied by these biological examples of duality leads to the recognition of two master "generative" dualities. These two epigenetic dualities are proposed as responsible for emergence of many of the cited specific dualities in biological systems as well as those found on many other levels of organization in physical and social systems. They are proposed as fundamental to a theory of emergence of hierarchical levels. Finally, some initial discriminations useful for an initial taxonomic categorization of dualities is presented and the function of duality in systems is briefly considered leading to the significant question, "why do dualities form anew on all emergent levels of natural and man-made systems?"

NEEDED: A METHODOLOGY FOR "EMPIRICAL REFINEMENT" OF ISOMORPHIES

Frequently criticism of attempts at formulating a general theory of systems (GTS) comes down to criticism of its internal methodology (Troncale, 1984a). Despite its claims for recognition, GTS does not have a consensus methodology of its own. A true general systems methodology would have to reside in and gain its validity from the regions "between" or "across" disciplines, yet most of the systems analytical techniques now associated loosely with the systems movement reside firmly within a related cohort of disciplines or are applied solely to one target area. The main product of GTS is recognition of isomorphies across disciplines, yet the absence of a cross-level methodology inhibits the study and verification of those isomorphies (Miller, 1983; Troncale, 1985a, 1985b).

Most of the isomorphies popular in the systems movement seem to be accepted because of a gradual increase in their citation in the literature which apparently renders them real *ipso facto*. Once demonstrated in one cohort of disciplines, they are often extended and applied to quite independent cohorts with little justification or critical challenge. Few of these extended isomorphies, now numbering as many as 75 in some treatments (Troncale, 1982, 1985c), have been rigorously demonstrated across all scalar levels of systems or have been related to specific "scale translation protocols" (Troncale, 1985a) in a way that would allow practitioners to use them in a robust manner through the mechanism of their empirical refinement (Troncale, 1985b). Connections between the isomorphies are almost totally ignored despite the fact that these connections are the cornerstone of the "special knowledge" inherent in any GTS (Troncale, 1982).

This criticism is not as much true of mathematically-based isomorphies as it is for many conceptual isomorphies. Mathematics constrains theory. However, even in these cases a related problem appears. The criticism recently leveled at the mathematical theorems and analysis typical of economic theory could be equally well applied to mathematical systems analysis (Eichner, 1983, 1985). Formal approaches simply

cannot equal up to empirically-based refinements. Beyond this, isomorphies proven for the more rigorous and mathematically-based disciplines are not proven for their extension to the "softer" disciplines. Given these several observations, the purpose of this paper is to study the feasibility of answering the question, "what can we do to provide some evidence of the widespread occurrence of "duality" and its interconnection with other isomorphies in generating systems function in the absence of an approved isomorphy-refinement methodology.

An interim methodology might consist of the following. Demonstrate existence of an isomorphy such as duality in the phenomena of a discipline using the empirical tools of that discipline. Do this iteratively for several related disciplines a cohort (for example, the cohort of behavioral systems, or living systems, or physical systems, or man-made systems). Extend these empirical demonstrations of the same isomorphy across the boundary to the next higher level of cohort complexity. Concatenate those demonstrations across several cohorts. This is the approach taken in paper at least as far as demonstrations across levels of the biological cohort. The isomorphy would be considered "refinable" if the accumulated data across levels improved our detailed knowledge (resolution) of the isomorphy and its function. If only a number of levels or cohorts of levels the isomorphy, then specific knowledge of the range of application of that isomorphy would be achieved. Knowledge of limits of validity and applicability is a sign of the maturity of a concept or tool. A candidate isomorphy would be considered "validated" if all of the levels examined with the reductionist tool of each respective level showed positive evidence of the existence of the isomorphy as well as consistent and recursive appearance at each level of some minimal sort of criteria for the isomorphy. Of course the last step assumes that there exists a consensus on the general characteristics or criteria that define each isomorphy (a condition that does not presently obtain).

These kinds of studies would gradually provide the needed demonstrations of the transdisciplinary non-scalar, invariant nature expected of such an isomorphy. But it is still debatable whether or not they achieve the needed, truly transdisciplinary general systems method. Specifically, both basic research and applied research related to the GTS need either a holistic analogue of the "correspondence principles" utilized in the natural sciences (Schaffner, 1967, 1969), or a demonstrable tight-coupling between and across the cohort systems phenomena. I have called this tight coupling, complete with its transformation algorithms, by the phrase "scale translation protocols" or "deabstraction rules" (Troncale, 1985a). The correspondence principles are used to connect macro-level or observable phenomena to molecular and atomic phenomena several unobservable levels downward. The analogue of this in GTS research would be used to "connect" the empirically derived features of an isomorphy in one discipline, or on one level, to the empirically-derived features of isomorphy on several different levels or disciplines.

But showing that the isomorphy is indeed present on many levels, and even discovering scale translation protocols still does not supply rules for proving and connecting the similarities in a way that is both descriptive and prescriptive of optimal systems functioning. This is exactly what is needed during this paper session, we will be providing many examples of duality in the specifics of many diverse disciplines. By comparing these we may derive a better definition of duality (showing it is refutable) the best we can do to help in the search for a truly general systems methodology, however, is to use this attempt to highlight the need and thereby encourage others to help fulfill it in the future.

OF SYNONYMS AND DISCINYMYS

Duality is a concept more than 3000 years old appearing in

verbal traditions that preceded the written Tao (Lao-Tzu. ca. 350 B.C.; Marton, 1967). An argument could be made for an even more ancient origin if one cites the many cases of dualogisms in primitive languages. Such an ancient concept collects many meanings and results in many synonyms, that is, different words with the same meaning.

Duality may be the most popular form of the word in the humanities in philosophy the preferred word might be dialectics. Certain computer-based mathematical algorithms are collected under the term duality. But in quantum physics and cosmology the same general phenomenon is called "complementarity." Dichotomy is a popular word used by the educated public. Other related terms are dimorphic, branching, divergent, bifurcation, and binary. So we are faced with the plethora of available terms shown in Table 1.

I have suggested and defined the term "counterparity" (Troncale. 1972, 1978) as a "neutral term" without the many pre-established meanings of duality which act as "noise" obscuring perception and interfering with communication. It has not been widely utilized in spite of the need to redefine the systems-science-based concept and characterize it independent of its common usage. (Similar resistance has been encountered in suggesting adoption of the term "heterarchy" to free this isomorphy from the connotations of the common term "hierarchy"). The use of a new name to isolate and "fix" a definition for a phenomenon is a time-honored tradition. That is why the natural sciences build their jargon from the dead languages of Greek and Latin.

Systems scientists must persevere. The local-scale connotations of many systems-related words greatly inhibits perception of the brood-scale and Invariant characteristics that could be perceived. Conclusions such as those reached by Robbins and Oliva (1984) in support of Miller (1978) that systems science may continue to use existing terms to describe systems phenomena are questionable because they completely fail to measure this interference problem.

Some of the synonyms for "duality" are popular, some scientific and discipline-based; some have precise and some very imprecise meanings. All have something in common otherwise they would not be synonyms. These commonalities will be our shopping list for criteria to define the Isomorphy. Each commonality must be subjected to scrutiny *vis a vis* its role in generating Important systems behaviors or functions. Those that survive will be used to examine other disciplines or other levels of complexity for possible examples of duality; and these, in turn, will be used to further refine the list of criteria after extending the list of criteria used to judge whether or not something is a duality or not, we will use the criteria to compare the synonyms of Table One to expose their hidden meanings. But what are "discinymy?"

Practitioners of a GTS need to be alert to the possibility of using a new term in this situation that would dramatically clarify for others and for themselves the special difficulty everyone faces in describing isomorphies that can be found in all disciplines. Very often researchers in a discipline have discovered aspects of the isomorphy on their own level or scale and named it in the jargon of their disciplines. When approached about the existence of the Isomorphy across disciplines they tend to respond. "Oh! that's just xxxxxx. We've studied that for years." The special features that each isomorphy takes on with each scalar level (because of its manifestation by the particulars of that level) obscures the general features it maintains across levels. Disciplinarians ignorant of the specifics of other levels, and often incapable (or reluctant) to see beyond their own particulars, have no mechanism for perception of the transdisciplinary, Invariant features of the term they use to define their level of awareness of the isomorphy. The term "discinymy" attracts their attention directly to these limitations. 'So discinymy may be defined as the several uniquely different jargon terms from disparate disciplines that name the same isomorphy. They are disciplinary-based synonyms (thus, concatenated into discinymy). There are many examples of discinymy such as the

use in biology of "homeostasis" as a specific case of "dynamic equilibrium ". Discinymy greatly complicate recognition of the isomorphic condition because the mere existence of independent words over emphasizes the differences between things far more greatly than their similarities. Professional Jargon, learned as it is immersed in the context of strict, disciplinary orthodoxy, becomes a barrier to open perception and a source of personal power few are willing to relinquish. Widespread recognition of the "discinymy" phenomenon could help raise awareness levels and aid in cross-disciplinary communication.

ANCIENT PHILOSOPHY: A BARRIER TO RECOGNITION OF DUALITY AS A SYSTEM ISOMORPHY?

Systems researchers are holists. As holists they are often steeped in Eastern philosophy. As proponents of Eastern philosophy they are quick to resist any insistence on perception of dualities because it runs counter to most Taoists, Buddhists, and Zen traditions. The wise men of these approaches to reality are clear about the inadvisability or inappropriateness of perceiving everything in the universe in terms of dualities (Morton, 1985, Wall, 1967). Although not systems researchers themselves, they needed to look no further than the many dualogisms in their languages to perceive that the common man was overly fascinated with fundamental dualities from the Yin/Yang to its multitudinous manifestations. Their problem was one of getting the common man to see beyond immediate reality to its inner substance. So they urged recognition of the integral wholeness of reality and portrayed the separation of reality into words as the beginning of the downfall of mankind. They emphasized that duality and paradox both are always overcome in nature by transcendence of the duality on the next level of complexity, although they expressed this in extremely vague and non-systemic images and metaphors it is no wonder then that systems researchers have a kneejerk response against duality.

Yet systems science has a tremendous opportunity in the next century of co-mingling both Eastern and Western perceptions and methods (Troncale. 1984b). General systems science can elucidate the mechanism by which dualities cause hierarchical levels to emerge (the theory of emergence) and thus demonstrate how nature ultimately and recursively transcends every paradox or duality. In this elucidation it will both be focusing on dualities and not focusing on dualities at the same time. I submit that this philosophical, perceptual, and emotional position is closer to the spirit of these ancient Eastern traditions than mere condemnation of dualities which actually misses the point made by the Wiseman. Therefore, dualities should be studied, not ignored, by systems researchers. They exist, even if recursively transcended. They seem to be potent generators of systems functions. One need not ignore the existence of two separate and distinct pillars just because together they support one unified portal.

EMPIRICALLY-DEMONSTRATED DUALITIES ACROSS LEVELS OF BIOLOGICAL ORGANIZATION

In the following exercise, twenty-four different candidate dualities in biological systems are presented in some detail. Why? First, to avoid the usual criticism of general systems theorists as vague holists. Second, to probe many specific examples of dualities for their underlying characteristics; general comparisons can only be as good as the specificity of the items compared allow. Our list of criteria for duality will depend on the sample used to construct the list and our care in analyzing the sample. Third, to help other workers in duality theory by giving them sufficient specificity to allow comparisons between this cohort of dualities and theirs in markedly different systems. Fourth, to emphasize how similar the function of duality might be on widely separated levels despite the incredible diversity or the particulars used by nature to manifest the duality. Fifth, to aid in perception of

potential "noise" in the recognition of dualities; not all dualities may be fundamental to systems function. A method for distinguishing between dualities critical to systems function and incidental dualities must be discovered. Some of the dualities described will not possess the criteria expected of the isomorphy and so are not participants in the process of systems emergence. Sixth, to aid in the perception of the apparent independence of the structural and Informational domains or mechanisms of living systems. The significance of these domains needs to be understood. Why should there be dualities in both domains for each scalar level? Conventional biology has demonstrated the Interdependence of these domains within the bio cohort; the wider perspective of systems science may be needed to perceive and understand the necessity for independence of these domains for systems building. Seventh, to provide many different examples of emergence of a new level of the putative biological hierarchy enabled by the Interactions among the dualities. Each of these new levels exhibits dramatically unique emergent qualities, yet each is caused by different dualities. This series of case studies could be used to define and test a general theory of emergence, presumed to be quite distinct from the conventional theory of evolution (Troncale. 1978, 1981b). Eighth, to indicate the extent of empirical support which exists for the phenomena described; the organization of the facts is unconventional, but the scientific evidence for the facts themselves is conventional, and as unassailable here as is the discipline itself. Ninth, to provide many particular cases of the two "master dualities" described at the end of the paper, at least for the biological cohort of levels.

The following examples, taken from the conventional levels of biology, are organized according to increasing complexity. Biological scientists have demonstrated by what mechanisms and at what times each of these levels appeared on our planet. Thus, the sequence of these examples of duality are often perceived as a continuous time series as well as one of increasing complexity. However, preliminary evidence from empirical testing of hierarchies in biological systems (Troncale, 1981a, 1982) indicates that this oversimplified view of the time series may be in error. An unconventional grouping of levels that is consistent with the evidence from clustering theory would be a better example of an emergence series showing increasing complexity. It is necessary to distinguish between the conventional complexity and time series and this unconventional sequence of origins taken from the hierarchical data before it becomes possible to study and explain the process of emergence. This has not been attempted in this paper as it will be the subject of a separate paper.

For each conventional level, both the proposed "structural" and "informational" dualities are presented, although described and listed separately for each level. One of the most significant questions facing general systems scientists concerns the validity of the assumed boundary between physical structure (found in all systems, but most typical of physical systems) and Informational structure (found in living systems, and most dramatically in human systems) and, therefore assumed to distinguish these latter systems completely from physical entities. When "scale translation protocols" are discovered between structure-dominant and Information-dominant systems which penetrate through to the general relations common to both, then GTS will have something of significance to say to the disciplines. The series of "structural" and "informational" examples that follow, organized on the duality and emergence themata, may be helpful in puzzling over this problem facing systems science

EXAMPLE DUALITIES: MOLECULAR LEVEL BIOLOGICAL COHORT OF SYSTEMS

The molecular level of bio-systems appeared about 4.0 billion years ago (billion = 10⁹). The spontaneous origin of

biopolymers from action of geophysical energy sources such as lightning, planetary heat, and ultraviolet light on the simple inorganic chemicals of the atmosphere has been demonstrated in the Laboratory by many Independent workers beginning with the Nobel Prize winning work of Miller and Urey in the 50s Polymerization of the first monomers into longer chains of nucleic acids and proteins may have occurred by catalysis by clay soils, action of sunlight on water-air interfaces or by freezing. The feasibility of all of those alternatives has been shown in the laboratory. Eventual complexification of the cell led to the following proposed dualities now evident on the molecular level.

(#1) Structural Duality- DNA Double Helix Base Pairing:

Deoxyribonucleic acid consists of two long chains of nucleotide monomers which are complementary in several ways. First, the two chains run in anti-parallel (opposite) directions. Second, adenine-thymidine (AT) and cytosine-guanine (CG) base pairs form between the two strands holding them together because of electronegative atoms on the bases which require hydrogen bonding to achieve their lowest thermodynamic energy state. Third, AT and CG base pairs form because they have exactly matching numbers of unsatisfied electronegative atoms in exactly aligned positions. Fourth, AT and CG base pairs form because each pairing consists of a smaller base (a pyrimidine) matched with its partner, a larger base (a purine) so that any of the four combinations possible always make a pair of nearly constant size (within 0.3 angstroms of tolerance) This provides for the necessary structural consultancy and stability along the chain. The resulting double-stranded polymer is relatively unreactive and quite stable compared to its single strand states. Here we see two populations, mostly similar, with small, but opposite differences, balanced in magnitude that cause them to interact and neutralize each other in forming an aggregate with new qualities.

(#2) Structural Duality- Antigen/Antibody and Enzyme

Substrate Stereochemical Recognition: Chains of protein monomers in water find their lowest thermodynamic energy state by folding hydrophobic (water hating) monomers inside and exposing hydrophilic (water loving) monomers outside of the three-dimensional shape they thereby assume. Additional influences such as certain monomers that form covalently bonded cross-bridges, and others that impose sudden bends in the chain of monomers, as well as the interactions among the side chains of the monomers assist this process. Each unique sequence of monomers forms a unique shape, but all versions of any one sequence reproducibly forms the same shape. The shapes so formed have complex surfaces alive with exactly positioned atoms. These atoms have moment-by-moment alterations in their charges or possess side chains with built-in charges. The result is rather weak electrostatic binding potential between the surfaces of proteins called van der Waals forces. But these can only act across very limited distances of about 1 to 3 angstroms. As evolution has proceeded many proteins have appeared whose shapes exactly complement each other. Bulges fit into gaps, ridges into grooves, and undulating planes into their complement. The many enzymes that find and bind to their substrates to change them, and the many antibodies made by vertebrates against invading foreign proteins have evolved these complicated, opposite shapes to recognize each other and bind by the van der Waals forces. Here again we observe the existence of two populations, whose subunits are similar, but are organized into opposite differences, small in magnitude relative to their overall composition, and which interact, neutralize left over forces, and form aggregates with new qualities.

(#3) Structural Duality- Duplicate, Paired Genes in Gene

families: Due to a mechanism called unequal crossing over and exchange of chromatid arms some genes duplicate themselves. The fifteen or more natural causes of mutations gradually cause these two duplicate genes to change in terms of their sequence of bases. One often retains the original

sequence to support the role that necessary single gene used to fulfill in cell function, but the other is quite free to assume to a new, but related sequence. As much time passes the now free wheeling sequence alien assumes some new function in the cell and actually expresses this role by forming aggregates with the original gene of the duplication. Many examples exist, but perhaps the best known is the hemoglobin family where three or four gene duplications have caused variants alpha, beta, gamma, delta, and epsilon. The most common molecule in the blood of adults is a tetramer of two alpha proteins combined with two beta proteins. Other combinations have specialized uses in other phases of the life cycle, e.g. in fetal blood. Many other gene loci exhibit this feature of forming heterologous multimers (e.g. microtubules, isozymes, etc.). In all of these cases we see two populations, mostly similar, but with minor variations that allow them to interact to form aggregates with improved function that fulfill some higher level need of their context.

(#4) Informational Duality- Intron/Exon Gene Segments: DNA genes were once assumed to consist of a linear sequence of meaningful information that directed the synthesis of RNA copies, and thence protein translations. But recently it has been demonstrated that the meaningful information (sense) is separated by variable lengths of pieces of nonsense, meaningless information. As many as 52 pieces of nonsense (introns) may be separating sense (exons) sequences which must then be laboriously cut out and integrated into a meaningful message. Informationally, sense is the opposite of nonsense. So here again we see two populations, but in this case much more variable in size, who are identical in their composition as far as subunits, but opposite in their configurations in terms of meaning. However, this possible duality does not have balance in terms of magnitude, nor does it exhibit the features of neutralization upon combination. The two opposites do participate in assembly of aggregates which have new qualities, but in this process the introns act rather passively compared to the other dualities cited. This proposed duality presents something of an anomaly, or perhaps a clue to feature or criteria yet unperceived.

(#5) Informational Duality- The Marriage of Protein and DNA in the Genetic Code: When the first protobionts formed, they were localizations of the early biopolymers without the organization of today's simplest cells. Merely bags, or higher concentration of biochemical, they were not guided by the sophisticated information transfer mechanisms which are now typical of cells. Why did the genetic code form which guides the transfer of sequences of nucleotides in DNA to sequences of amino acids in protein? The answer lies in perception of how the marriage between the two leads to a combo much more capable, of survival than either one of the two alone. If one examines the strengths of DNA, one sees they make up for the weaknesses of protein, and vice versa. DNA could form very long chains of monomers, which meant it could store incredible amounts of information in small space, and it could also replicate this information by the base pairing mentioned above. Since it was unable to form three dimensional shapes, but rather tended to remain a loose, delicate strand only 20 angstroms in diameter, DNA was very fragile and subject to breakage by almost any force in the vicinity. Meanwhile, protein did not have the built-in mechanisms DNA had for reproduction of itself or for stabilizing the formation of very long sequences of parts, yet it was very adept at forming three dimensional shapes that were chunky aggregates capable of withstanding local forces. These shapes tended to fit into each other and form even much larger, still stronger structures. But in not being able to reproduce, the large number of complementary proteins copies needed to make these aggregates could not be formed. Protein was limited. At the same time, DNA could not utilize its greatest asset of containing and reproducing lots of information because such long strands would break immediately without protection. However, if DNA could associate with and stimulate the synthesis of many protein copies, then proteins

could make protective aggregates that would protect the DNA and both would prosper. Many reiterations of improvement would cause increasing amounts of DNA to code for increasing amounts of protective protein aggregates which would allow for longer DNA coding for store protein, etc. Here we have two major populations, opposite in terms of their functions (not their structures), with the opposite needs and strengths well balanced in magnitude and complementarity. By falling into the genetic code the limitations of both might be said to be "neutralized" although this strains the usual meaning of the term. But clearly a new aggregate was formed with major new qualities.

(#6) Informational Duality-Palindromes and Transposons: Palindromes were known in linguistics before molecular biology. "able was I ere I saw elba" and "a Toyota" are well known palindromes. They read the same both ways. Recently short DNA sequences, organized in a similar manner, have been found in the genome of many organisms. A nucleotide sequence is found on one of the two chains of DNA (which of course must have its opposite on the complementary strand) and then much further downstream or upstream of this position an exactly opposite, complementary sequence, of the same size and length can be found with its complement. When excised from the overall DNA chain these two palindromic sequences find each other, their complementary opposites interlock (now to their matches downstream rather than their partners across-strand) forming a stable, double-stranded DNA circle. This became such an important mechanism that parts of genes became secluded between the palindromic opposites so that they could apparently be waved around in the genome (and even across species it seems) more easily....these are called "transposons." or mobile elements. Again we see two populations with an overriding similarity, but different in part and oppositely, balanced in equal magnitude, and able to interact, neutralize each other and promote, not so much a new aggregate now, but a new level of variability. This is an important difference characteristic of informational but not structural dualities to which we shall return.

EXAMPLE DUALITIES: ORGANELLAR LEVEL: BIOLOGICAL COHORT OF SYSTEMS

The organellar level originated as a subspecialization of the cellular level and probably, therefore, came after the first cells were well along the road of evolution. This is an example of a difference between the time-of-origin sequence and the sequence of increasing complexity. As usual the discrepancy is due to man's anthropomorphism; he uses a ordering criterium that seems important to him for organizing reality, but it might not be the ordering criteria utilized by nature.

(#7) Structural Duality- Chromosome Structure: In all diploid organisms, the DNA is folded into a tightly packed configuration by histone proteins resulting in a length many times shorter than the original DNA. This configuration is usually divided into a number of packets called chromosomes which are constant for all normal individuals of a species. Although different species of organism have different numbers of chromosomes to carry their different types and amounts of genes, most of the chromosomes possess a similar, generalized structure. Each chromosome consists of two distinct parts, called chromatids, joined somewhere along their length. The two parts are called "sister" chromatids to denote that they have exactly the same type of genes along their length; they are duplicates. However, the organelles (microtubules) that separate the two duplicates during cell division are able to tell the two apart and guide them to opposite sides of the cell. Here we have again doubleness and high similarity. But we do not seem to have oppositeness of even a small degree unless one considers the molecular biology of how the two chromatids are normally separated to opposite sides, which is not yet understood. Nor do we have the aspect of neutralization as in the last examples. The existence of the double nature of the chromosome does allow

division of the original cell into two, and thus creates a population of cells that also enables the creation of variants in the population, but this may be only indirect causation of variation compared to our other examples of duality. Perhaps this is not a valid duality.

(#8) Structural Duality- Cell Association Glycoproteins and Cell Border Proteins: It is very important that cells recognize each other and distinguish between like and unlike cell types during embryology of the organism and thereafter. This is accomplished by specialized proteins partly buried in the cell membrane and partly exposed. After decades of research it appears that the proteins responsible are those which contain carbohydrate moieties attached to the protein.

Complementary sets of these proteins in highly organized arrays on the membranes of similar cells recognize and bind to each other. Some are so highly organized that they have been given names to recognize their organellar status (dictyosomes, for example). In order to bind they must follow the rules described for protein fit described in duality #2. But since they are active in arrays on a higher level of organization, and since they are the parts of a cell that are responsible for binding, they are an organellar level duality. Again we witness the common features of two populations with significant similarity, but complementary opposites resulting in the formation of aggregates at a higher level (cellular tissues) which exhibit new features. The opposites are matched in magnitude and specificity such that they enable the distinction between types of cells. In other words they create differences constructive of the next level of complexity.

(#9) Informational Duality- Homologous Chromosomes: In advanced organisms there are two copies of each of the chromosomes described in duality #7. Each chromosome is from one of the parents. Each has two duplicate sister chromatids. The two copies of two-chromatid chromosomes have identical "types" of genes on them called "loci"; otherwise they would not be from the same species. Since they bear this overall similarity they are called homologous chromosomes. But within each place for a gene type, they may have different specific information coding for a different variation on the theme of that gene type. For example, both homologous chromosomes would have the same place for lip characteristics, but one might have the variant for wide lips the other for thin lips. In this sense, both are similar, but different, often opposite. Their differences are small compared to their similarity, however, and balanced in magnitude. In this example of possible duality though, the difference does not result in a force that causes neutralization into an aggregate. But as in other informational dualities it does yield the result of enabling variation on the next level. And this different result of informational dualities may give us a clue as to why there are redundant structural and informational dualities on each level of biological organization.

(#10) Informational Duality- Euchromatin versus Heterochromatin: The total gene set for a cell is not homogeneous. There are two different functional states of the chromatin (DNA + bound proteins). Euchromatin is less tightly coiled, synthesizes more RNA, is turned on, is more susceptible to bent destruction. DNase digestion, and drugs, is lighter, and replicates late in the S phase of the cell cycle. Heterochromatin is more tightly coiled, does not synthesize RNA, is repressed, is less sensitive to heat. DNase digestion, and drug inactivation, is heavier, and replicates early in the S phase of the cell cycle. Despite these differences the two populations of nucleoprotein are mostly the same consisting primarily of genes coiled around histones, with non-histone proteins attached. Again we see two major populations, fundamentally identical, but with some small differences, balanced in magnitude, and as enumerated above, exactly opposite natures. However, as in other informational dualities this does not result in two opposite vectors that cancel each other out in forming a new aggregate so much as opposites that increase the number of variable states possible on the next level of organizational complexity. It appears that

structural and informational dualities may perform slightly different functions and that is why they coexist on the same level.

EXAMPLE DUALITIES: CELLULAR LEVEL: BIOLOGICAL COHORT OF SYSTEMS

The cellular level is thought to have appeared somewhere between 3.5 billion years ago (evidenced in stromatolites as masses of fossilized microorganisms) and 3.1 billion years ago (evidenced by microfossils of the first prokaryotic, that is, simple bacterial cells). The appearance of cells may not have required an advanced metabolic system or even genetic code, laboratory experiments show that concentrations of biochemicals of the protobiont type could occur due to evaporation of water from clay micropores, from slow rates of freezing of organic droplets, or from the automatic formation of coacervates and microspheres. At those primitive times none of the following dualities were present. Also at this level of complexity, it is more difficult to separate structural from informational dualities. In the following a duality is designated structural if either the mechanism of the duality is based on structural characteristics, or results in structure. It is designated informational if it influences the potential for variation on the next level and in a manner not dependent on a primarily structural mechanism.

(#11) Structural Duality- Enzymes That Go Either Way:

As the action of more and more enzymes have been elucidated, a general feature of enzymatic action emerges. Once it was thought an enzyme was designed for but one type of action, but now it appears many enzymes can perform exactly opposite actions depending on their context. The most studied example is DNA polymerase I. In some cellular conditions it acts as a polymerase which places nucleotide subunits into a chain of DNA according to the sequence dictated by the partner strand. But in other cellular conditions it acts as an endonuclease which excises (pulls out) nucleotide subunits from a preexisting DNA strand. Here we see not two populations of fundamentally similar entities with slight differences acting in opposition, but one selfsame entity acting in opposite ways, or exhibiting opposite "phase states." The actions are clearly opposite vectors, but they do not neutralize each other in the usual sense of the word, although both are required for the enzyme to accomplish its role in the cell. Neither one new aggregate formed. Nor does increased variability result. Actually DNA polymerase I is the DNA repair enzyme that neutralizes normal mutations loads by correcting mistakes. It causes convergence, not divergence of information. We will use this distinction later to distinguish between structural and informational dualities.

(#12) Structural Duality Anabolic/Catabolic Metabolic

pathways: As the cell progressed in complexity it evolved many series of steps in changes of substrates by sequential action of different enzymes designed to catalyze each step. These are called "metabolic pathways" because they constitute the energy transfers that give life to the cell and because the same series of enzymes take the same substrates through the same series of modification steps each time much like you and I would follow each other's footsteps up a mountain (creating a pathway). Analysis of the multitudes of pathways in cells (their bureaucracy) has resulted in recognition of two types. Some pathways build up needed complex biomolecules from simpler precursors (anabolic). Some breakdown complex molecules into simpler subunits needed for the anabolic pathways (catabolic). Again we observe two populations, primarily similar in structure (they are composed of enzymes and substrates with similar characteristics even if different enzymes and substrates), and exhibiting opposite but balanced outcomes. On this level of complexity neutralize each other by matching incoming materials with their transformation into themselves. However, here a new aggregate is not formed so much as a former aggregate maintained.

(#13) Informational Duality- Post-Mitotic Sister Cell Migration

Patterns: New techniques have demonstrated that just after cell division, the two new duplicate cells migrate away from each other in exactly opposite, mirror-image patterns. The molecular basis for this phenomenon is not understood, but recent work on the cytoskeleton of the cell (composed of multiple fibrillar and membranous organelles) indicates that such movements are mediated by these interacting structures. Some kind of "molecular memory" as well as "symmetrical polarity" would be required in the cytoskeleton for the two now separated entities to perform this complementary "dance." This suggests that such balanced, dual symmetrical processes exist in the undivided cell as well undetected by our present resolution of technique. Again in this case of duality, we see doubleness, oppositeness, similarity in fundamental composition of the two entities, and a balancing of the opposed vectors. But in this case no neutralization is evident, nor is a new aggregate formed. However, the potential for new variation does appear.

(#14) Informational Duality- Synaplinemal Complexes in Meiosis: The evolution of a special variation on cell division termed meiosis about 1.3 billion years ago allowed for sexually reproducing organisms. The major feature of this reduction division is the pairing-up (binding) of the homologous chromosomes described in proposed duality #9. Specific nuclear proteins recognize the individual loci (gene types) of the two generally alike, but specifically different chromosomes and act as interlocking bridges pulling the two independent chromosomes together into one complex until the moments before cell separation. Here the fundamental identity consists of the similarity of gene types on each of the chromosomes while the difference is the unique, specific variant for each similar gene type that could be carried by each of the homologous chromosomes. These differences may be termed "opposites" although they are not opposite in the normal sense as much as variant. As in the above examples the similarities are dominant, and the dissimilarities smaller in magnitude, but significant. Here the aggregate formed is fleeting, and its sole purpose is the enabling of much increased variation at the next level. For example, a human couple is enabled by this mechanism to produce about 6.4×10^{13} (13) different possible offspring. Clearly a dramatic increase in variation!

(#15) Information Duality- Polarity Fields in Development/Ontogeny: Biologists have tried to determine how the new tissues appearing in the embryology of an organism know how to spatially and temporally organize themselves into the finished type. Many experiments indicate that chemical concentrations are produced, diffuse, and are maintained at different amounts across the embryo. This asymmetry of chemical concentration creates gradients that act like morphogenetic fields giving cells within the fields information about their position and neighbors. Any gradient forms a spectrum with definite poles; a high concentration exists at one end, and a correspondingly low one at the other. Multiple signal gradients such as this create multiple polarities. One could visualize the cells at two poles of any field as experiencing two extremely opposite populations based on the same signal, and balanced proportionally though oppositely in magnitude. Here again, as in other informational dualities the opposites do not themselves neutralize each other in the formation of a new aggregate on a new level so much as the existence of the difference allows or enables new potentials of variation within the present level.

EXAMPLE DUALITIES: ORGAN LEVEL: BIOLOGICAL COHORT OF SYSTEMS

Organs require multicellularity, and multicellularity is not thought to have appeared until about 700 million years ago. The cells described in the former dualities had to evolve for almost three billion years before they themselves reached the level of complexity required to support multicellular states. Multicellular states require eucaryotic cells which are thought to have appeared only about 2.0 billion years ago. The

mechanisms giving rise to different cell states are still not understood despite many decades of study.

(#16) Structural Duality- Antagonistic Muscle Groups:

Everyone knows that they can move their limbs up and down, forward and back, into and out from the body. Comparative anatomy shows that these and many other more complex movements are possible because the muscle groups are organized in opposite pairs relative to their attachment to the bone structures. These muscles act so clearly in opposition that they are called antagonistic. Still the muscles acting against each other are fundamentally similar. Again we see opposites, balanced in magnitude, and vectors that neutralize each other. Here the vectors do not result in a new aggregate, but do enable the opposite duality to perform its function.

(#17) Structural Duality- Paired Organs: As we get closer to human dimensions less explanation is needed. Two eyes, ears, lungs, kidneys, and sex organs provide a fail-safe mechanism that preserves life. But this possible duality only proves that doubleness is not enough to define a systems-level, functional duality. Although fundamentally identical, paired organs are not opposite. They do have aspects of mirror imaging to them, but this is only at the gross level of anatomy, and in any case does not result in opposing vectors that neutralize in any way, or form aggregates at higher levels, or even enable increased variation. Clearly, the catalogue of dualities needs to be classified by a dynamic taxonomy yet undiscovered. Can we blame past workers for not perceiving the function of duality in systems emergence or origins of hierarchical levels if they did not possess the taxonomy necessary for discriminating the many different functions performed by duality?

(#18) Informational Duality- trilateral Hemispheres of the Brain:

The work of Nobel Prize laureate Roger Sperry and his many colleagues in demonstrating the tendency of the right and left hemispheres of the brain to specialize in opposite perceptual and functional roles has been overly popularized. Despite the connections of the corpus collosum rendering the two parts a functional unity, it is clear that individual humans tend to favor one role or the other in their behavior and approach to life much as they favor one eye, one side of the tongue, or one hand over the other. This duality has many of the features of the others. Both hemispheres are similar structurally to the extent that they can even exchange or alter their normal roles by taking on the others role. But their natural tendency is to specialize in opposite skills; the right more adept at perceiving form, wholeness, synthetic processing, non-linear, non-sequential thinking, and the left more adept at logic, sequential thinking, analytical processes, and words. Here, as in most informational dualities opposite vectors are not recognizable, and no aggregates are formed, but increased variation is enabled within the level. It is questionable whether or not this duality should be placed on the organ level where its physical form is evident, or on the next levels where behavioral results are manifested.

EXAMPLE DUALITIES: ORGANISM LEVEL BIOLOGICAL COHORT OF SYSTEMS

The organism level is surprisingly the most poorly defined of all biological levels. Preliminary evidence from empirical testing of biological hierarchies indicates that it might not even exist as a level at all in nature as presently named by man (Troncale, 1981a, 1982b). It may be an invention of the mind of man in an effort to categorize. Organism means any free-living entity. This mixes cells as simple as bacteria with creatures as large as the whale, and as behaviorally complex as man. Truly a messy word. An indication of this anthropomorphism of the word is revealed in trying to pinpoint the origin time of this level it does not fit in well with the sequence already established for the others; usually this is a sign in science that something is wrong. Should we fix the time of origin of the organism as equal to the first protobionts (est.'d to be about 3.8 billion years ago), or the first bacteria (3.5 billion years ago), or the first eucaryotic single cells (2.0 billion years ago), or the first multicellular, macroscopic

creatures (700 million years ago)?

(#19) *Structural Duality- Bilateral Symmetry*: If a longitudinal cut is made down the midline axis of many organisms exhibiting a cephalic and a caudal end, the two halves will have mirror image symmetry. Everything on one side will be duplicated on the other but in opposite structural orientation. Again primary similarity, with minor differences, the differences being opposite, and complementary. But in this case, the structural similarity does not lead to a force causing an aggregation that neutralizes the force. Perhaps the bilateral symmetry in the finished adult organism is not the place to look, but rather at the developmental forces that created the bilateral symmetry in the first place during ontogeny. There, opposite forces and neutralization might be detected, and bring this structural duality in line with those previously discussed.

(#20) *Informational Duality- Diploid Organisms*: At some point just before the evolution of sex (about 1.3 billion years ago), organisms evolved that possessed a complete duplicate copy of their genome. This is the meaning of the term diploid (two sets of chromosomes). Although structurally represented by the duality discussed in #9, and functionally in the process described in #14, the existence of diploidy actually preceded both of these dualities, both sets of genes were originally identical, but soon after sex evolved only the types of gene places were similar with slight variations on the actual coding of the gene in the gene place possible. Again we see two populations fundamentally and mostly similar, with slight differences, enabling increased variation although not built upon opposed complementarities.

EXAMPLE DUALITIES: COMMUNITY AND ECOSYSTEM LEVELS:
BIOLOGICAL COHORT OF SYSTEMS

All of these levels appeared simultaneously with the appearance of the first cells. Free-living cells form populations, communities, and micro-ecosystems. There are less dualities listed for these levels due to my inexperience with them; perhaps my biological colleagues will suggest possible dualities unknown to me to complete this analysis.

(#21) *Structural Duality- Sibling Species*: Ecologists have recognized some complementary species organization at the boundary of species and ecosystem levels. For example, the two species of fruit fly, *Drosophila melanogaster* and *Drosophila simulans* have opposite characteristics when together in the same environment. *D. melanogaster* is slightly larger in size, more physiologically adaptable, and found in greater numbers while *D. simulans* is smaller, physiologically restricted, and found in lesser numbers. The two populations are reciprocal (opposite) in these characteristics. Yet the two species are closely related. Again we see fundamental similarity, some dissimilarity, and opposite organization. In this case the two opposites are clearly in conflict as well as cooperation. Together they form an aggregate system.

(#22) *Informational Duality- The Process of Evolution*: The process of evolution could be characterized as two opposing processes resulting in origins of new aggregates, as well as promoting oscillations and cycles. The process of natural selection reduces the amount of variation in the gene pools, while the process of mutation increases the variation. Both must be present for the process of evolution to proceed.

(#23) *Informational Duality- Neuropeptides and Peptidases in Brain Function*: I include this phenomenon on the population and community levels because of its role in emotional reactions critically important to interaction between individuals in populations that form into communities. Neurohormones are active in the brain in controlling pain as well as in the intestines where they control digestion and appetite, or in the kidney, controlling blood pressure. Neuropeptides, such as enkephalin, are opposed and balanced in normal brain systems by naturally-occurring opiate antagonists which compete with the neuropeptides and interfere with or block their effects. As many as 100 neuropeptides exist, presumably each coupled with another compound that

opposes its action. In this example, as in the others there exist two major populations with opposing actions. In this case, however, the actions may be in opposition and result in a cancellation or neutralization of each others effects, but the structure of the neuropeptides, specific neuropeptidases, and antagonists are not as fundamentally similar as in many of the other cases. Again the system has greater Variety possible due to this informational duality, but the two opposed forces do not form a higher level aggregate.

(#24) *Informational Duality- Bird Songs*: Presumably this duality occurs on the population level within a species. Birds' songs are used as a signal and in defense of territories, and as a signal attracting potential mates. Analysis of bird songs by sonograms and statistics indicates that in some cases bird calls are organized in a reciprocally complementary manner. The same basic song exists in two forms, each form derived from the original with one exhibiting those elements omitted from the other, and vice versa. This results in two populations of signalers using opposite signals based on fundamental similarities. The signals bind the Individuals together into the population.

(#25) *Structural Duality- The Role of Homogeneity versus Diversity in Ecosystems Stability*: There has been a very active debate in the last decade over which of two possible conditions makes an ecosystem most stable and resistant to disturbance. Some researchers maintain that high degrees of diversity (many different species) makes an ecosystem more resilient to changes in its environment. Others maintain that high degrees of diversity can actually cause instability, or result from instability. It is too soon to determine which of the positions is most correct (possibly both are in unique conditions), but one thing is clear. There are two opposing mechanisms involved in ecosystems dynamics; one is increasing diversity and another decreasing diversity. These two forces are acting in opposition and may be balanced in the most stable ecosystems. Their further elucidation will result in recognition of still another duality.

CRITERIA OR CHARACTERISTICS THAT DEFINE DUALITY
DOUBLE IS NOT ENOUGH!

Examination of these biological examples of duality leads to the recognition of the following seven characteristics or criteria.

Two Major Populations- Significant forces or processes in bio-systems often occur in pairs, not singularly. They most often occur as large populations whose membership is continually renewed by the dynamics of preceding levels of the hierarchy. Their function on their level depends to a large degree on the existence of these two healthy, spontaneously renewable populations. This suggests that the serious researcher should look for the origins of dualities and for the role they play in systems behavior in statistical fluctuations and population dynamics both at its level and in the parts of the preceding level.

Central Stability— The two major populations share a self-similar, fundamental identity or at least a very high percentage of similarity. They are alternative variants from the same mold, emerging from the same process. In an earlier paper I termed this feature of the participants in a dual pairing, "central stability" (Troncale, 1972). This was meant to draw attention to the fact that the majority of the energy and structure of each individual half of the duality was devoted to manifesting the similarity they shared. This feature also suggests something about the origins and action of dualities. They depend on this innate and dominant similarity for their attraction to each other, their binding or coupling on the same level. Awareness of "central stability" brings other advantages besides clues about the origins of duality. Central stability is quantifiable in many cases. Its quantity can be contrasted with the next criteria and used to quantify a totally new cross-level feature of systems that could not otherwise be observed or be quantified. Further, central stability actually arises, in most cases, from counterparities that have interacted from

previous levels. Thus, the central stability on one level is quantifiably related to the "satisfied" counterparty of the previous level on the one hand, and simultaneously related to maintenance of the duality that brings about the next level. Three levels are related in one quantum.

Peripheral Instability- In many of the biological examples listed here (as well as the dualities studied at other levels in other cohorts of systems) there appears to be a small percentage of the total structure and energy of each of the dualities that is variable. This relatively small portion is termed "peripheral" to indicate its diminutive stature and its existence at the Interface between the utility and its surrounding entities. This portion is unstable in that it is highly reactive, while the central stability is so named because it is unreactive. As a result peripheral instability is also termed "unsatisfied counterparty" and is the reciprocal of the above described "satisfied" counterparty. The variable portion is free to assume many different potential states. Due to this freedom and to the mechanisms on the previous levels that cause proliferation of large populations of each half of the duality, a large number of variants are produced for each half. But all of these variants still share the central stability in common. One can visualize the central stability as the "carrier" for the peripheral instability. In addition, all of the relatively small variable portions (unsatisfied counterparties) are built along the same plan, and so can interact with each other. Use of these two terms is important to draw attention to their structural and functional isomorphism across the many levels of organization described and despite the distinctly different particulars that manifest the isomorphism in this bio-cohort (multiplied by the many other cohorts that could be added). Otherwise human attention is commandeered by the particulars and the isomorphism goes unnoticed.

Opposite Tending, Opposite Vectors- Although many peripheral variants are formed only a small range of peripheral instabilities are stable in nature. Further, only those that participate in higher levels of structure survive. And only those that are opposite in their peripheral instability are capable of interacting vigorously enough to participate in forming higher levels of structure. So when man observes these mature systems long after they have reached dynamic equilibria, he finds that newly formed levels have dualities that possess counteracting forces or tendencies. It is to this important feature that the word "counter" in the compound word counterparty is pointing.

Opposites Balanced in Magnitude- Since many of the dualities are formed on the same game plan and are restricted to the same range of percentage of the structure and energy typical of their class and level of entities, they must be nearly equal in magnitude. This similarity in magnitude distinguishes duality interactions from the many other interactions that occur in natural systems. Interactions between entities at different levels do occur but do not share game plans or magnitudes. The word "parity" (equal) in counterparty indicates that the opposite tending forces are within the same range.

Opposites Complement. Vectors Neutralize - - Consider that all of the variants possible in terms of the peripherally unstable portion actually do form. Now this would result in two populations at either extreme of the possible conditions. These populations would produce many entities randomly that were mutually complementary because they are built on the same gameplan, but are opposite tending. The extremes formed would be reciprocals of each other, and once combined would neutralize each other. No instability would be left over; what was peripheral instability would now be converted to the next level's central stability; unsatisfied counterparty on this level would become satisfied counterparty on the next.

Aggregates Form Spontaneously Beginning New Populations— The opposite and complementary nature of the peripheral instability populations are naturally attracted to each other because their neutralization is consistent with the 2nd Law of

Thermodynamics and the lowest energy state. But in achieving this state they produce a new scalar magnitude of central stability, which has new qualities, and these new qualities, in turn have potential populations of peripheral instabilities at the new scalar levels. Again two new populations form and we are at the beginning of this list again: the entire sequence of seven steps (also criteria) repeats itself.

Other possible characteristics of duality might be obtained from the listing of these biological examples and their continued analysis. For example, sometimes the dualities seem to "Enable Oscillations and/or Cycling" on the next level. But not all dualities participate in all characteristics and the list of criteria is therefore dependent on a more adequate taxonomic classification of dualities.

SYNTHESIS OF LEVEL-BY-LEVEL DUALITIES: MASTER 'GENERATIVE' DUALITIES AND THEIR SYSTEMS FUNCTION

Study of the twenty-four examples of biological dualities listed here, as well as the proposed dualities for several other cohorts of systems (Troncale, 1978), suggests that all of the diverse examples of duality represent variations on three very fundamental, "global" dualities. These dualities have all of the characteristics expected of the isomorphies of a general theory of systems; they are transdisciplinary, non-scalar, invariant, highly interconnected with other suggested isomorphies (Troncale, 1982) and considering those interactions, self-defining. These dualities are so primeval that they deserve to be called "generative" since they are hypothesized to be responsible for the endless series of recursive origins of hierarchical levels evident across natural systems (Troncale, 1972, 1978), as well as the generation of the many manifestations of local dualities in the particulars of each level. If a specific mechanism is to be proposed to explain the process of emergence, it will undoubtedly have to include some, if not all of these master, or global dualities.

Invariant Duality: Fragmentation versus Integration: Analysis of the unbroken sequence of origins typical of the metahierarchy (Troncale, 1972), and validated by the disciplines at each level of the sequence, suggests that there are repeating cycles of fragmentation and integration. For example, Milne's isotropic, homogeneous universe at the moment of the big bang fragments into sub-subatomic particles, these integrate into sub-atomic and atomic particles, these fragment out into a heterogeneous clumping which gives rise to the root cause of galaxies through integration of clumps exaggerated by inflation of expansion, galaxies fragment out into local nebulae, which integrate into more local gas clouds that fragment out into stars, which integrate into clusters, whose stars then fragment out into binaries and surrounding gas rings, which rings integrate into planetesimals and eventually planets, whose bulk fragments into layers causing plate tectonics and climatic cycles, which participate in integration of inorganics to biopolymers, which fragment or diverge into diverse types, and begin the series of levels described in more detail in the middle of this paper.

It is important to recognize that cycles of fragmentation and integration seem to be closely related to cycles of divergence and convergence, or cycles of combination and separation (the latter as described by Bergson, 1972). It is not clear whether or not these are all the same primeval process, or bear significant nuances of difference.

Although the particulars that fragment or integrate are different for each cycle, it appears that the overall processes of fragmentation and integration deserve recognition as a phenomenon in their own right. Their continual, alternating reoccurrence demands study and explanation. Such order does not occur in nature randomly. The alternating influences of fragmentation and integration qualify as a duality because they are opposite forces, resulting in opposite outcomes, are balanced in magnitude for each cycle of the sequence, their action is based on the existence of central stabilities (satisfied past counterparties) and peripheral instabilities (unsatisfied

immediate counterparities), and because both of the opposite processes result in the appearance of new aggregates.

Invariant Duality- Stability versus Variation Processes: In information-based systems, especially those based on biological systems, each level of organization evolved a mechanism for insuring maintainance of information fidelity on that level coupled with a distinctly different mechanism for insuring that some small variation of information also occurred on that level (Troncale. 1978, and end of 1983). On the molecular level information stability mechanisms like DNA replication, conservatism of the genetic code, and unit cistron organization are opposed by information variation producing mechanisms like DNA mutation (12 separate causes), permutations of the triplet codens, and intron/exon gene structure. On the organellar level information stability mechanisms like linkage of genes on chromosomes, and constant numbers of chromosomes within a species are opposed by information variation mechanisms like crossing-over of chromosomes, and deletions, insertions, inversions, and translocations of chromatid pieces. On the cellular level Information stability mechanisms like mitotic, somatic cell division are opposed by special division types such as meiotic, reproductive cell division. This matching of mechanisms for stability end variation occur on higher levels of biological systems as well as in such systems as linguistics and music (Bernstein, 1976).

Again this qualifies as a duality because of the existence of two opposing mechanisms, tightly coupled on each level so of the same scalar magnitude, each with opposite outcomes. At each level the two mechanisms are built upon the same gameplan, for example, all molecular level stability and variation mechanisms involve DNA. As in the examples of particular dualities shown for bio-systems, the mechanisms for stability are dominant, with the mechanisms for variation (peripheral instability) much smaller in effect (with a proportion range of 1 in 50 to 1 in 100,000: instability to stability: variation to fidelity). As In the information duality examples cited for bio-systems the action of this duality does not lead directly to aggregate formation by convergence, so much as it enables divergence of types on the next level.

Invariant Duality- Continuity versus Discontinuity: In many physical dualities there is evident an alternating cycle of the appearance of discontinuity (well separated and defined objects), and the appearance of continuity (undefined and undefinable fields). It is as if each feeds upon the other; each requires the other as its context; so each must follow the other inevitably. Man has specialized in describing the discontinuities or particles and is only belatedly aware of the continuities. But when he observes changes in the objects he, ironically, first describes their continuous changes first (Newtonian, linear) and is only now becoming aware of the discontinuous changes (phyletic gradualism versus punctuated equilibrium in evolution; or differential equations versus catastrophe and bifurcation theory for modeling real systems). Notice that the two uses of the terms in the emergence of hierarchical levels (between levels) or to describe changes happening to established objects within a level are exactly opposite.

It is also very important to note that it is impossible to perceive such long-term, broad-scale cycles such as these without adopting a transdisciplinary view. It is impossible to study any of these cycles without doing so across many scales of magnitude. This is where general systems science achieves preeminence. The disciplines cannot directly study such invariant phenomena. As Chuang-Tzu said, "You cannot speak of ocean to a well-frog, the creature of a narrower sphere. You cannot speak of ice to a summer insect, the creature of a narrower season."

But it also true that general systems science cannot study such phenomena without the local resolution provided by the disciplines. Mutual respect and encouragement as well as sincerely constructive criticism is required on the part of systems scientists and reductionists to accomplish the task at

hand The feud should end and cooperation begin. Perhaps we should note that human fragmentation of reality and knowledge should be coupled with human integration of reality and knowledge just as such cycles of fragmentation and integration are coupled tightly in nature.

A TENTATIVE TAXONOMY OF DUALITIES

The detailed comparison of many specific, proposed dualities across many levels of the biological cohort of systems suggests several ways to distinguish between types of dualities. Such discriminations are a necessary first stop to Improving perception of a general theory of systems and places GTS at about the same stage of development that evolution was at the time of Linnaeus, which is to say not it is not even aware of the appropriate taxonomic categories much the less the significant dynamics causing them (Troncale, 1985b).

Taxonomic Category- Structural Dualities: As shown in the level-by-level analysis of biological dualities, structural types are based on arrangements of subsystems in space, without involvement of a "code", or Involvement of transfer of order. New aggregates are formed by the interactions caused by structural dualities. The vector forces or tendencies caused by the unsatisfied counterparities (dualities) are neutralized by the formation of the aggregate. Thus, the 2nd Law of Thermodynamics is obeyed and drives the aggregate formation (conrescence). The variant types on the preceding level converge on the next level to stable neutralized states in these cases of duality. Structural dualities increase stability. They are characterized by *convergent* effects active on *their* level.

Taxonomic Category- Informational Dualities: Informational dualities differ from structural in virtually all of these characteristics. As shown in the level-by-level analysis of biological dualities, informational types are based on sequences of subsystems strictly according to a "code" shared by both "sender" and "receiver", and there is a net transfer of order involved. New aggregates are not formed on the next higher level in many cases of informational duality. The combinations possible in informational dualities do not result in complete neutralization of attractions on the preceding level. Rather the existence of the informational duality on the preceding level makes possible, or significantly increases the number of combinations possible on the next level. Informational dualities increase variation. They are characterized by *divergent* effects acting on the *next* level.

Taxonomic Category- Combination-Producing Dualities: Some dualities give rise to the attractions or forces that drive subsystems within a level of complexity to Interact. The result of these various interactions within the level is the production of that population of variants types typical of the level. These variant types, however, are incapable of exhibiting dualities of their own. Combination-producing duality is lesser in magnitude and can result in subspecialization levels.

Taxonomic Category- Emergent Dualities: These dualities are of greater magnitude than combination-producing dualities. Emergent dualities give rise to attractions or forces that drive whole systems to Interact resulting in entirely new levels of complexity. Emergent dualities produce a population that itself can exhibit new dualities. The new levels with new emergent qualities are hypothesized to be significantly different from subspecialization levels, and attempts are underway to measure and demonstrate these differences (Troncale, 1981, 1982).

It is not clear whether or not these four taxonomic categories are mutually exclusive, or overlapping. It is also not clear whether or not the master "generative" dualities described above represent other viable taxonomic categories. Additional taxonomic distinctions could be made to organize the list of biological dualities beyond the above suggestions; for example, division into "static" versus "dynamic" dualities. Much more work is required to resolve these important questions and expand the consensus list of taxonomic

discriminations.

A PLEA AND A PLAN FOR COLLABORATION

Did this analysis and synthesis fulfill the requirements of the method outlined at the start of this paper? It did try to provide evidence for the existence of dualities at many levels of the biological cohort of systems. But to fulfill the need described the astronomical, atomic, chemical, geological, sociological, symbolic, man-made, and other cohorts would also have to be examined and compared and synthesized in a similar manner. No one Individual has such a range of expertise. Several additional steps are required, therefore, to even begin development of a generalized duality theory. First, the above analysis would need to be criticized by many other biologists until a reasonable consensus is attained on which are and which are not allowable dualities and in which taxonomic categories each might fit. Second, additional dualities, especially on the higher levels of biological organization, need to be suggested and examined. Third, specialists expert in the other cohorts of systems need to complete equally detailed and debated analysis of levels in their systems. Fourth, all such proposed examples of duality would need to be synthesized to extend the list of suggested criteria as well as validate those already suggested. Fifth, the dynamics of interaction described in the criteria sequence should be evaluated with this wider listing of specific dualities in real systems. Sixth, the proposed taxonomic types revealed in the analysis of biological dualities should be tested against the dualities from other disciplines to see if such taxonomic types hold for all cases.

Such a grand scheme of collaboration would result in a sizable number of related publications characterized by heavy and detailed cross-referencing and incremental improvements. Besides drawing attention to the potential of duality theory, such a development would clearly test one alternative methodology for empirical refinement of a proposed isomorphy and could have lasting effects on the development of a general theory of systems. If repeated at the same level of detail for the other 50 to 75 isomorphies already recognized as contributing to a general theory of systems, the "special knowledge" of GTS would be self-evident and impressive. Systems science would be then capable of constraining theory by use of evidence, and suggesting new avenues of evidence gathering through use of theory. Both method and application would benefit from more robust theory.

REFERENCES

Eichner, A. (ed.)

1983 *Why Economica Is Not A Science*. Sharpe, Armonk, New York.

1985 "The trouble with economics" *Nature*, 313: 427-428.

Merton, T.

1965 *The Way of Chuang-Tzu*. New Directions, New York. 160 pp.

Miller, J.G.

1978 *Living Systems*. McGraw-Hill, New York.

Robbins, S. and T.A. Oliva

1984 "Usage of GST core concepts by discipline type, time period, and publication category" *Behavioral Sciences* 29: 28-39.

Schaffner, K.F.

1967 "Approaches to reduction." *Philosophy of Science*. 34: 137-147. 1969 "Correspondence rules." *Philosophy of Science*. 36: 280.

Troncale, L.R.

1972 "Origins of hierarchical levels by the action of systems field axioms. Proceedings of the 16th Annual Meeting, Society for General Systems Research, Louisville, Ky., 45 pp. (available from author).

1978 "Origins of hierarchical levels: an emergent evolutionary process based on systems concepts." pp. 84-94, in R.F. Ericson (ed.), *The General Systems Challenge*. Society for General Systems Research, Louisville, Ky.

1981a "Are levels of complexity in bio-systems real? Applications of clustering theory to modeling systems emergence." pp. 1020 -1026 in G.E. Lasker (ed). *Applied Systems and Cybernetics*. Vol II. Pergamon Press, New York.

1981b "On a possible discrimination between bio-evolution and a theory of systems emergence." pp. 225-234 in W.J. Reckmeyer, (ed.), *General Systems Research and Design*, Society for General Systems Research, Louisville, Ky.

1982a "Linkage propositions between fifty principal concepts." pp. 29-52, in G. Klir *Applied General Systems Research: Recent Developments and Trends*. Plenum Press, New York.

1982b "Testing hierarchy models with data using computerized, empirical data bases." pp. 90-102. in L. Troncale (ed.) *A General Survey of Systems Methodology*, Inter-systems, Seaside, California.

1983 "Towards a formalization of systems linkage propositions." pp. 341-349 in G. Lasker (ed.), *The Relation Between Major World Problems and Systems Learning*. Intersystems Publications, Seaside, Ca.

1984a "Methodology or megalomania?" *General Systems Bulletin*. XV(1): 4-6.

1984b *The Tao of Systems Science: Systems Science of the Tao*. Institute for Advanced Systems Studies, California State Polytechnic University, Pomona, Calif., 60 pp.

1985a "The future of systems science: obstacles, potentials, case studies" *Systems Research Journal*. 2(1): 43-84.

1985b "On the possibility of empirical refinement of general systems isomorphies." (these Proceedings)

1985c "Knowing natural systems enables better design of man-made systems: the linkage proposition model." in R. Trappl (ed.). *Power, Autonomy, Utopia: New Approaches Toward Complex Systems*. Pergamon Press, (in press).

Watts, A.W.

1975 *Tao: The Watercourse Way*. Pantheon Books, New York.