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New Science Building and Research: From Systems Biology to Theoretical Informatics

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Abstract: *Briefly introduced the status and related theories foundation of Theoretical Informatics (TI) and Systems Biology (SB). These two disciplines were compared and analyzed, mainly from the background, epistemological approach, informational energy of open systems, which these three aspects can demonstrate the two disciplines be of connected or similar attributes or characteristics, to indirectly discourse the necessity, the rationality, the feasibility and the vital significance of the establishment and researches for TI. Explore how to draw, reference SB model of development to promote the prosperity and great development of TI.*

Keywords: theoretical informatics, systems biology, development patterns, system, emergence theory, information, informational energy

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A fall in with exchange greetings, the first author discussed with Professor Li Zongrong to his Theoretical Informatics(TI) research which he was engaged in, although only a few brief introductory note, it has aroused the first author considerable interest. The first author asked Prof. Li some materials to study, mainly his doctoral dissertation “Theoretical Informatics: Concepts, Principles and Methods”(Z. Li, 2004) and post-doctoral thesis "On the Worldview of Information Science"(Z. Li, 2008). These two papers have been serialized in "Medicine Information" on various issues, the first author also read off after a few times because of the working and the time limitation, but each time may not wait for the next read on, always eat no fragrance or sleep no rest, can not wait to see how Prof. Li came to reasonable argument for the next part, and would like immediately learn full text with the joy and excitement. Reading these two big papers of Prof. Li, greatly benefit from. The TI is really complied with the time and the discipline tidal current, which is of forward thinking, clear views, full arguments, reasonable proofs, strict logics. Maybe the first author show too much in adjectives use, but that is the case, none to brag. Actually Mr. Li's papers did not need the first author words to the utmost praise, because he has gained international peer recognition and praise: an outstanding contribution to the theoretical foundations of informatics but will, moreover, be a milestone in the development of a worldwide Science of Information. The first author only is really expresses her own feelings after studying these two papers shallowly, and sincerely expresses her admiration to schoolmate and colleague Li in this. The first author is aware that, Prof. Li has

paid more than 20 years of effort and sweat, also once suffered a lot of criticism and pressure, but remaining on his ideas and stuck with it, have had today's achievements. The first author feels delighted for Mr. Li and wishes TI grow up as soon as possible.

The first author has also been very concerned about information science, and her doctoral dissertation is about bioinformatics. After reading Li's paper on the TI, she associated with the birth and development of emerging interdisciplinary SB, which the two have much in common. After a brief communication with Mr. Li, the first author decided to join the international research team on TI, with Li and other domestic and foreign scholars, learning together, exploring the theory of information science. In this article we will try to compare and analyze TI and SB, indirectly elaborate the necessity, the rationality, the feasibility and the vital significance of the establishment and researches for TI; will discuss the basic theory, the epistemology method and the world outlook of TI, to promote its prosperity and development.

1. The Present of Theoretical Informatics and Main Arguments

Knowledge on the information system is a large group of subjects, including information science and information philosophy of the two major categories. Information science can be divided into two basic levels, applied informatics and TI (or domain informatics and general informatics). As the basic theory of the information science, TI, its establishment and the consummation are the main symbols of the development and mature for the information science knowledge system. TI is the public theory which suitable to all information phenomenon and each informatics discipline, it is common to solve each concrete domain information problem, and it is the basis and core of information science. The computer widely used in nearly all disciplines, has promoted a great number of domain informatics. In contrast, the research achievements of TI, as a public foundation, are few, and the progress is slow. Moreover, various applied informatics face the specific discipline respectively, all only has an effect in some concrete information field, but mainly to the comprehensive information technology, few theoretical explorations and refinement, so it is incomplete. Along with the times and social progress, science and humanities and social science development call for TI, social ideology transformation, new worldview establishment summon TI. International synonymous with TI is Unified Theory of Information (UTI), Foundation of Information Science (FIS), etc, and many scholars, from different countries and different professional field, are actively involved in this research field.

Li (2004) contributed to a framework of TI. The construction includes the description of the position and role of TI in the whole information science system, the explanation of the significance and nature of TI's problems, the discussion about TI's fundamentals in the aspects of world outlook and epistemology, the expression of TI's main concepts, principles, and methodology, the statement of TI's basis of informational philosophy, the introduction to some TI's theoretical and practical applications, etc. TI's main study methodology includes two types of syntheses: one is to integrate the results of natural science, the humanities, and social science in an inter-disciplinary way; the other is to sum up the accomplishments of domain informatics, TI, and information philosophy in a cross-level way. In comprehensive study, it pays attention to the vertical integration of information evolution in the universe in the past and to the horizontal comprehension of different domain informatics at present.

Information is the meaning of signals and symbols. We found the duality of information existence, information movement and evolution. Cosmic elements have four Yuan: material, information, material energy and informational energy. Information as a logical non-material existence has the non-spatial characteristics with no direct observation. We can quantify is only the information carrier. Therefore, the TI's goal and answering domain, is an unusual scientific problem, with the existing physical background knowledge, scientific methodology and philosophy ontology is incompatible. By revealing the limitations of physical paradigm and

quantitative methods, indicated that in the evolution of life information, the role of material energy is more and more weak, while the more and more strong role of informational energy. The development of modern science requires a new paradigm of information science, which is both fundamental theory for recognizing information phenomena and scientific methodology for designing information systems. On this ground, based on genetic information evolution and explosive growth of human scientific and cultural facts, mutatis mutandis, the three basic laws of thermodynamics comprehensively deduced three laws of informatics: information is not conserved, informational energy keeps growing with the time, and information growth has no upper limit. Among them, the second law is the core of TI.

Similar to the construction of material knowledge system, the process of constructing the information knowledge system consists of three stages: theology, philosophy, and science. Since 1950's, the information science disciplines from the empirical thinking of observation and experiment in applied informatics, up to the theoretical thinking for searching the common nature of information, and then to the beginning of the philosophy thinking seeking new philosophy ontology as root of information science. Based on the description of the relationship model between material and information, Li (2008) mainly expounds the information science worldview, namely, the unity of opposites in the worldview of material and information. The paper first discusses the new science standards for the information era, advocating "correspondence theory" and "practical theory" criticizing "consensus theory", to defend for information science "science". Then puts forward a theoretical model of material and information relationship as “double duality” (all things of the world with material and information duality, but also space and time duality (i.e., the static structure and the dynamic process)), and demonstrates “two worlds theory” reasonable. Finally elaborates three distinctive features and eight main principles of information science worldview (or information worldview for short), in a sense, these characteristics and principles just are opposite and complementary to the material scientific world outlook.

2. The Rise of Systems Biology and Rapid Development

Launched in 1990, the Human Genome Project (HGP) is the first greatly scientific project in the history of life sciences; the plan is an important turning point of biology development. Led by HGP, a bunch of Omics appear, which gradually pushes the era of molecular biology into the era of SB, the biology changes from decomposition to integration, transforms by the descriptive science into quantitative predictive science(Kitano, 2002; Yang, 2004). As one of the sponsors of HGP, American scientists Leroy Hood is one of the founders of SB, he believes that "SB will be the core driving force of 21st century biology and medicine." Based on this belief, Hood established the first Institute for Systems Biology in the world in the end of 1999. He gave SB such a definition; SB is to study a biological system, all components (gene, mRNA, protein, metabolite, small biomolecule, etc.) composition and interaction between components under specific conditions(Hood, 2003; Hood, James, Michael, et al, 2004).

March 2002, “Science” published a SB album, then the other well-known journals have published research papers on SB. September 23, 2003 Harvard Medical School established the world's first SB department. Then California Institute of Technology, Massachusetts Institute of Technology and Princeton Universities and so on in succession, have set up SB research institutions. Since 2000, the International Conference on SB, held annually around the different themes of the new SB’s technologies, new ideas, and research project development and progress. Chinese scholars also take positive regard to SB, since December 2003 after the establishment of Shanghai Institute of SB, Shanghai Jiaotong University "System Biomedical Research Center in Shanghai", Shanghai University of TCM "Recipe Card and SB Research Center", etc. institutions were established. The Sino-British Conference on SB was held in June 2005 at

Zhejiang University, “Shanghai, China - Germany Baden-Württemberg SB Symposium” in October 2005 at Shanghai Jiaotong University, the 2nd Sino-SMA Computational SB Symposium in May 2006 at Shanghai Jiaotong University, ICCSB-2006 First International Conference on Computational SB in July 2006 at Fudan University(Chang, 2007). Fourth National Bioinformatics and SB Academic Conference will be held in October 2010 at Zhejiang University. SB has not only been recognized by biologist, also has aroused a large number of experts outside the field of biology concerned, at the same time has attracted the attention of Governments and policy, financial support.

Nevertheless, so far, the precise definition and understanding of SB is not uniform(Kling, 2006), academician Chen Zhu summarizes the SB should have a few basic features(Z. Chen, 2005): the hypothesis-driven, quantitative research, and high throughput features because of the Omics technology platforms for applications, covering nano-science to the ecological system of different scales, and having significant interdisciplinary hallmark. The ultimate goal of SB research is to resolve the complexity of life processes, use of holistic, systematic research means to discover and reveal the essential law of life activities.

SB mainly research entity system (such as individual organisms, organs, tissues and cells) in the modeling and simulation, dynamic analysis of biochemical metabolic pathways, signal transduction pathways of various interactions, gene regulatory networks and disease mechanisms(Flintoft, 2010; Geschwind & Konopka, 2009; Nottale & Auffray, 2008; Rho, You, Kim, et al, 2008). SB primary mission is to describe the system state and structure, namely to dedicate to the system analysis and pattern recognition, including elements of the system and their environment definition, as well as the interactions between system elements mutual and environment and system mutual of in-depth analysis. Next must carry on the dynamic analysis to the system evolution, including steady-state characteristics of the system, bifurcation behavior, analysis of the phase diagram, etc. In addition, the system state of scientific description of biological systems is hierarchical, with different levels of description may be completely different; System science to the system evolution mechanism analysis more emphasized overall and partial relations, to analyze the subsystem function how to form the whole system performance, functionality, and behavior of the system as a whole should find out each and micro-level ties.

Systems biology research includes two aspects. The first is to obtain experimental data, mainly including various Omics technology platform providing the biological data, followed by the use of biological models in computational biology. Therefore, SB, scientists are divided into "wet" experimental section (laboratory studies) and "dry" part of the experiment (computer simulation and theoretical analysis). "Wet", "dry" is the real test of the perfect integration of SB(Q. Xu, Wang, & Li, 2008). SB integrates a variety of biological information, experimental data, and establishes mathematical models and verifies the perfect model by experiments, finally forecasts the behavior of biological systems.

SB is not only a major development of scientific theory of life, and has a very broad application prospects, such as new drug development(Nicholson, Connelly, Lindon, et al, 2002), disease prevention and control(Mani, 2010; Ye, 2009), fine germplasm resources cultivation(L. Li, Xian, Li, et al, 2009; Meyer, Arentshorst, El-Ghezal, et al, 2007; Park, Lee, Kim, et al, 2007; Sindelar & Wendisch, 2007; Srivastava & Varner, 2007) etc already have more and more attention by the scientists from various countries. SB research, will not only promote the life sciences and biotechnology development, but also the entire economy, society and humanity itself are also with significant and far-reaching impact.

3. Theoretical Informatics and Systems Biology Comparison

Through comparison analysis, we discovered that TI and SB in the generation, development, research methods and theory system of, have many common places, may verify mutually, profit from mutually.

3.1. Similar background, adapting to the development of the times and subjects

For the history of the development in the natural sciences, and often this happens: When the emotional experience and a natural object or phenomenon of some aspects of the knowledge accumulated to a certain extent, it will some people see the situation, a comprehensive summary to make great discoveries and inventions, establishing universal theory or make important scientific hypothesis. Producing a scientific theory or some new technologies, it has a mature and complete step by step process. When this process is complete, a large comprehensive and leap will appear in theory and technology. Two thousand years, in natural history, there have been many times in the synthesis, which have relatively large integrated 10 times, such as Copernicus "the sun at the center of", the establishment of the Newton's law of universal gravitation and three laws of mechanics, the establishment of the discovery of three laws of thermodynamics, cell theory and the creation of biological evolution, the creation of relativity, quantum mechanics establishment, and so on. After each comprehensive and leap, the development of natural science gave new vitality, and socio-economic development appeared new ball game(Luan, 1986).

On TI research is scientific development and social progress of the urgent need. Currently, a number of domain informatics has matured, its technology, products and services have been together constituted a powerful information market, information industry, information economy, to promote the whole of mankind to achieve the industrial society into an information society. Nevertheless, the information society actually does not have any specific information science as a basis for knowledge system. Existing domain informatics, research object as a special, limited way of thinking, but also bound by the paradigm of physics, can not reveal the general rule of all information phenomenon. Now, we face the task: as a whole, from the organic links within the information phenomenon, to study and grasp the information, change the parts into a whole, change the local as a whole, change simple for the complex, reveal and grasp the fundamental nature of the information phenomenon and basic laws, create TI and establish a complete information science, to lay the foundation for the establishment of the unity of science, inclusive of material and information.

20th century biology, from the macroscopic to the microscopic process of development, from the morphological, phenotypic description to the organism's various elements and their function by the gradual decomposition, refinement. In 1953 Watson and Crick established the DNA double helix model was the sign of the times from the biology to molecular biology, 1970s appeared the genetic engineering technology, and it has greatly accelerated and extend the development of molecular biology. But the organism is a complex system, only through a variety of molecular mechanisms, approaches, and network integration to a comprehensive, systematic way to clarify the complex biological phenomena. Launched in 1990, began the HGP on biological comprehensive and systematic study to explore, so research shifted from the decomposition to the integration, the framework has changed from a single biological laboratory for the big science projects with the traditional biological laboratory combined model. Australia's Macquarie University in 1994, Wilkins and Williams first proposed the proteome concept. 2003 has been completed the human and the various model organism genome sequencing, for the first time revealed the code of human life. Biology and mathematics, physics, computer science more closely overlapping, causes the development of biology from the descriptive to quantitative prediction of the science. HGP and subsequent development of various omics technologies (mainly genomics, transcriptomics, proteomics, metabolomics, interactionomics, and phenotypeomics, etc.) gradually push the age of molecular biology to SB era(Yang, 2004).

3.2. Consistent epistemology methods, from reductionism to emergence

Bertalanffy divided the thing overall characteristic into two kinds: cumulative

(additivity) and constitutive (non-additivity) (Guo, 2003). Usually, the material characteristics of the system is cumulative, just need to add up the various parts of the characteristic features can be whole; system structural properties or information characteristics do not have the additive, the overall characteristic depends on the specific relationship between parts. Has the additive property system usually is may return to original state; But has the constitutive character system then may not return to original state mostly, or the use of reductionism methods is restricted. Therefore, the system additive may be called reducibleness, whereas the constitutive called irreducibleness. Usually people say the "whole is greater than the parts" is (only) for the purposes of irreducibleness. System irreducibleness ubiquitously exists in nature, especially in life, society, areas of thinking. System irreducibleness ubiquitously exists in nature, especially in life, society, areas of thinking. Once the various parts of the system in accordance with a method to form, we can have the attributes, characteristics, behavior and function, which partial or the partial sum totals do not have and so on; the overall once returns to original disparate parts, these properties, characteristics, behavior, function, etc., will cease to exist. This things (or nature), which the whole has and the part does not have, is called the “Emergent Property”, or the “Emergence”(Miao, 2001). Can really play for the reductionism the role of the revision and the supplement, is not the whole theory, but is the emergence theory, or about emergence scientific methodology.

The information science achieved the empirical goal the main method is the emergence theory, namely in the observation, the experiment, the hypothesis, the inference discusses the pattern or the model which the new nature can emerge. The core concepts and ideas of Emergence are material elements and information elements constitute a system of "structural model." Here's structure, including hardware and software structure, which can be spatial structure, temporal structure, but also a logical structure, algorithm structure. In the physical world, the material characteristic of the structure model is a key factor in the decision system. For example, the carbon elements arranged in different ways, can lead to graphite, diamond and other substances in different forms and characteristics. In the world of information, communication, control, calculation of success and efficiency, without exception, depend on the overall system model elements, including the hardware architecture model, but mainly a software model. In a particular information subject, these structural models often become the core of all knowledge. Structural model of these basic concepts, principles and methods have become the theoretical foundation of the discipline, and even become common ideas and beliefs, that is the subject of the paradigm. The information science shares the basic paradigm, called information science paradigm.

The Cybemetics founder, American scientist Wiener is one of the pioneers to understand the phenomenon of life, the earliest scientific point of view from the system, his research led to the birth of biological control theory(Weiner, 1948). 1969, Bertalanffy proposed General systems theory, he pointed out in his article that the organisms is an open system, its composition and biological function of depth will eventually need the help of computers and engineering and other branches to complete(Dickson & Moser, 2007). At that time, research tools and time far from mature, therefore not be accepted by people and scale. As the life science research into the "post-genome" era, genomics represented a broad variety of Omics to carry out, the new large scientific works started to appear, beginning with the biology, mathematics, engineering disciplines interwoven, cross; More frequently because modern medicine more frustrated in a variety of complex multi-gene disease grim situation, combined with a system thought of multi-disciplinary research thinking to biological problems to be re-ignited and quickly pushed to the forefront of life science research.

SB is also known as Integrative Biology，Predictive biology(Liu, 2005). Post-genome era biology faces a great challenge is how from the overall level of biological systems to reveal various biological phenomena through the interaction of the DNA, RNA, proteins and

small molecules. At present the scientific community in general consensus that the phenomenon of life is impossibly explained thoroughly by analyzing the composition of the basic units (genes, proteins and biochemical metabolites), and through the composition of the system from the interaction of basic unit and their dynamic behavior start to carry out systematic research in order to finally answer the scientific issues on speciation and implementation of life functions. Systems biology is born in this context. Compared to traditional biological analysis forms only a basic unit of biological systems, more emphasis on systems level in living organisms to carry out research on life phenomena, that is genes, proteins and metabolites in biochemical reactions for the formation of interconnected nodes, dynamic characteristics of the network to explore and explain complex life phenomena(Brazma, Krestyaninova, & Sarkans, 2006; Bruggeman & Westerhoff, 2006; Kirschner, 2005; Newman & Weissman, 2006).

In fact, the integrity and integration of SB research is the very vitality. The rapid development of modern molecular biology, gene individual analysis and so on, causes the scientists gradually became aware of the complexity of species or life with the gene individual number not directly related. Therefore, on objective needs researchers from a holistic, synthetic point of interpretation of living systems. Meanwhile, a variety of low flux, high-throughput biological experiments means to make the transition from genes to cells, to tissues, to different aspects of individuals at all levels to conduct research on life-support systems possible. Massive use of accumulating data by these means, also for the researcher under the conformability viewpoint explained systematically the life phenomena provides the objective conditions(L. Chen, Wang, Fei, et al, 2007). With the systematic approach to understanding a biological system should and is becoming the mainstream of biological research methods, aimed from the system level understanding biological systems, with emphasis focused on four areas: system structure identification, system behavior analysis, system control, system design.

3.3. Be the Open System, Emphasizing the Role of Information Energy

Information duality theory is the basis of TI. The information both has the material characteristic, and has the non-material characteristic. Information is dependent on material carriers absolutely, so no information can exist without material carriers, it must be material, and characteristics of material; Meanwhile, it has a relative independence to special carriers, so material is only a relying-on for its existence, and information can change this. Radically, information is immaterial and characteristics of immaterial. The material characteristics of information only reflect its forms and phenomena, while immaterial characteristics can show its contents and essences. Immaterial characteristics of information mainly embody in its non-spatial characteristics. The information duality and its immaterial characteristics are both the basic views in information science and its basic approach. The duality of information existence determines the duality of information movement. Information movement is composed of the two interrelated movement modes: material carrier movement and purely information movement, which are driven by different energies and submit to different movement laws. Basically, the driving force of the information movement is not a material power, but the power of information, called “intelligence”. Measurement problems of information are different from that in physics, because information is a nonphysical, abstract and logic existence, and does not have the basic properties of physics objects, such as size, weight, temperature, color, odor, and etc., so the process of information can not express with mathematical formulas, but only to be described with the designed programs in a certain language.

If Wiener takes things into two parts, separating the information from the material, and defining that information is not material; then we can split energy into two, separating the information energy from the material energy and point out that the driving force of information movement essentially is not the force in physics, but the power of the informatics. In the level of human society,

knowledge does not mean intelligence, a variety of different types of algorithms and programs are the engine of data processing and knowledge inference. If the information processing capabilities, namely information "acting" ability, be called "Information energy", then the energy of the universe can be divided into two types: material energy and information energy. Thus, the "Trialism" of the universe (matter, energy, information) can be replaced naturally by "Quadruplicitism" (material, material energy; information, information energy). As all things are a unity of material and information, information energy and material energy are also unified. As the symbol is the signal of signal, information energy controlled material energy. Biological information energy, even human culture energy, in essence, is energy of the logic, but in a sense, it is also the physical energy. Physical energy is the primary information energy, and the information energy is the advanced physical energy. The unification and evolution of energy becomes the logical theory. The evolution of the universe, ostensibly, is the evolution of material structure and function, but is evolution of the energy composition and effectiveness in nature.

Based on the concept that the energy can be divided into material energy and information energy, we propose the concept of information entropy and information negative entropy in order to correspond with the concept of material entropy and material negative entropy, to reveal the self-organizing systems is just to use the material negative entropy and information negative entropy, to contain the increase of material and information entropy, enhance the complexity of the structure and function to achieve the evolution from simple to diverse and complex. Evolution of the energy is to reduce "information negative entropy" and it's the driving force to increase the complexity of the system structure and function. The less information negative entropy tends to be the larger the driving force of evolution. Cultural information energy is the most advanced form of energy in the universe. Second Law of Thermodynamics predicts a Heat Death of the universe, and the second law of informatics predicted an informationizing and digital universe. Thus, the development direction of system science disciplines correspondingly has been clear: to achieve information turn, that is to establish information systems science on the basis of the information science and control theory.

Material and energy are the central concept of the material sciences, information and information energy (that is, knowledge and intelligence) is the center of the whole concept of information science. Quaternion elements of the universe can be understood and accepted by people with common sense. In human society, material production must be with a prerequisite of consuming energy and raw materials, and then products can be completed. However, the materials substances and physical-chemical resources are required less in the information production, it does not consume the raw information, also does not consume the information energy. On the contrary, intelligence is a growing type of energy. The non-consumption type of knowledge production and the intelligent unceasing proliferation are the inherent mechanism of explosive growth for the information product. In the information world, resources exhaustion and energy shortages can never come true, and it does not lead to the trend of balance, but rather to unlimited extension of a thriving, high-end intelligence system.

Biological systems display its complexity from a variety of space levels. The human genome only have 25000 genes, but can create one hundred thousand kinds of protein (many genes have multiple functions), even if only to consider the interaction between proteins in pairs, they may also produce five billion kinds of compounds. Tissues and organs is the next level of biological complexity. Even if the apparent similarity of the organs, such as the function of the liver in collaboration with the system is completely different from the behavior of the separate cells that compose of the organs (cells are sensitive greatly to the surrounding environment and its interaction with the neighboring cells). Such as the separated liver cells may survive in the nutrient solution, but will lose their unique features quickly. More complex the whole organism, that is, it is not just the sum of some organs and cells. Higher

level of biological complexity depends on the level of biological communities, where the research topics are like the spread of infectious diseases, diversities as ecosystems and economics. Time and space are separated by complexity of the biology. To the molecular level with 10^{-9} seconds as a unit, the characteristics of Brownian movement plays a very important role, but in the whole organism level, the system may exceed 10^{9} seconds, almost one's whole life time. Rules and mechanisms formed by self-selection, biological systems have extraordinary ability of self-organization and aggregation. Turnover and renewal by the components, biological systems also have strong self-maintenance abilities. Perhaps it is the exact characteristics to distinguish biological systems and other systems that they can change their gene expression or, more directly, through signal transduction and protein modification to adapt to changes of the environment (this adaptation reached a peak in higher organisms)(Lei & Gu, 2007).

Life phenomenon is a complex system, and SB should be the system science to study the life phenomenon. As a complex life, whose components are not simple stack, but have extensive interactions with each other. These interactions of life are not linear, but woven into a network. This wide-existing interaction network leads to another important feature of life phenomenon's complexity, "order and hierarchy". As the life of the constituents, has a stable interaction, thus forming an orderly structure, with self-organization. Another feature of life complexity is that the system is open; life can evolve in this process. Life is not like a simple "self-steady state" system, which can be through the regulation-control of negative feedback to stabilize their states, and thus adapt to the outer changes. Life is an open system far from equilibrium, through the continual formation of new properties or new features to adapt to the outside challenge or change.

Information is the basis of SB, high throughput detection technologies are used to produce "massive" information. Through the analysis or excavation of the "massive" information, we can further elaborate the regulatory relations between the components network, and then we can control and design the system in a regular way. In the era of pro-molecular biology, biologists consider life as a special "energy" of the organism, following the rules non-existent in inorganic realm for life activities. In the era of molecular biology, the researchers think of life as a sophisticated machine, the genes and proteins run according to the laws of physics and chemistry. In the post-genomic era, scientists think of life as the information carrier, all properties can be obtained from the flow of information. Hood believes that biology should be considered as an information science, this view contains three connotations. First, the core of biology genome is digital. Biology is a science which is completely different from all other disciplines, such as physics, chemistry and geography, because the disciplines other than biological can only analyzed by way of analogy. Since the core of biology is digitalized, biology can be completely deciphered. Theoretically, we can have a better grasp of biology than any other discipline. Second, the digitalized core of life is showed as two types of information, the first type of information is the gene of encoded protein, the second type of information is the regulatory networks of controlling gene acts. Clearly, the gene composed of a DNA sequence is digitalized. It is worth emphasizing that the information about gene regulatory network from the essence is also digitalized, because transcription factor binding sites controlling gene expression are also nucleotide sequences. Third, biological information is in a hierarchy order, and flows along the different levels. In general, the biological information flows in such a direction: DNA → mRNA → protein → protein interaction networks → cells → organs → individual → group. It should be noted that each level of information provides a useful perspective for understanding the operation of living systems. Therefore, the important task of systems biology is to obtain as much information for each level as possible, and then to integrate them.

According to the viewpoint of system theory, the key of constituting a system is not the components of the system, but the interaction or relationship between the components. The

interaction or relationship, in essence, is information. From another perspective, life is an open system which is far from equilibrium, in order to maintain their ordering, life systems must be constantly exchanging energy with the external environment in order to offset the process of entropy production. In his book named "What is life?" which was published in the 1940s, physicist Schrodinger pointed out that the life lives on "negative entropy flow", while the "negative entropy" is actually another representation of information. Therefore, we can say that life system is a process of information flow, SB is to study and reveal the laws governing the operation of this information(S. Xu, 2004).

4. Prospects of Theoretical Informatics

Through the above analysis and comparison, we can find TI and SB, in many attributes or characteristics are strikingly similar, some almost identical. They are emerging interdisciplinary field of physics, chemistry, mathematics, computer science, biology, systems science, and so on, and that their research results also promote further development of these disciplines. The development in the future, they can play their own unique advantages, together addressing concerns on major issues of current, such as medical and health, the environment and resources, energy and life, provide ideas and other help for showing us a beautiful picture of future society.

Although TI and SB have the similar natal period, the current development situation is completely different; SB has been widely recognized by academics and the community, established a number of major international cooperative research centers and has gotten a lot of funds from research institutions. However, TI is not so lucky, and has not been fully recognized. Although scholars have started to pay attention to it, the TI is still "vulnerable group". If vulnerable subjects want to obtain the "mainstream" academics recognition, it must seek to points of integration with accepted and integrated by the mainstream academics while developing their own disciplines, more importantly to make achievements which let the mainstream academics approval, while they themselves can not be subject to the achievement, and make them to recognize the superiority of TI and the presence of rationality.

Only recognized by the international mainstream academics, that is having the "legal" status, information science scholars could have a chance to greatly preach theory and practice of strategy of TI in the international academic arena and promote the holistic development of TI.

The development of TI can learn from and reference SB model of development for international cooperation and grand coalition, establish the joint research centre, and strive for funds and project support, the more important is to create an environment in which scientists from different fields can work together to solve today's most challenging scientific problems of information. This multi-disciplinary joint program not only allows scientists fully understand the complexity of information systems, but also allows scientists from different fields to share their research ideas. To meet the future applications of information science and the development of the field, some new TI curriculums should be opened as soon as possible for the graduate and undergraduate students to stockpile the talented person. These measures will be able to bring information science to a whole new realm.

Science is still groping forward, the establishment of scientific theory can not do without the hypothesis, “as long as the Science is thinking, its form of development is the hypothesis”(Engels, 1984), some of the bold creative hypothesis are infants and prototype of thereafter insights. Of course, the fundamental purpose of scientific research is not the formation of scientific hypothesis, but arrival at the other side of the truth by testing and certificating scientific hypothesis. According to whether things reflected by scientific hypotheses and phenomena can be directly observed, that is the relationship between things and test hypotheses reflected by scientific hypotheses and content of scientific observed by hypothesis verification, scientific method of hypothesis verification can be divided into direct and indirect verification. Direct verification, directly

observe the things and the phenomenon reflected by scientific hypothesis through scientific observation or scientific experiments, to make a direct scientific hypothesis confirmed or denied, as inferred hypothesis of unknown celestial body that may exist, the hypothesis of energy conversion and conservation, and so on, they are examples of direct verification. Indirect verification directly observes the logical conclusions leading by the scientific hypothesis by the way of scientific observation and scientific experiments, verifies and proves indirectly scientific hypothesis by the logical conclusions. In the development of the natural sciences, the vast majority of scientific hypothesis were tested and proved by this method, such for Mendeleev periodic law validation, validation of Einstein's gravitational wave hypothesis(J. Li, 2002).

For domain informatics, in addition to Shannon's mathematical theory of communication, the remaining subjects aren't now and after verified by a direct method to test and prove their hypothesis, only by an indirect method. On the TI, the situation is even more special, because it integrates many domain informatics. Findings on TI, such for information duality, information energy as the fourth elements of the universe, unity and coevolution of information energy and material energy, the three basic laws followed by various types of information phenomenon, TI framework establishment, are based on hypothesis-led, and see the "hypothesis - deductive method" as the basic method of scientific thinking, the major modes of whose reasonable verification are all indirect at present or in the future.

TI as a new science, is in the embryonic stage, whose research scope, research goals, methods and means, application field are to be refined concretely, but because of the importance for TI on scientific discovery and social progress, it's no doubt that information science will become an important direction of development in the future.

Not only at present the domestic and foreign related theory information study research occupies the initial stage, in fact only then just started, moreover academic circles even have an atmosphere of "pessimism", think it was too difficult, have the suspicion to its feasibility. However, we believe, it's the same as that the information age did than the industrial age, the future development of TI is great, and it is possible to achieve a higher degree than the material science theory. On the one hand, the formation of scientific hypothesis of TI needs a cognitive process; on the other hand, the verification of these hypotheses, especially through the indirect method, it is a historical process of development. TI has a long way to go, as information workers exploring the mysteries of information, we should try to create the current situation for the new things, promote academic prosperity. How to follow the trend of the times, and how to carry out in-depth and detailed studies in the information field, are the problems we should seriously consider.

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