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# What is Information?

## An Interpretation Based on the Theory of Modern Complexity Science

Zhikang Wang

Sun Yat-sen University, Guangzhou, P.R. China.

zdwangz@126.com

**Abstract.** This study seeks to answer the question “information is information, not matter or energy” asked by Norbert Wiener, focuses on the relationship between the material system and information, and makes the two concepts of information and information entity clear based on the theory of modern complexity science. Information is understood or defined as the form of interactions between different layers of matter systems, which not only broadens the knowledge of interactions and causality in nature but also enables AI.

**Keywords:** Information, Hierarchical interactions, Informatization, Information causality, Information entities

### 1. Introduction

The progress of Information and Artificial Intelligence Science since the 20th century, in a sense, has benefited from the proposal of the information concept and the formation of information entity, but both are not very clear in science and philosophy. They need to be explained through hermeneutics.

Norbert Wiener said, “Information is information, not matter or energy. No materialism which does not admit this can survive at the present day” [6, p.182]. What is information, then? This is still a question for science and philosophy.

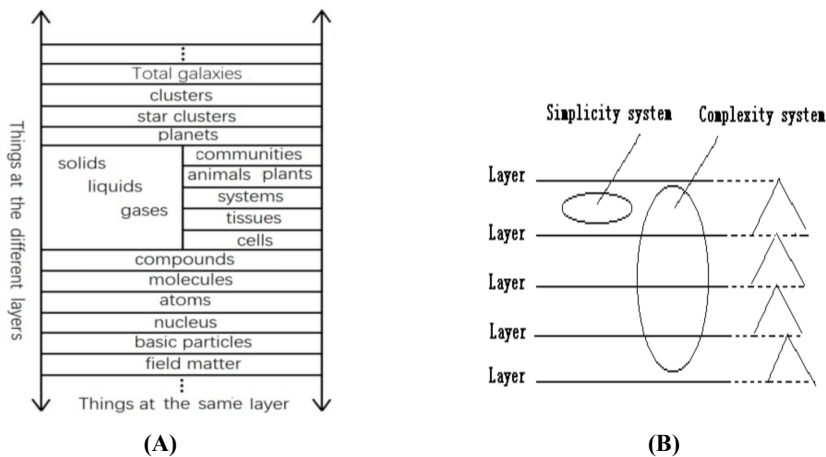
Before we dive deep in what information is, the word information is used only in the sense of human culture and its transmission, so it is one kind of abstract description about "message" and "thought". As existence of the objective world, information begins after scientists learning about the special way of biological heredity and the communication mode of machines and animals. Although the concept of information has not been clear, but its importance has been increased for science and philosophy to the point that neither scientists nor philosophers can ignore its position in the objective world. Norbert Wiener's question promoted positive thinking in the sense of information ontology, yet there was no obvious progress before the viewpoint of world changed from simplicity to complexity, namely before the birth of complexity science. Obviously, the answer to the question is very important to us because it involves the

human artificial intervention in biological information and communication, and the realization of artificial intelligence.

The rest of the article is going to explain and define information from a new perspective. I will explain how information can be understood or defined as “a form of interaction between different layers of material complexity systems”, how it is realized, and I will demonstrate it based on the biological systems and communication systems by the theory of modern complexity systems. Information is considered as the entity (so-called “Relationship entity” by Aristoteles [1, pp.156–157]) that maintains itself in transformations with different carriers of material layers, so it answered Norbert Wiener’s question about the relationship between matter, energy, and information. This paper tries hard to clarify the essence of information, and reveal the essence of artificial intelligence which is a new information mutual relationship established at different layers of the material system.

## 2. Material hierarchies and complexity systems

Everything in the world, no matter how huge and small, is the unity of “multiple” and “single”, which is the concrete manifestation of the unification of material diversity; as such, everything can be called a material system. When we begin to chart a variety of things presented before us in the relationship and order their qualities (see Figure 1(A)), we find a hierarchical relationship between the various specific forms of matter [2, pp. 1–8][7]. This is a reality manifestation of the unification of diversity in the material world. The things at the same material layer are called “simple diversity”, they can be easily distinguished through the conceptual methods of general formal logic, but the things at different material layers are called “complex diversity”, to distinguish these things we usually cannot find the logic or other theoretical criteria. In further research, we can also find that the chart reveals the two most basic situations of the unified



**Fig. 1.** (A) Continuity and discontinuity, diversity and unity of the material world.  
 (B) Simplicity system and the complexity system.

diversity of things: one is at the same layer, and the other is across different layers. For the reasons above, the system composed of the unified diversity of substances within the same layer is called the “simplicity system”, while the system composed of the unified diversity of substances across different layers is called the “complexity system”. From their parent, the matter hierarchy, we can see the fundamental difference between simplicity systems and complexity systems (see Figure 2(B)), and the secret of the complexity of the world [5, pp.109-112].

### 3. How information comes into the view of scientists

From the brief description above, it is not difficult to find the dilemma of traditional scientific theory dominated by reduction. There are many layers inside and outside complexity system, the existence of layers blocks the direct causal link from the local to the whole and generally presents the characteristics of emergence and mutation, so the overall nature of a complexity system cannot be segmented and cannot be reduced to its local properties by analytical approaches. This situation is prominent in studying biological systems and mechanical machine communication systems. Scientists first explain the genetic mechanisms of life in ways such as messaging and symbolic recording in human culture. The introduction and use of the concept of "gene" (basic reason) marks the beginning of people's understanding of the world into the information field, in which, the objective existence of information is accepted, that is, there is real existence on the objective world that can only be found through the human spirit, and be explained by the human spirit. The cognitive focus of the world extends from physical interaction to information interaction, and physical reduction to information reduction. Let's see the process of this transformation in the following chapters.

#### 3.1. The reduction of three types of determinism

**The reduction of mechanical determinism.** There are three types of determinism, they are used to deal with interrelationships between the layers of systems. First is the reduction of mechanical determinism which claims that any high-layer law can be recovered by complex calculations into low-layer laws, which is the mechanical laws of a single or a small number of particles, and that the material hierarchy is irrelevant.

**The reduction of statistical determinism.** The scientists trying to make such efforts believe that the relationship between various things and material layers can only be attributed to the laws of statistics, and that all material movements can be described by pure statistical methods between the two layers. This view claims that non-statistical features between hierarchies are just unknowable and any further exploration is meaningless.

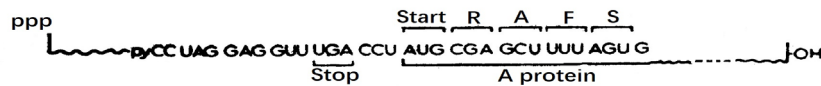
**The reduction of cryptodeterminism.** A famous theoretical physicist, one of the founders of molecular biology, Erwin Schrödinger was the first to point out that neither of the reduction forms of determinism, mentioned above, is possible in a biological genetic system. Erwin then put forward the theory of genetic cryptography [3, p.23], arguing that the high and low layers of organisms cannot be restored through the traditional scientific theories we know, that there are many cryptographic relations between

them, and only through translation can they become physical and chemical laws we know. The proposal and establishment of cryptodeterminism is a major thought revolution in scientific epistemology and methodology. It marks a new stage in human research on complex things, including humanity itself (cryptodeterminism is also known as information- determinism).

### 3.2. Interpretation of information on biological genetics

1953 James D. Watson and Francis Crick discovered DNA double helix structure and a special relationship between nucleotides forming DNA molecules and amino acids of protein molecules, this relationship cannot be explained by traditional physicochemical interactions. Scientists explain this particular interrelationship in “natural language” by using the characteristics of human cultural transmission, and it is interpreted as a similar text communication coding relationship (see Figure 2) . A set of cryptobooks used by the whole organic world was then discovered, thus, the theory of biological genetic information was finally established.

In this way, the scientific vision really moves into the information world starting with the biological system: a world with special interactions.



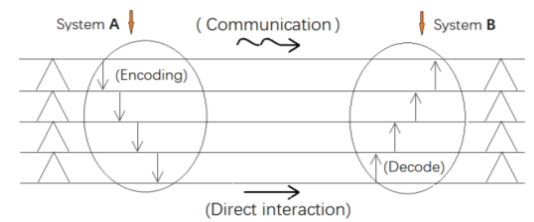
**Fig. 2.** Nucleotide program and corresponding proteins of the mRNA molecule of phage R17 (part). The bioinformation interpretation based on human cultural information model. The genetic characteristics of organisms are recorded in encoding form, similar to a string of characters in human culture, it is material and also informational.

### 3.3. Information and communication connections are established between different and across layers of the organism

The living system should obtain time, so that the various parts of it are coordinated and unified, and the spatial and temporal relationship between the parts at each layer can be adjusted at any time. So, how does one layer change its state of time and space according to the change of another layer? Therefore, there must be a set of communication connections between the high and low layers in organisms, in addition to the “native” and “evolutionary” connections determined by the cipher book, which occurs not only between the various relatively separate parts of the same material layer, but more importantly, between the various parts of the different material layers.

The best way to establish communication connections is to send messengers to each other at different layers, as in the human social system. Take humans as an example, it has been found that the three messengers delivering life information between the layers of human body are: hormone, prostaglandin, and adenosine cyclic phosphate (cAMP), they work together to complete the task of delivering life-sustaining information in a relay way, and it is really similar to human communication [5, p.123-124].

Figure 3 illustrates vividly the information interactions (communication) that occur between the two systems. It shows that the information transfer between the same layers must be accomplished by a direct physical interaction at another layer. Norbert Wiener emphasizes that communication between machines, animals, and humans has the same mechanisms [6].



**Fig. 3.** Information interactions between different systems. Information transfer at the same layer is achieved through direct interactions at different layers.

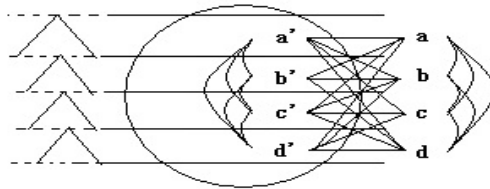
#### 4. The Interaction between Layers in Complexity System and Its Informatization

Now, let us come back to the main question of this paper, how to understand the presence of information. To explain the changes in the overall properties of complex systems, many new concepts for causal analysis are created, such as: downward causal, bidirectional causal, causal feedback, causal cycle, causal network and causal map etc., which all face the problem of the causal chain fracture between different and crossed layers in complex systems. Don't the interactions between the whole and parts or layers in a complex system like an organism follow the laws of physical causality?

##### 4.1. The change of causal ideas

The interactions between different and crossed layers lead to complex causal relations inside and outside the system (see figure 4). However, the traditional concept of causality (once questioned by David Hume) is a view of causality focusing only on inevitable connections, which attributes accidental connections to the defects of the cognitive ability of human being. In this way, the traditional view of causality cannot explain the complex causal relations of the hierarchy in complexity systems. The basic tenet of traditional determinism is to ensure the smooth flow of necessity and causal chain, it is to set the existence of the universal physical mechanism of "cause" and "result". However, life phenomena violate and do not exactly follow such a determinism. The mutual relationship between different layers and crossed layers inside and outside organisms appears in the form of coding. The same information content can have different material carriers, and the inevitable and accidental results of the interactions between layers can be transformed into information forms. Life exists as an "information entity", transforming and moving between different layers. In complexity systems like biological

system, the interpretation of information causality is far greater than the traditional mechanical and statistical determinism, and the traditional view of causality yield to the view of information causality.



**Fig. 4.** Layers and complexity.

**Information causality.** The existence of the material system hierarchy indicates that there are not only quantitative points of inflection, but also qualitative points of inflection between layers, which have relations of containing and being contained. The attributes of things having sudden or emergent characteristics in different layers cannot be normalized or restored, therefore, the unfolding form of causal relation of things between hierarchies is not traditional, eternal or universal. Based on mechanical and statistical decisions, the interactions between the layers develop special coding relations, representing the information causal connection, and the interaction turns to the “information causal form”.

**Causation encoded and information causality analysis.** The causal connection (inevitable and accidental) of all layers and elements of material system is written into an encrypted form and stored in the carrier at various layers. The interactions of crossed layers are the initiator. A large number of accidental and inevitable connections can collide and intersect: The accidental connection at the same layer is transformed into the inevitable connection between different layers, which in turn restricts the accidental connection of the same layer, and the accidental connection between different levels can also be transformed into the inevitable connection of the same layer, so that any changes happened at all layers within the system are mutations or protrusions relative to the other layers and system as a whole. We are unable to find the direct (physical) cause for the results at another layer, and it is the locking of action by hierarchical interactions on randomness. The originally complex causal connection transforms into simple information connection (from certain point of view, information is a mapping of complex hierarchical relationships of matter systems). Complex causal relation of different and crossed-layer translates into “information causal relations” with coded form, and different hierarchies and attributes are the performance of information entities. This explains why the structure and attributes of different layers cannot be reduced and reducible between the layers, but can be unified through the transcription, translation and decoding of the information entity, then achieve the overall attributes of the system. The causal analysis of the complexity system is thus transformed into the “information causal analysis”.

#### 4.2. Information entity



Information entity is the "model" of the overall attributes of the system, hidden in the intercommunication of different layers, existed according to the carriers, but independent of the carriers.

**Information entities flow in the material system.** The information that encodes overall attributes of the material system is stored in various hierarchies, it is converted between different layers through interaction, layer by layer or across layers, by bottom up or top down. During the conversion process, the information carrier experiences different material forms.

The relationship between different layers in the material system is no longer a pure physical connection, but an information connection that encodes the material form. The phase transition (leap) between matter hierarchies has limited kinds of possibilities, it does not depend on mere mechanical decisions or the regulation of continuous functions, or mere the law of statistics, it also depends on the law of information. The transformation of matter forms at different layers depends on mutual complex connections. Erwin Schrödinger once pointed out that "genetics shows that there are many small, incredible atomic clusters, they are so small that are not enough to represent accurate statistical laws, but they definitely have dominant impact on the order and regular events within living organisms" [3, p.20-21], and predicted that there is an information entity in the activity.

**Information entities remain their immutability in the information flow.** Information entity that represents the overall attributes of the system (subsystem) has a certain autonomy or intrinsic regulation. No matter what the information carrier is, how it transforms, the information entity moving in different layers of the system through the hierarchical interaction must always maintain their own immutability, and the information content will not be easily changed, so that the system keeps the structure and the overall attributes stable to a certain extent. Information entities can be considered, in a sense, as attractors for the complex interactions of the components at various layers of the material system.

### 4.3. The role of the hierarchical interactions

Over time, many inevitable and accidental interactions occur inside and outside the system. In this case, the change of various layers of the system must occur accordingly, which are usually locked by the hierarchy of the system, and the interaction between layers appears as the behavior of the information. A complex physical system is also an information-generating system, in which each layer can act as an information carrier, an information intermediary, an information generator and receiver, and a messenger, and the interaction between the layers plays the role of information encoding, communication, overcoming the change, loss or tampering, and error correction of the content in the process of information carrier conversion, thus ensuring the integrity of the information entity and the overall attributes of the system. The following figure 5 (see Figure.5) shows how physical interactions between layers in complexity systems become information interactions, and why we say that information is a special form of interaction locked by the system hierarchy relationship.

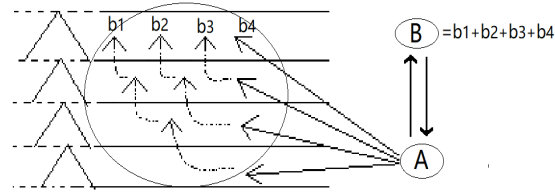


Fig. 5. Physical interactions are encoded by the hierarchical construction of the system.

## 5. Short Conclusion

There is no independent information in nature, and information is not pure objective reality. Information is the product of our human interpretation of a special form of interaction that occurs between different and crossed layers of complexity systems in nature. Information and the other related concepts and terms describe only a form of interaction in nature that can (or can only) be understood and operated by the spirit. The existence of information is inseparable from our deep understanding to the human cultural signaling and complexity systems. A causal interpretation of information on interactions between layers of complexity systems not only broadens traditional causal beliefs, but also makes AI possible.

Plato's *Epinomis* thinks hermeneutics as a guess of the will of God from symbolic symbols. Then, information as a form of interaction between the layers of material complex systems is a successful guess by scientists.

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