BIOLOGICAL FORM AND COMPLEXITY: REFLECTIONS ON THE ART OF TAI CHI

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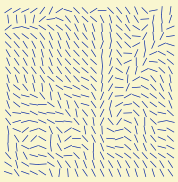

THE QUEST FOR COMPLEXITY

Vassily Kandinsky, father of the abstract movement, Bauhaus professor and one of the great figures of contemporary art, believed in the existence of an «inner necessity» that drove the artist inescapably to create. Naturally, one hundred years after the publication of «*Concerning the Spiritual in Art*», both the definition of and the necessity for creation are still the subject of much debate, with the very concept of art itself being called into question. However, it may be interesting to consider an impetus that is similar for the scientist, whose inner necessity is more obvious, an impulse that one might call «inner curiosity», a need to know and furnish the natural phenomena with a reasonably objective explanatory basis that satisfies our intellect. The search for complexity in nature responds directly to this inner curiosity and is grounded in different conceptual bases. On the one hand, this quest contains a component that has been inherited from monotheistic Western religions, whereby human individuals are viewed as the centre of creation and their brain as the most complex structure in the universe. One can easily find this sort of view in any biology text book, reflecting at the very least a certain lack of humility in the face of the immensity of nature. At the same time, the search for answers to the problem of complexity is a recognition that natural phenomena

are organised on different scales and that the possibility of predicting a phenomenon ranges from absolute certainty to that which is impossible to anticipate. There are many other foundations for the quest for complexity. One of them can be found within the art of Tai Chi.

In November 2008 I took part in a conference on mathematics and biology on the Japanese island of Okinawa. There, as I practised Tai Chi on a coral strand looking out over the China Sea, meditating, I was reminded of the old idea of the *koan* to be found in Eastern metaphysics, in which an apparently paradoxical question is posed containing an impossible analogy, an unfeasible metaphor or an essential aporia, obliging one to think further; in my case, on the many questions of science and biology. Some time later, I thought about *koans* again when I was reformulating an old question, commonplace in nineteenth and twentieth century biology: is the complexity of the organism present in the fertilised egg? The question is not in actual fact a *koan*, but rather a scientifically valid inquiry. One can make observations, calibrate a notion of complexity and find reasons for answering in the affirmative or the negative. For example, preformationism, with its classic image of the homunculus squashed into the sperm, argues that everything was already present in that seed, and that the complexity of the individual is maintained throughout the process of growth. In contrast, epigenesis, the theory that opposed this dynamic determinism of embryology, argued that nothing was preformed, but rather that the complexity deploys and emerges, gradually, as the embryo goes through the different stages of development. Modern biology sees epigenesis as a valid description of embryonic growth, although it is known that there are «pre-patterned» molecular moulds of gene expression that mark the exact place in which certain embryonic structures appear. The discovery that a similar process might have occurred during the evolutionary process gave rise to the hypothesis of ontogenetic recapitulation, i.e. that during development embryos went through «primitive» states of their historical, phylogenetic, inheritance. This hypothesis has sparked much controversy and now stands in modified form as one of the pillars of evo-devo, the science that analyses the dynamics of evolution on the basis of similarities found during development. What today's evo-devo shows is that, in fact, the complexity of one ancestor is present and regulates the complexity of a descendant species through embryonic development. The nineteenth-century question —and my *koan*— is therefore echoed in a question (and a new *koan*) for the twenty-first century: is the complexity of a species present in its evolutionary history?

For me (and I hope for the reader too) these two questions, reformulated in the mysteries of the *koan*, invite me to make an effort of scientific imagination. The dynamics and the symbolism of the practice of Tai Chi, an ancient martial art and space for meditation, whose physical implementation is known as «The Form», can also act as a *koan* and help us to discern some twists and turns on the road of bio-

logical complexity. However, there is nothing more artificial than trying to respond to a *koan* with scientific logic and reasoning. We shall therefore use Tai Chi as a metaphor, as an artistic action/expression that evokes aspects of the complexity of organisms. We can justify this choice on the grounds of the profoundly conceptual nature of the practice of Tai Chi, which contains forms and symbols that move through space pointing to the four cardinal points through the continuous execution of circles. Each movement is an equation of the surrounding space, a complex model of the relationship between the terrestrial and the celestial. The result is the self-organisation of a complex whole, the self-organisation of the complexity of the Form. The movements start from a discrete series and combine to create a harmonious space where the practiser 's mind can escape and search for him or herself. The formation of this discrete space suggests certain points in common with the arrangement of the natural morphospace.

THE NATURAL MORPHOSPACE IS COMPLEX AND DISCRETE, LIKE THE FORM

The question of the complexity of the world and, in particular, of organisms and evolutionary phenomena offers us a chance to reflect on the way morphological organisation is generated. For a Tai Chi practitioner and instructor, this issue also evokes other questions that come close to the viewpoint of art. Those who practise Tai Chi seek the same thing as artists and scientists. Their inner necessity, which with each movement leads them to embark on a journey of personal quest, and their curiosity to understand the unhurried movements of this ancient practice, drive them to seek physical harmony through precise positions in space. In the practice of Tai Chi, the movements of the different parts of the body (deliberately slow so as to enable a state of meditation in the practitioner) is part of a set of three harmonies: hand/foot, knee/elbow and hip/shoulders, which at any time maintains the organisational/formal consistency of the whole represented by the human body. As a result, one might say that the complexity of the Form could be separated into the harmonies that these coordinated movements present. However, this is not the case: any such analysis of the constituent parts cannot explain the complexity of the whole, since the intentionality of the practitioner generates meanings that cannot be deduced from a simple observation of the movement. And there is more: each movement (sixty-four in the long form of the Yang style) has a symbolism that relates it to some natural object such as the clouds, the sun, the moon, the wind, or an animal such as the tiger, the monkey, the rooster or the bear, or a plant such as the lotus. And if this were not enough, the collective practice of Tai Chi turns each

individual into another element, as if it were the cell in a body, whose movements must be synchronised with those of the other practitioners, leading to the emergence of a macrostructure in perfect harmony. The complexity is engendered from basic and limited principles that arise out of the individual's intention.

In the case of organic form that intentionality is absent. It is the result only of a series of evolutionary and developmental constraints. The complexity of the organisms and the many —numerous, but not infinite— shapes they have taken on during the evolutionary process does not have deliberate (teleological) objectives as the movements of Tai Chi do. Instead, its motivation is an entirely generative one: the formation during embryonic development of structures that interrelate and grow until they form the organism. In this dynamic there is a hierarchy of events which, as we shall see, is subject to a series of discontinuities. The final consequence of this dynamic and of this balance between the permissive and the restrictive are discrete shapes in space: not all complexities are possible. This is what we call the discretization of the morphospace. Not all forms are possible and not all transformations can be maintained in an evolutionary dynamic. And although the inheritable substratum of organisms (the sequence of bases of adenine, guanine, cytosine and thymine) may change more or less randomly amongst themselves, contributing to form almost unlimited genetic complexities, the coding of the genes in functional proteins is much more restrictive. And cellular behaviour in a metazoan (a multicellular organism) is even more so, though subject to the same general physical constraints that I find, for example, when I move my hands like clouds (a characteristic Tai Chi movement). As a result, the organic form evolves discretely, responding to a generative logic that is related to the chemical and physical constraints of the functioning of the proteins and the structural constraints of both the molecules making up the cells and the cells that make up the tissues, and so on to the formation of the individual.

THE GENERATIVE STRUCTURAL HIERARCHY IS NOT CONTINUOUS

On the scale of both time and space, the phenomenon of life appears throughout at least ten orders of magnitude. The options for generating complexity are therefore vast. As well as these scales in which the phenomenon of life appears, there is something singular in biological organisation, a hierarchical organisation that might be termed «blocks within blocks» where small elements form part of larger elements, from atoms to individuals, populations, species, tribes and other higher taxonomic ranks. There is a generative hierarchy that takes into account the

dynamic processes that generate levels of biological complexity and a hierarchy of parts that is more reductionist, in the sense that it presents biological organisation like a succession of Russian dolls.

This distinction is important. According to the reductionist premises, organisms can be described in terms of parts and their interactions. In this paradigm, biology as a whole can be reduced to molecular biology which can in turn be reduced directly to physics. This requires certain conceptual leaps that on occasion are difficult to reconcile with the biological data. In the organicist paradigm, on the other hand, it is understood that, in disassociating the components of the organisms, one is losing the possibility of accessing (and therefore, understanding) the properties emerging between levels. Biology's view of a composition of parts within parts assumes the existence of specific combinatory rules for each level of organisation. This is what is commonly understood as rules of self-organisation. A classic description of this type of organisation describes a process where small parts nest into each other to form larger parts. For example, atoms form molecules, molecules form subcellular parts, subcellular parts form cells, cells form tissues, tissues form organs and so on up to the individual. In short, this description traces a continuous line between atom and organism. The analogy is also made to reduce the complexity of species to populations, social groups, family groups, individuals, and so on down to atoms. Generative hierarchy, on the other hand, highlights an interesting issue: while we move upwards in the hierarchy of parts from atoms to species, we find discontinuities, breakpoints where the generation of a component at a higher level of organisation is no longer possible. So how do these new levels of organisation arise? In reality, they do not arise as more elementary components, but wherever the hierarchy is broken, the levels form as a recursive and autonomous process. This happens both on scales of embryonic development and at evolutionary scales. We find four levels of recursive generation: the genome, the cell, the organism and the species (as shown in the diagram). These four levels cannot be produced as an assembly of elementary parts (although they are of course constituted by them), but need a pre-existing template provided by the structure itself to produce a new element. The genome is formed from existing genomes, through enzymatic replication performed by the polymerases; the cells generate new cells through mitosis, the individuals reproduce to form other individuals and species originate from previously existing species. Generative hierarchy is a clearly biological phenomenon that emerged with the appearance of life on earth. Since the first genome or the first cell or the first individual or the first species was formed, the generative hierarchy has continued to act down to the present day and will continue to operate as long as there is life on our planet. In other words, life self-perpetuates itself in a continuum which (re)generates different discrete levels of organisation.

DIALECTICS ENGENDERS THE COMPLEXITY OF THE WORLD

In the old Taoist tradition, the complexity of the world is established from a combination of opposites: different mixtures of the active/full principle (Yang) with the passive/empty principle (Yin) generate the so-called «10,000 beings», an unexpected number with regard to biodiversity seen from the perspective of Chinese knowledge several millennia ago. Incredibly, this confrontation between the full and the empty begins in «the nothing» (Wu chi) which, through the Tai Chi, is capable of generating both the Yin and the Yang. The symbol of the Tai Chi, the well-known black and white circle with small complementary circles within each half, represents that mixture or combination in which the full possesses the empty and the empty possesses the full. From that combination are born the elements that form the trigrams and hexagrams: lines that are solid or broken depending on whether they are Yang or Yin, and which are combined like zeros and ones in a binary code that represents the world immortalised in the *Book of Changes* or *I Ching*.

The paths leading to «the complex» in biological phenomena involve dynamics of organisation and self-organisation at molecular and cellular scales that integrate together until they form the individual. Beyond the individual scale, there are other scales of organisation that emerge from the interaction between individuals to constitute the whole contained within the biosphere of the Earth. In the approximately four billion years since the origin of life on earth, biological evolution has generated millions of species, most of which are already extinct. This process of genealogical transformation operated from the beginning, dominated by single-cell life for nearly three billion years, until one billion years ago when life underwent an explosion of biodiversity that culminated in the radiation of the Cambrian, approximately 500 million years ago. Since then, despite the ceaseless activity of evolutionary dynamics, little has been originated in terms of the «structural designs» of living beings. One thing does seem clear: the evolutionary dynamic has generated different complexities throughout this time. Singularly, from the emergence of cellular life to the radiation of Cambrian biodiversity, the increment from «simple» to «complex» appears to be an accurate interpretation, albeit nonlinear and discontinuous.

The biology of organisms and their evolution is subject to a dialogue between structure and function, together with a system of maintenance and transformation of information, the genome. Structure encompasses shape, size and matter, whereas function refers to the actions that those structures perform, which can be of two types: actions to maintain the stability and structural congruence of the organism and actions to respond to the challenges of the environment.

The former are strictly biological, for example, the forces that develop between the cells of an epithelium to maintain the integrity of a gland; whereas the latter run a wide gamut of possibilities, from biological functions per se such as obtaining food and copulating to social and cultural ones, such as searching for a mate and skill in playing a musical instrument.

In nature, we have suggested how the generative hierarchy builds complexity thanks to recursive principles of repetition. The metaphor of generation of complexity as an interaction between opposites goes beyond a mere analogy. In living beings there are, in essence, binary divisions that repeat what already exists almost perfectly, providing a starting point for future transformations. The most characteristic element of the complexity of life, the genome, is a passive (Yin) principle, which requires enzymatic complexes (the active, Yang, principle) to manifest itself both for its binary replication and for its expression and transformation into proteins. The appearance of cellular division split the whole into two halves and enabled the generation of biodiversity of multicellular organisms, thanks to mechanisms of adherence, a dynamic which is repeated whenever an embryo starts out with the first division of the fertilised egg. Individuals and species follow this pattern of division, allowing change over time. Ontogeny and phylogeny ceaselessly trace the paths of biological complexity. Evolution does not halt, it is a vital principle that makes use of this dynamics. It is a perpetual movement of forms that sketches the complexity of the world. Just like Tai Chi.

References

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ABEL RASSKIN
2009

-DIAGRAM 1-
DISCONTINUITIES IN THE GENERATION
OF COMPLEXITIES IN THE BIOLOGICAL HIERARCHY

-DIAGRAMA 1-
DISCONTINUIDADES DE LA GENERACIÓN
DE COMPLEJIDADES EN LA JERARQUÍA BIOLÓGICA