BIOMIMETIC MANAGEMENT

Building a bridge between people and nature

Bogatyreva O.A. and Shillerov A.E.

Bogatyreva, Olga A. and Shillerov, Alexandr E.

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ISBN-13: 978-1514771891
ISBN-10: 1514771896

Cover design and artwork	Vladimir TIMOKHANOV
Book design	Jean LEPRINCE
Editor	Rachel JARAI
Printing	CREATESPACE

First Edition

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Preface

We wrote this book for people who are interested in the theory of complex system management as well as its practical aspects. Examples of complex systems come from ecological systems formed out of different species of animals and plants, social systems formed out of people or other animals, organisms formed out of organs, cells formed out of molecules, a brain formed out of neurons, or even robot swarms formed out of robots. The field of complex systems cuts across all traditional disciplines of science, as well as engineering and management. Our readers might have different backgrounds – in biology (ecology, socio-biology, system biology, ethology), computer science (complex adaptive systems and networks modelling), sociology (management and organisational behaviour), engineering (robotics and biomimetics) or even philosophy (from science methodologists to those who are interested in *Naturphilosophie*).

The main reason that we regard any system as complex is the presence of indirect effects. Processes are hard to understand because the causes and effects are not obviously related or immediately visible. Action "here" often has effects "over there" and "whenever". For example, when extremely complex systems such as technology, ecology and society come to interact and interconnect, some interacting components, which may be useful and harmless within their own domain, suddenly generate long lasting disasters when they interact with other components. For example, transport development has changed our lives – people move across continents for holiday and business. Such mobility of people presents the opportunity for international cooperation in industry and cross-cultural enrichment, but it unlocks a means for local microorganisms, plants, insects and viruses to spread globally. Our transport system thus works like a mixer in the world ecosystem and we deal with its consequences every day. The need for some guidance in how to deal with complex systems has become more and more evident in our efforts to solve societal problems or avoid global ecological problems caused by our local actions. Achieving the sustainable management of our society and the environment we all belong to is a crucial goal for our success and even survival.

We believe that building a bridge between people and the eco-

system we all belong to must be the source for such success. That is why our book is called "Biomimetic management - building a bridge between people and nature".

So, what is biomimetics? Biomimetics is about using the laws of Nature as rules for action. For example, engineers regard living nature as a great source of new technological solutions. They started borrowing ideas for new forms and mechanisms (well known examples are Velcro, the lotus effect or use of dolphin's or shark's skin for improving the hydrodynamics of boats). We have now even started borrowing ideas from the functioning of neuron networks.

Sociality is the main property of Life; we may also say that there is no single creature that does not belong to any social group on Earth. Taking ideas from living social systems and implementing them straight away into business applications is very tempting indeed. But apart from great interest, there is nothing for business to rely on – no procedures that guarantee success, thus making such projects risky and expensive. The economy is a complex system that comprises social and technological components. The social component may be considered a direct analogue to natural societies, but the technological component's behaviour and evolution is very much different to biology. According to our research there is only a 12% similarity in approaching challenges in biology and engineering, and some trends for the direction of evolution processes in technology and biology are even opposite. So, inspiration from biology at present is an irresponsible strategy, because there is no single proof that biological mechanisms being literally applied to the economy will not cause new economic disasters. Moreover, there are plenty of strategies in biological systems that are not acceptable for application in contemporary human society due to cultural, moral, economical and other reasons.

Our book is a step forward in creating the possibility of using natural solutions without the risk of failure. It presents a methodology and even a mathematical method that allows the transfer of relevant biological laws and regularities into management. We question some of the common scientific prejudices and pre-assumptions about living systems which consequently opens a great range of possibilities for novel solutions in business and management.

We have derived the laws of the formation of natural social systems through 20 years of studying the behaviour of individual ants of six different species in their natural environment (see Chapter 4 for details). As a result, we have developed and tested experimentally a model of organisation where a single person has the power to affect group behaviour. Nearly all our data on ant behaviour presented in this book is published in journal papers and conference proceedings. But scientific papers do not allow us to share our emotional experience while studying ants as individuals. In a book we can tell stories that cannot be told in "scientific" publications but which are valuable for understanding the nature of ants. Ants learn during their whole lives; they communicate with each other, sharing their experiences and maintaining the coherence of the colony by some "miracle". And you are about to discover that "miracle".

Ants are clever little creatures with their own personal attitudes; the decisions made by a single ant can change the management style of a colony and even speed up their social evolution. Yes, you will be surprised that we managed to speed up the social evolution of one of the ant species so that they showed us in two weeks' time a process which might take millions of years through "natural selection's work"! This means that it is not necessary to spend millions of years in random trial and error to introduce change in the evolution of sociality in living nature. We certainly would never spend such a long time to introduce changes in our organisations! One clever solution allows skipping long processes of evolution on the way to success. This is exactly what we would like to learn from living Nature.

A fundamental equation that drives self-organisation in all living systems, including human societies - the most important of our discovery, is presented in this book. This equation estimates the degree of cohesion of any social group and allows prediction of its further development. Also the fundamental equation allows calculating so called system (or emergent) effects of the group. In other words we now can tell how much a whole is greater than the sum of its parts. As a result of our work we discovered the hidden mechanism which rules two universal phenomena of Life – the fractal representation of structures on different scales (we see similar branching in tree crowns as we see in roots, veins on leaves,

etc.) and the golden ratio, which is even called 'God's number' because one can find it in nearly every biological form. The fundamental equation of self-organisation *explains the very mechanism of the origin of fractals* and golden ratio phenomena in Life.

This book is the further development of work that we started 25 years ago and that was published in Russia in 1998 in the book "Social Synergetics". Working in the field of biomimetics at the University of Bath (UK), we have advanced our approach and created a much more elaborate model, making it easier for practical use in human management. This book is the first study to develop methodology for Social Biomimetics in order to make ideas from biology safely applicable for organisational management.

We hope that our ideas will be useful for the many people who are also interested in socio-biology, complexity theory and self-organisation.

Self-Organisation and Self-Management

"The universe begins to look more like a great thought than like a great machine"

James Jeans, astronomer

Here you will learn that:

- Manipulation of the environment as a pinnacle of adaptation.
- Sociality is a "simple" psychological phenomenon rather than a complex physical one.
- Management is the arena for social evolution.
- It is not the strongest or fittest of the species that survives in social evolution, but the most intelligent that survives. It is the one that is the cleverest creates the most adaptive social systems.

What is biomimetic management?

In this book we ask if we can find answers to the problems of human management in the social organisation of animals, in particular in an ant colony. This means that we will discuss biomimetic management. Biomimetics (bionics), a relatively young strategy in engineering, is about mimicking natural principles of action in technology. Biomimetics is not simply copying nature – it involves extracting laws and patterns from nature under conditions specific to the system and then, by analogy, applying these regularities to construct a new system[1]. Our book is the first scientific attempt to apply a biomimetic approach to social groups' behaviour. To make biomimetics applicable to sociology and management we need to define the "building blocks" of social construction together with a general guide and set of instructions: a "what to do if…" or "what not to do if…" Of course, the building blocks of human organisations are different from the ones which ants use, but socio-biology can give us an idea of where to look for the appropriate "blocks" and the rules of manipulation of such "blocks" in the most relevant and efficient way.

Nature is the best source of ideas for how to avoid failure and to survive, as the mechanisms have been tested by millions of years of the existence of Life on our planet. Biological systems are robust to perturbations in their environment and embody innovative solutions to problems, but their behaviour is not predictable from simple inspection. Management is a more general phenomenon than we used to think and is very common in nature. Living nature is especially adept at preventing conflict and it is likely to teach us some valuable lessons. Ant societies are simpler than ours: therefore it is easier to observe the archetypes of management mechanisms. It is always helpful to see the roots of a process which we are dealing with as this may give clues to solving our challenges. This book is about the search for these roots. We hope that ants can enrich our knowledge of natural ways of making complex systems adaptable and sustainable and therefore help us to solve burning questions in management and organisational behaviour.

So, the questions to be answered by living nature in this book are:

1. What allows natural management to make groups practically immortal? In our book we show how an ant colony can change its management style to adapt to extreme growth or harsh environmental changes.

2. How does a society sense its cohesion or instability, and regulate

(1) Vincent J, Bogatyreva O., Bogatyrev N, Bowyer A, Pahl A, 2006

Top-Down, Bottom-Up or Up-side Down

We praise attempts that have been made,
We call ourselves amazing,
While Occam, brandishing his blade,
Runs after us a-chasing.

Victor Fet

Methodology and methods

In this chapter you will learn:

- How the complexity of Life can be simplified and applied to modern engineering and management.
- Which is cleverer: the system we are in or us?
- Why the super-organism concept of the description of social life does not work.
- Why intention prior to action is needed.
- How to think globally and act locally.
- How to achieve predictable adaptability in management.

Understanding natural laws is a challenge for a scientist, especially if the aim is to implement these laws as rules in design and management. Biological systems are robust to perturbations in their environment, they learn innovative solutions to problems, and their global structures and behaviours are not predictable from simple inspection. The prototypes offered by nature are self-organised, self-dependent, self-adapted and self-regulating. To understand this idea of 'self-', we first need to understand its meaning in Life. There are many different ideas as to this meaning: a summary of opinions lists at least five features of such a self-functioning: system should be open to information, far from equilibrium (dissipative), sustainable, adaptable, and free to choose its own future.

There are at least four paradoxes that arise from the above definition of self-functioning. Firstly, the greater the freedom in a system, the more order the system has. The second paradox is that a system will compensate for change by attempting to incorporate the change into itself and hence return to the state it was in before – Chatelier's principle , or "Equilibrium Law": when a system in equilibrium is disturbed the system adjusts itself in such a way that the effect of the change will be nullified. If this is the case, how does a system ever evolve? This leads us to the third question, which is how can we recognise the identity of a system if that system is open to change? Finally, the fourth paradox concerns learning new information. We are able to find new information only if we know that it is there for us to discover. What a system is able to recognise is limited by its past and current situation, so how is a system ever able to find new information that lies outside these boundaries? This means that the direct application of physical complexity theory to living nature encounters methodological and even pure practical obstacles. Idea of "self"-action is not very popular in science that explores inanimate nature. Let's clarify why this is so.

There are two main concepts to describe the complexity of Life[13]:

- Top-down: hierarchical control – deterministic approach.
- Bottom-up: stochastic approach.

There are five fundamental principles distinguishing bottom-up and top-down intelligence concepts (table 1, Fig. 1):

(13) Johnson, 2001; Bonabeau & Thiraulaz, 2000

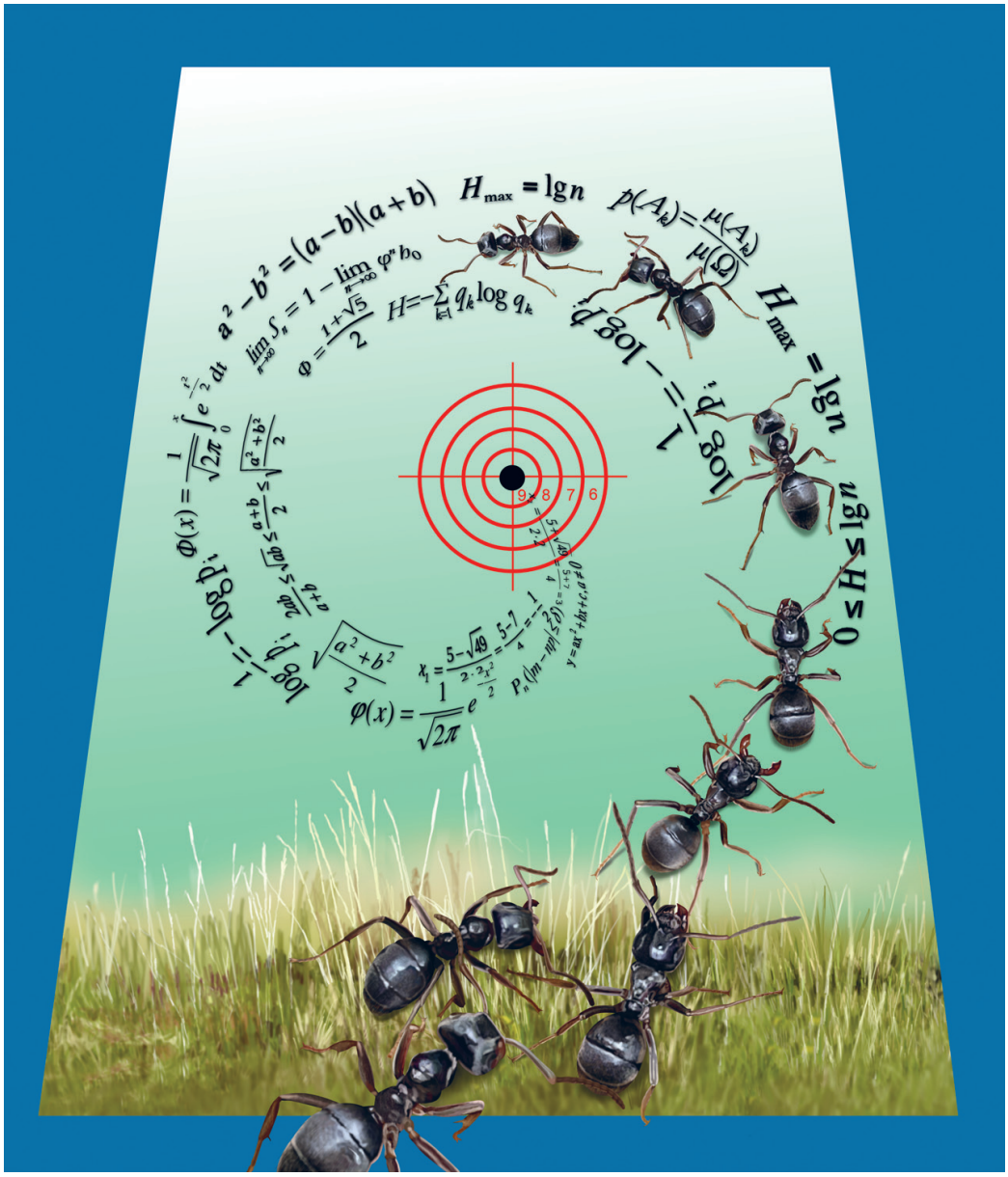
CHAPTER 2

Social Attractors, Hierarchies and Fractals

All animals are created equal,

but some are more equal than others

George Orwell - Animal Farm



In this chapter you will learn:

- How to judge the quality of a team by measuring quantity in the behaviour of individuals.
- How to deal with surplus information.
- How to calculate emergent effects.
- How dynamic fractals describe social behaviour.
- How many possible directions there are in our social evolution.
- How to describe, predict and manage adaptability and stability of a group.

In case you are not very interested in mathematics you may skip this chapter and read only the conclusion - this will not affect your understanding of the following chapters.

Concepts of chaos and order are at the centre of complexity theory, which deals with the behaviour of non-linear systems. There is no doubt that order (when everything is predictable and definite) is easily described using a deterministic approach, but it is difficult to apply this approach to the description of chaos in living systems in the same way that we would apply it to the description of chaos in physics. We mentioned in the previous chapter that there is a subjective origin to uncertainty and probability in physics which deals with inanimate physical reality, which means that with perfect knowledge of the initial conditions and of the relevant equations describing the chaotic system's behaviour, one can theoretically make perfectly accurate predictions about the future of a system. If something unexpected happens it is *a priori* regarded as the consequence of some cause which we have not noticed or do not know yet. So, in practice such predictions are impossible to do with arbitrary accuracy due to emergent effects - the intrinsic feature of complexity. In dealing with inanimate physical systems, knowledge of such emergent effects can be obtained to enable precise predictions: we all know for sure that frozen water (ice) possesses properties that emerge due to low temperature and which the water did not have before - it gets lighter, becomes solid and increases its volume.

Probability in living systems is not only affected by the lack of knowledge of the observer, but also by deliberate decision making of organisms that often do what they like but not what they "should do" according to our "scientific prediction". In inanimate nature, chaos and order are described within the same deterministic concept and there is no contradiction between the methods that they require for mathematical modelling. In spite of the fact that chaos in living systems has an objectively probabilistic (the object of an investigation makes a decision deliberately as it wants and chaos and uncertainty is not related to the lack of our knowledge.) rather than deterministic origin: what we perceive as chaos and uncertainty is simply lack of our knowledge. In this chapter we will attempt to adapt the methods from physics and information theory to make them suitable for describing the specific features of chaos in Life.

Chaos and probability in living systems has mostly an objective origin: living creatures can unexpectedly change their mind and

CHAPTER 3

ANTropology

Do Ants Have Bureaucracy?

Ants are able not only for simple perception,
but also have mind, consciousness and memory.

Cicero

In this chapter you will learn that:

- Ants are creative individuals with diverse qualities and behaviour.
- Ants have weekends off, work in teams, teams have leaders.
- A leader activates, but does not suppress. Ant leaders are not professionally effective but socially active.
- Social evolution may happen in two weeks time without natural selection
- Ants can manage social and ecological crises.
- Ants can change management style in a colony when they need this.

In this chapter we will describe some of the answers provided by living nature, which we have discovered by studying management in ant colonies. We will also show how these answers could be used to solve the most pressing issues of human management listed in the next chapter. Our mission began a long time ago (the empirical data for this book were obtained from 1976 to 1998 in Kazakhstan, Tuva and Western Siberia) when we decided to look at the internal workings of an ant colony from the point of view of an individual ant. Just as Linda Gratton, Professor of Organisational Behaviour at the London Business School, recently studied how business strategy is developed through people[47], we wanted to find out how colony management is developed through ants[48]. We wondered if each individual contribution to the history of the colony is as vital for ants as it sometimes can be for humans. Do expressions such as "society is ready for change" mean anything to ants? How do individual ants perceive these changes and participate in them? At this time in Russia we were well versed in Marxist concepts of social revolutions and were curious as to whether revolution is possible amongst ants. If revolution was not an option, we wanted to discover how ants could be provoked into revealing the secrets of the way they manage their social life – a social life which seemed to be organised without the disasters so familiar to Russians.

It appears as though evolution is as disastrous for living creatures as revolution, but over a different time scale. Natural selection causes a lot of deaths, which supposedly aid the prosperity of the species. In the life sciences, a commonly held point of view is that death drives evolution towards adaptation of species. All creatures try to avoid death. Individual and group deaths are not necessarily interconnected. The group can die or 'dissolve', but its members are sometimes accepted by other related groups (adoption of children is very common amongst social animals, although adults are rarely afforded the same treatment), or can create a new group. For example, one way to form a new ant colony is by splitting, known in ethology as sociotomy or social fragmentation. This process is very common amongst bees, ants and termites: workers, soldiers and nymphs (amongst termites) migrate or march to a new

(47) Gratton, 2004
(48) Bogatyreva, 1981

Chapter 4.

Lessons From Ants For Management Theory

"I look at an ant and I see myself"

Native South African proverb

In this chapter you will learn:

- Organisations are built on a shared goal (social attractor) that emerges from the bottom-up and survives by top-down manner.
- Management can be measured on a scale. This allows global manipulation instead of local control
- Chaos happens because of poor management.
- Social evolution is driven by interactions of individuals and diversity of their intentions.
- Leadership, not suppression (as ants practise it), provides adaptability of a group. Periodic Table of human management puts numerous existing theories of management in one logic framework.

In the previous chapters we tried to rehabilitate the role of intentions and action in a global context in biology – despite the opposite paradigm currently being in favour. We used to deny intention in Life, due to the complexity it demanded of our understanding of natural laws. With this concept we became overloaded with information that was all equally important for us. If we had a general picture of the whole process, we could cope with this information overload by choosing different contexts according to our needs and values. We proposed a "System Thinking Cube" model to enable understanding of the general picture. Now we can deal with a reality driven by not only actions and interactions, but also the complex interrelated network of different intentions that create the context for any action. Actions and information do not make sense or exist outside of a context. Context is usually defined intentionally: an interaction happens in regards to she circumstances, which we call context. Individuals do not just randomly bump into each other. Without intention, it is not possible to merge top-down and bottom-up methodological approaches, a process which is absolutely essential. Moving biology into engineering increases the need for the concept of intention in the life sciences.

There is no uncontrolled chaos in Life. If life gets out of control, it is heading for extinction. Why then, do we need to allow chaos in our societies?

To rehabilitate the concept of intention in management theory is a much simpler task than its rehabilitation in biology. The question concerning the role of intention and vision in strategic management is one of great practical importance [78]. We perceive that human organisations undergo successful development due to the efforts of some individual or group consciously intending the occurrence of a particular state and persuading others to aid the realisation of this state[79]. Ralf D. Stacey describes in his book, Managing the Unknowable, how study after study confirms the importance of forming a vision well in advance of acting to ensure success; this means that the organisational intention or deliberate predetermined agreement by company executives must be established before any action is taken.

Managers need some fundamental navigation principles to

(78) Stacey, 1992
(79) Hamel & Prahadal, 1989; Stacey, 1992

The Fundamental Equation For Self-Organisation

Nature is written in mathematical language

Galileo Galilei

Nobody lives completely alone. There are no unsocial forms of Life on Earth. Therefore, management is a basic biological phenomenon, which is very often considered to be a set of local phenomena in different fields of biological science. Human management has deep roots in natural history and it is very tempting to investigate these roots. There is a real need for a general system theory of management. Its absence costs us money, time and sometimes even lives. Such a theory is vital to the understanding of organisational behaviour and the behaviour of different social groups in sociology, as well as product development and marketing in engineering. To predict and therefore prevent future problems, we need to have a global picture of the process we are all involved in. Taking all above into the account, biomimetic management is very much attractive strategy . There are at least ten prejudices about living nature that circulate amongst general public and even in professional biomimetic communities[121]. The origin of such prejudices is understandable – biology used to be for biologists only and knowledge presented in "biological" format is not accessible for non-experts. Moreover, managers share all methodological problems of studying societies with biologists. To provide theoretical and methodological basis for biomimetic management we need to be honest and accept that some of common assumptions are either wrong or can be true or useful only in certain circumstances[122].

1. " Life is always perfect" or "Nature is always wise" – not always true.

Mind the millions of the died-out species in the course of the history of our planet and those, which are dying out now. The whole reason of origin and development of the technology itself (tools, transport, agriculture, medicine, etc.) is to compensate the imperfection of living Nature. And it is not the unique feature of humans, many animals also compensate their weakness by building nests, burrows, shelters, accumulating food for themselves or their off-springs, use various objects as tools. So: "Nobody is perfect!"

2. "Living Nature is energy efficient and uses only the energy it needs. Life optimizes rather than maximizes " – not always true.

(121) Benyus, 1997
(122) Bogatyrev, 2012

fective. Leaders are more teachers, pacemakers and advisers than suppressive bosses.

7. Law of Social Succession: Two counteracting dynamic Golden fractals of order and chaos considered for three main types of interaction (person-person, person-group, group-environment) generate the diversity of system states and therefore strategic management styles. There are only 27 possible destinations in the evolution of any complex living system represented in the "System Thinking Cube" model.

a. There are only five sustainable cells where any organisation feels comfortable and therefore tries to avoid change, while all other 22 cells require effort from the leader to maintain coherence and the productive functioning of the company.

b. In each cell, the organisation needs to have a specific approach to product design and manufacturing, marketing and advertising strategies (each cell targets a specific customer type), product or service pricing strategies and last but not least – an exact style of personnel and operational management (each cell requires a specific leadership style and distribution of tasks between personnel and departments, management of manufacturing processes, etc).

c. Living systems give us a receipt for immortal existence – choosing the right strategy for a position in a company for each cell guides the evolution of the organisation towards sustainable success – those five cells of the "Cross of happiness" (Fig. 19).

d. Keep a balance between task distribution, control style and resource availability to position a system within a sustainable cell of the "System Thinking Cube". Feed first then give freedom. If not – the system will end in autocracy. In our book we used a lot of mathematical equations. Now we would like to express them in more "human" language. These equations describe functional relationships between the categories which are very popular in management:

$$individual\ freedom = \frac{(personal\ interests) \times (probability\ of\ action)}{\sum[(others'\ interests) \times (probability\ of\ interactions)]}$$

$$individual\ input = \frac{(personal\ willpower) \times (probability\ of\ action)}{\sum[(others'\ willpower) \times (probability\ of\ interactions)]}$$

– The fundamental equation for self-organisation –

$$leadership = \frac{(personal\ willpower)}{\sum(others'\ willpower)}$$

$$competition = \frac{\sum(inividual\ freedom) \times \log(individual\ freedom)}{\log(group\ size)}$$

$$cooperation = \frac{\sum(individual\ input) \times \log(individual\ input)}{\log(group\ size)}$$