SERGEI KAPITSA

PARADOXES OF GROWTH

GLAGOSLAV SCHOLARS

WORLD POPULATION AND THE GLOBAL DEMOGRAPHIC TRANSITION

In memory of Andrei Kapitsa

SERGEI KAPITSA

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LAWS OF GLOBAL DEVELOPMENT OF HUMANITY

GLAGOSLAV SCHOLARS

PARADOXES OF GROWTH

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CONTENTS

A Note from the Author

The very first time you meet someone you are always interested to know how old they are, and depending on who you see before you—a little boy, a young woman, a venerable elder—your attitude toward each of them will be different. Thereafter, you might be interested in the composition of the person's family, how many brothers and sisters your interlocutor has. When you travel to a different city or country, you will want to find out what the population there is like. Now, if our planet were to be visited by an alien, his first question upon encountering us would undoubtedly be: how many people are there here and how long have they been living here? This book is dedicated specifically to this eternal cycle of questions.

We will search for the answers to them with the help of a quantitative and complex study of the history and the foreseeable future of humanity. For this purpose the author drew on the facts presented by demographics, in which the object of research is the quantity of the population of the countries of the world. Contained within information about the number of people on Earth are the results of the social, economic and cultural undertakings of history, which opens up the opportunity for a collective analysis of humanity's history. When we analyze this problem, all of humanity is viewed as a single object, as one developing system. The model of growth itself is based on the methods and images of physics and refers to mathematics for a description of data from the past. However, the connection between the growth of the world's population and the duration of development cannot be grasped without taking into account the relativity of historical time—when one's own scale of time in history is compressed by tens of thousands of times as a result of this development.

In light of this acceleration of growth, the sources of the global demographic revolutions that all of humanity is currently experiencing

become more understandable. A critical transition from explosive growth to constant quantity is tied to contemporary and critical issues about the lives of the people: the falling birth rate and global safety, the systemic and financial crisis and changes to the model of development itself during the transition to societal knowledge.

The modern era is marked by a change in our history, a demographic revolution, and calls for a new level of generalization and synthesis. It is therefore of interest to appeal to scientific concepts which presumptuously describe themselves as exact and quantitative, despite the fact that during the study of the growth of humanity throughout history, details about development in space and time are inevitably lost, and the picture of past events only provides a rough description of the past. With such a logical, quantitative approach to the description of history, difficulties in marrying it to the traditions of social sciences naturally arise. However, the author hopes that this experience of an interdisciplinary understanding of history will prove to be useful and fruitful. In an epoch of sudden shifts, the discussion of issues of global safety presents itself as particularly pertinent.

Physicists have created a weapon that is capable of destroying all of humanity. It is time they and society recognized the consequences of thoughtless arms races as a dead-end path to conflict resolution, the need to assume responsibility for understanding its consequences, and the need to stop.

In the modern world, the global crisis is reflected in the fact that, on all levels, economic power itself doesn't correspond to our social development and management, as can be observed in the way our actions and thoughts diverge. Nevertheless, the author hopes that this book will help with the interaction between the two most important forces, in the shape of our mind and our material development, which, for Russia, is particularly pertinent.

Finally, the fully developed approach in this book enables us to analyze the contemporary global systemic crisis, which so suddenly but not unexpectedly befell mankind. There is strong reason to believe that the demographic revolution, during which there is a sharp transition from exploding growth to the stabilization of the population, is the reason for the global crisis of a growing population and economic development.

It is here that the true source of the crisis and the urgent worldwide changes in our epoch can be found. In our country M.S. Gorbachev was called upon to solve these problems. His response to the challenge of the time was a call to engage in a "*new way of thinking*" in an epoch of rapid changes, changes over which those who had initiated them had already lost their power.

The author's interest in this range of problems arose during his participation in the Pugwash Conferences on Science and World Affairs and in discussions about the dangers of nuclear war, and later in the work of the Club of Rome, when the importance of research into global problems was acknowledged with particular clarity. It soon became clear that the dynamic of the Earth's population growth provided the key to these things.

However, the development of this field of study was not immediately understood or accepted. A first article, *Phenomenological Theory of the Population Growth of Earth*, was published in the magazine *Progress of Physical Sciences* (v. 106, #1, 1996), and an explanation of the conclusions it contained was given in the last article, *To the Theory of the Growth of Population of Earth* (UFN (Uspekhi Fizicheskikh Nauk), v. 180, #12, 2010). Details of these conclusions, **data about** anthropology and history and bibliographical references can also be found in published works and the report which was presented to the Club of Rome and published in 2007 [3].

The book is addressed to all who are interested in this problem but aren't experts; hence it has been adapted so that it can be understood by readers from various professional backgrounds. The book consists of three parts. In the first part, the concept of the model is examined and an account of the basic results of mathematical simulation, which led to the theory of the growth of the world's population, is given. In the description of this model, anthropological and historical views and data are touched upon, to the extent that the quantitative information required in order to construct the theory itself and provide a basis for it is contained within them.

The second part is dedicated to an interpretation of the development and history of humanity, and later the author turns to the present and to the future that may be in store for us. This discussion of global problems

does not lay claim to fullness of analysis. Its goal is to show the possibilities opened by a collective analysis of world history, based on an examination of the population of Earth as a single system. This is the central thesis of the entire concept developed by the author.

In the third part, the collective theory of the growth of humanity and all the calculations required for it are set out. This part can be omitted during a first reading. For the sake of fullness and persuasiveness during the recounting of interdisciplinary problems, the author took the liberty of repeating the essential ideas and conclusions.

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In Search of a Model for the Growth of Humanity

Introduction

This study is based on a quantitative description of humanity as a dynamic system. Its growth and development are bound to the interaction that grips all people: coming into existence with the appearance of man, with the gift of consciousness. It is no wonder that Aristotle's (384–322 BC) major work *Metaphysics* begins with the assertion that "All men by their nature strive for knowledge."

It is specifically our developed conscience, language, and culture that make us fundamentally different from other mammals, which is why there are a hundred thousand times more of us than there are animals commensurate to us. In essence, this particular study of the growth of humanity as a global problem is dedicated to this question.

Work on this issue led to the proposal of a quantitative model of growth and development [1, 2, 3]. It was not very clear, however, why this model, the mathematical means of which are so very simple, not to say elementary, turned out to be so substantial and effective. Therefore, not only is the model of human population growth presented in this article, but it also shows how the results are supported by views of anthropology and history, and how they compare to the conclusions presented by economics and an analysis of the stability of development. Thus the presentation is dedicated not so much to the conclusions of the fundamental mathematical equations as to a clarification of the circumstances of their adherence to the reality and views of the other sciences, primarily the social ones.

Thomas Malthus[1] was the first to address this cycle of questions. Despite the fact that he studied in the theological department of the University of Cambridge, he had a strong knowledge of mathematics. During my visit to his memorial office at Jesus College, I noticed the role that the writings of Leonhard Euler[2] had played. This great mathematician developed mathematical analysis in such a way that we recognize it even now as a reliable tool for physicists and engineers. Malthus mastered it fully—it was no accident that he came ninth in the University Mathematical Olympiad in 1783. I was of the hope, therefore, that contemporary social scientists would also be able to master mathematics at the level demonstrated by the author of the first model of population growth.

Malthus' approach and worldview is directly related to the development of classical mechanics in the eighteenth century, and served as a response to the mechanical Newtonian methodology and the views of the epoch of the Enlightenment. He was influenced by the views of the Physiocrats, who maintained that agriculture and the production of produce define the development of society. Malthus' own proposal, to the effect that the exponential growth of the population is limited by resources, defined all the subsequent development of similar studies for a long time to come.

The last reference to such an approach was the first presentation to the Club of Rome[3] of *The Limits of Growth* [4]. In 1972, following the ideas of the American scientist Jay Forrester[4] about the mathematical modeling of complex systems, the authors of this presentation, under the leadership of Dennis Meadows[5], having analyzed a broad database, attempted to describe the current development of humanity. The basis of the lecture was a simulation of the global process of growth as the sum of its component parts. Thus attention was drawn to these global problems,

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[1] English priest and scientist, demographer and economist.

[2] Swedish, German, and Russian mathematician and mechanic

[3] The global 'think tank' that deals with a variety of international political issues

[4] Known as the founder of the System Dynamics, which deals with the simulation of interactions between objects in dynamic systems

[5] A former director of the Institute for Policy and Social Science Research at the University of New Hampshire

which represents a great achievement by the authors of the first lecture to the Club of Rome. However, the results, based upon a reductionist policy in adding up the factors of growth, revealed all the limitations of linear models and, consequently, of the concept of resource limitation of human population growth.

In this respect, the remarks of the American economist, Nobel Prize laureate Herbert Simon, are of particular interest:

> Forty years of experience modeling complex systems on computers, which with each passing year were becoming larger and faster, taught us that brute force would not lead us along a royal path to an understanding of such systems... Thus, modeling will demand reliance on fundamental principles, which will lead us to a solution to this paradox of such complexity.

The current work is a response to this challenge. Indeed, an integrated description of humanity leads us to the conclusion that social processes of development are directly related to the growth of the population. However, this is a non-linear connection, in which there is no simple cause and effect of growth and development. Therefore, such an approach is possible only if we examine the whole of humanity as an interconnected whole.

In this view of things, the position of the majority of prominent modern historians, such as Fernand Braudel, Karl Jaspers, Immanuel Wallerstein, Igor Diakonoff, and Nikolai Conrad, who affirmed that a true understanding of human development is possible only on a global level, is important. To a large extent, they developed a holistic view of global history, which became an essential premise for studies of this kind, in which the development of mankind was examined from the very beginning.

It's no wonder that the Academician Conrad wrote in his final collection of articles, *East and West* (1972):

> Thus, the knowledge that we have of the past combined with what our modern science opens to us with regard to the past and also the future, allows us to interpret the course of the historical life of humanity and by this means outline a philosophical concept of history. This is only possi-

> ble, however, by paying attention to the history of all of mankind, and not to particular groups of peoples or countries…
>
> *The body of evidence suggesting that human history is the history of all mankind and not of individual nations and countries—and that to understand the process of history one must study the history of humanity—is huge, and is made up of facts from all areas of life. All of history is full of them" [8].*

The German historian and philosopher, Karl Jaspers, in his book *The Meaning and Prescription of History* (1948), begins the first part of *Global History* with these words:

> By the width and depth of change in all human life, our epoch is of decisive significance. Only the history of humanity in its entirety can give us a scale for an understanding of what is going on in modern times[5].

Jaspers gives a detailed argument of the importance of an examination of the history of humanity as a global process, when all humanity as a whole becomes the object of research. He singles out processes of development, which span the entire world. However, historical science has come a long way in its knowledge of the general laws which determine the growth and development of humanity.

It should be noted that this search was not easy, since, just as in demography, the fragmentation of facts and circumstances in the continuously increasing multitude of particulars prevented these attempts from capturing the general patterns. It was no wonder that the distinguished economist Friedrich Hayek noted,

> The division of the study of society into specialized disciplines led to a situation in which all of the most essential questions were neglectfully cast into the margins of an unclear philosophy of the development of society.

The above-mentioned historians' views became the starting points in the approach to the growth of the world's population and the development of humanity as one whole, a developing dynamic system. However, in

demography such a point of view was systematically denied, inasmuch as the task of demographics was viewed as linking population growth with the specific social and economic conditions in an individual country or region and on this basis giving recommendations on demographic policy. It was specifically this that hindered the acceptance of a global and phenomenological approach, and the conclusions that result from it, by demographers, as well as social scientists, who are conceptually bound by the borders of countries and by the traditions of their science.

It should be emphasized that the phenomenological approach is understood by us the way that it is accepted in physics, and not in philosophy. We appeal to the general principals of self-similar development, the causations expressed in statistical representation, and on this foundation we build a theory. We are not therefore referring to so-called elementary occurrences and factors, by summarizing which we can describe the whole. Experience shows that even for systems that are simpler than humanity, such an approach to building an effective model is often practically impossible.

The first and most successful experiment at a phenomenological approach was developed in thermodynamics, when gas was examined as a system made up of many interacting particles. Due to collisions between the molecules found in an isolated system in thermodynamic balance, their condition can change slowly and reversibly. In this case variables such as temperature and pressure can be introduced, determining the thermodynamic condition of the system, and we can also turn our attention to our ideas about energy and entropy, without going into a detailed understanding of the properties of the atoms or molecules of which gases are composed.

In the future, when studying the development processes of complex systems—open systems, far from equilibrium, in which irreversible processes of evolution and growth occur—it turns out that the phenomenological approach opens a path to understanding such systems on a new basis. Even for a system as complex as humanity, it enables us to describe the processes of growth and development of the Earth's population.

Only by attaining a global level of analysis and broadening the scale of the problem to examine the entire population of the world as a single

entity, as an interconnected system, was it possible to describe the development of humanity as a whole. Furthermore, such a generalized understanding of history turned out to be not just possible, but also very effective. Not only can our past, including the most distant events, be described from this standpoint, but the global demographic transition we are currently experiencing can as well, and on this basis, one can propose a picture of our development in the foreseeable future. To this end, the method of research and point of view in both space and time had to be radically altered, and humanity had to be studied from its very beginnings, as a global structure.

> ***"Only by looking at the entire population of the world as a single coherent system was it possible to describe the development of humanity as a whole."***

In this case, we should not look for the reason for growth in the sum of all the relevant factors, but in the collective interaction that envelopes all of humanity and determines its development. Furthermore, it became clear that the development of this dynamic system is not only non-linear and irreversible, but is also far from equilibrium, and that a demographic revolution is currently taking place. It is a phased transition into a new condition, in a physical sense specifically. Throughout history, humanity has never before experienced such a profound reconstruction of the system, and that is what makes our era so unique.

It should be noted that this approach has not been easily accepted. It was not for nothing that the great mathematician and physicist, the academician Ludvig Faddeev, discussing the author's paper at the Presidium of the RAS, astutely pointed out that every generation is usually convinced that it is exceptional. For that very reason he drew attention to the need for consistent affirmation of the conclusion drawn. This is indeed the author's objective, to a large extent. This is why we are going to draw on a phenomenological, holistic description of growth, and examine humanity as a single, highly-intertwined system, in which there is a control mechanism that governs development, and in this way we will understand what is happening. The understanding gained can then become the basis of our solutions and actions.

"Humanity has never before experienced reconstruction through a path of transition into a new condition."

The emergence of the system that we call humanity is the result of its *self-organization and evolution*, which led to its emergence as a qualitatively new object, separating it from the rest of the living world. This is why we refer to methods, using collective interactions for a description of causal relationships in the evolution of complex systems. By complex systems we mean systems, the development of which depends on the number of relationships between all the people on Earth. Then the extent of the complexity of the system is not determined by the total number of people, but in the first approximation of the quantity of the world's population squared. This is expressed by the nonlinearity of the process of growth and the impossibility of referring to simple cause-effect connections between growth and development.

"The passage of time in history is irregular and is dependent on the process of growth itself."

Furthermore, it transpires that the passage of time in history is irregular and depends on the process of growth itself. The compression of historical time strongly intensifies the rate of growth and adds a special significance to everything that is happening in our era of demographic revolution.

Thus, when interpreting the phenomenological theory of the growth of our planet's population, it is necessary to refer to ideas about the physics of non-linear occurrences and unbalanced processes, developed in the sciences of the 20th century, and right from the outset discard the additive and linear approach. It is important to note that a similar theory, hypothetically, must operate using statistic distributions for variables. But in the first instance, the author confined himself to a simplification, in which their average and effective values are input.

Referring to the idea of the complexity and interconnection of the system with which we describe the development of humanity, we pursued the goal of clarifying the meaning of the conclusions reached and identifying the limits of the extent to which they apply. As a result, we are following an approach developed in theoretical physics; this allows us to

base our conclusions and effective theory on phenomenology, as opposed to the reductionism presented by additive linear models. Moreover, the basis of the theory takes human consciousness as the primary factor that determines the growth and development of humanity.

Let us return to the question of the human population in comparison with all other animals. The most important point is the fact that there are a hundred thousand times more of us than animals that are comparable to us based on diet and weight, such as wolves or bears at our latitude, or large monkeys in tropical countries (Figure 1). This essential fact demands an explanation. After all, these animals were regarded as our distant ancestors in the mythological consciousness of primeval people. However, between us and them there are no intermediate forms, which might in simple terms explain the creation and evolution of man; as if man falls outside the animal world. Ideas such as this serve to guide those who still insistently propose non-evolutionary paths for the emergence of intelligent man.

Biologically and by evolution man is very close to the animal kingdom. Nevertheless, there are no animals comparable to man either biologically or nutritionally; animal populations exist in a limited natural habitat, and the number of different species is determined by the dynamic equilibrium with the surrounding environment, which never developed as swiftly as that of man.

> ***"It is our developed consciousness, language and culture that make us different from animals, and that is why there are a hundred thousand times more of us than there are animals comparable to us."***

The growth of our population is extremely unusual and is happening right before our eyes: 75 years ago I was taught at school that there were two billion people on Earth; at present there are almost seven billion of us. This singles us out amidst the entire animal world and makes our species, the growth of its populatio and its development, so distinctive. Furthermore, people living in the Neolithic Period, 10,000 years ago, surrounded themselves with domesticated animals, which also multiplied in quantities far surpassing their wild counterparts in headcount. Thus, the number of cattle in the world stands at more than two billion, and

their emissions of gasses that affect the climate, such as methane and carbon dioxide, into the atmosphere are comparable in scale to emissions from human industrial activity. The aforementioned circumstances must be taken into account when we address the general problems of growth and the development of mankind.

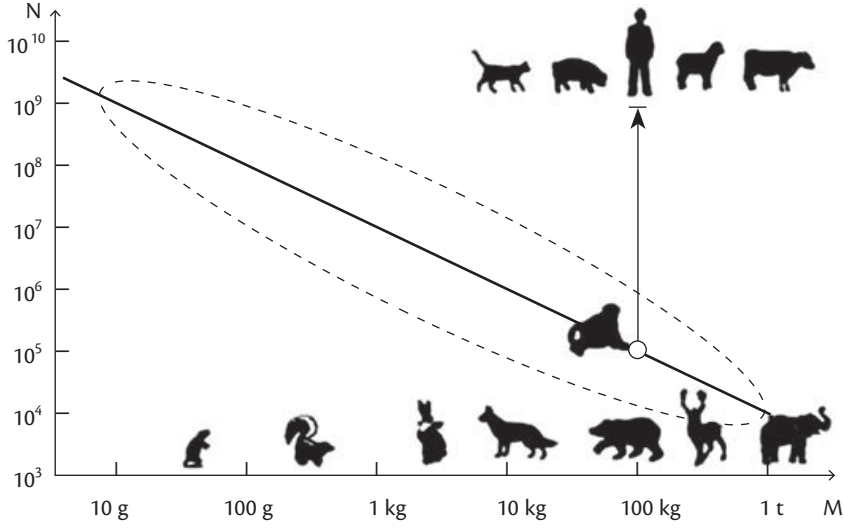
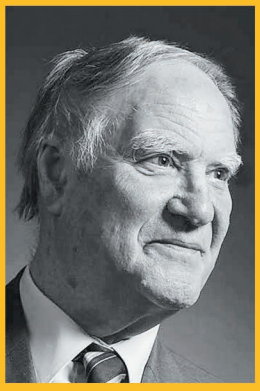


Figure 1. The numbers of various species of animal on Earth in relation to their mass

At the same time man represents one species – *Homo sapiens*—the intelligent human, with one uniform number of chromosomes, enabling people from different races to interbreed. But specifically in terms of intelligence, man differs from the entire animal kingdom, and it is because of his developed mind and language that mankind's population has grown so rapidly.

In order to present the various stages of growth and development over time, it would be useful to analyze this growth on different scales, regarding them as a *magnifying glass of time* (Figures table 2, 5, 7, 8, 9, 18 and Table 1).



Sergei Kapitsa was an outstanding Soviet and Russian scientist, professor and TV presenter. During his lifetime he was responsible for 14 inventions and 1 discovery and wrote hundreds of books and articles which were published in many languages around the world. He conducted scientific research and worked in numerous fields of science (aerodynamics, magnetism, applied electrodynamics, nuclear physics, the history of science and demographics, to name but a few). Professor Kapitsa was one of the founding fathers phenomenological mathematical model of hyperbolic growth of the world population and the global demographic transition.

The book *Paradoxes of Growth* addresses the vital problems of a global demographic revolution, when humanity moves into a period of limited reproduction. The answer to the questions of why this happens, and what the consequences of it might be, affects not only the distant future, but also our approach to solving the problems of modernity, and in particular our analysis of the causes and results of the global crisis.

In his book, Sergei Kapitsa examines the concept of the model and the main results of the mathematical modelling which led to the theory of growth of the world's population, and offers an interpretation of history and of the development of humanity, the present and the future that likely awaits us. The discussion of global issues is not intended to be a comprehensive analysis; rather, it serves to reveal the opportunities offered by a quantitative analysis of the history of the world. The concept developed by Kapitsa concerns human civilization as a whole and may provide certain forecasts for communities – in the broadest sense of the world – and nations, as well.

In this book, the famous Russian scientist, Sergei Kapitsa, explains complicated theories in an uncomplicated manner that is easily accessible to readers with no specialist knowledge.

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