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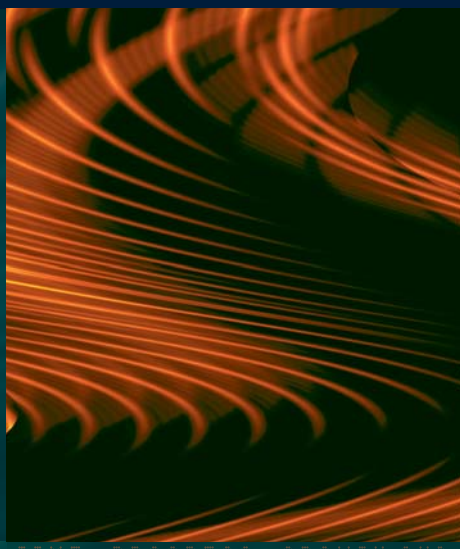

Filipe Duarte Santos

TIME, PROGRESS, GROWTH AND TECHNOLOGY

How Humans and the Earth are Responding

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Time, Progress, Growth and Technology

How Humans and the Earth are Responding

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Filipe Duarte Santos
Department of Physics
CCIAM-cE3c. Faculdade de Ciências da
Universidade de Lisboa
Lisbon, Portugal

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To Regina Branco and António Duarte

Preface

The guiding thread of this book is time and how *Homo sapiens* has been dealing with it during his journey. Time is present in all human actions, experiences, emotions, and expectations. We do our utmost to keep it as long as possible so that we can continue to enjoy living. Various concepts of time have emerged in the course of history that continue to be developed, showing their inexhaustible potential creativity. Our relation with time has been deeply changed by modernity and we now live under the constant pressure of time acceleration. There is an irresistible need to fill up time completely and permanently with everything planned and needed for self-interest and everything possible or enjoyable, as if we were afraid to face it alone. Concurrently, future time has become increasingly dominant, menacing, and uncertain.

The main aim of the book is to try to understand how the "new time" emerged by identifying the main concepts, ideas, hopes, processes, and systems that throughout history have shaped the present world with all its diversity and human achievements, challenges, problems, and crises. The underlying motivation is to understand the current global civilization essentially with the tools offered by science and to explore the possibility that this exercise may also shed light on the future.

Homo sapiens is the only surviving species of the genus *Homo* that emerged in Africa around 2.6 million years BP at a time of a global climate change that transformed a large part of the African tropical forests into savannahs. Natural selection in the new environment led to a strong encephalization that enabled the development of increasingly complex social behaviour and eventually to the development of symbolic thought, the capacity for spoken language and symbolic representation. The biological evolutionary process leading to the new species was completed between 300 000 and 200 000 years BP. After that time *Homo sapiens* underwent an extraordinary cultural evolution.

The Agricultural Revolution was the first major advance in that evolution and occurred very recently relative to the beginning of human time, just 10 000 years BP. It deeply transformed our relation with nature through the domestication of plants and animals. It also contributed to the development of new technologies and to increased social stratification, bringing about large scale violent conflicts and

wars, densely populated cities, a much more diversified list of goods and services, consumer excesses, and a remarkable development and diversification in the visual arts, literature, and architecture. However, energy consumption growth and economic growth continued to be small, almost non-existent during the next 97.5 centuries. That situation changed radically just a quarter of a millennium ago during the Industrial Revolution, with the beginning of the high-energy-consumption-per-capita era, based on coal and later on oil and natural gas, and the proliferation of technological inventions based on the practical applications of modern science. Almost simultaneously with the invention of an improved steam engine by James Watt, Adam Smith proposed the concept of absolute advantage that played a crucial role in the development of capitalism and the instauration of the strong-economic-growth era. Until the mid-eighteenth century, average global growth in the production of goods and services—what is usually called global GDP— was very small and was driven almost exclusively by demographics and the colonisation of new lands by Europeans. This situation changed drastically with the advances of the Industrial Revolution and the development of capitalism. Economic growth gained pace first in some European countries and then progressively spread to a large part of the world, although with temporary slowdowns during major wars and crises.

Enlightenment and rationalism introduced the ideology that reason aided by the methodology of science guarantees that "the perfectibility of man is absolutely indefinite" (Condorcet 1795) and will lead the whole of humankind to a world of individual freedom, human rights, equality, solidarity, well-being, and material prosperity. There have been many social, economic, and political developments since that time, but we continue to be immersed in a culture that assumes the inevitability of progress, although recognising that there have been and will be periods of decline, deep disappointments, and dramatic intervals.

The French Revolution represented the first major burst of time acceleration but it also established a new relationship between the past and the future characterized by opposing ideas: on one hand human progress and on the other the uncertainty of a future without reference points. The future became more uncertain but in return it became filled with the promise of progress through the use of reason. Trying to unveil the nature and characteristics of our common immediate and middle term future, for each community, each country, and the entire globe is a fundamental and indispensable everyday task for politicians, business people, financiers, economists, stock-market analysts, writers, and political commentators around the world. But although these predictions and projections are all systematically used to construct a supposedly more secure and better future, its uncertainty is increasing.

Technology or "the useful arts", as they were called in the 1787 US Constitution, underwent an accelerated progress from the first quarter of the nineteenth century onwards, which revealed its power to influence and characterize the evolution of societies in Western Europe and North America. The establishment of science as the most powerful driver of technology happened in the second half of the nineteenth century through various inventions based on modern science and in particular with the generation and detection of electromagnetic waves by the German

physicist Heinrich Rudolf Hertz (1857–1894) in 1887, following their theoretical prediction by the Scottish physicist James Clerk Maxwell (1831–1879) in an 1864 paper entitled *A Dynamical Theory of the Electromagnetic Field*, a discovery that revolutionized the way humans communicate. The twentieth century saw the establishment of another very powerful link, this time between technological progress and economic growth through the concept of total factor productivity, considered to be the residual attributable to innovation and technological improvement, which cannot be explained by changes in inputs.

These two links created an oversimplified causal chain between scientific research, technological innovation, and economic growth that erroneously convinced humankind that it had assured the perpetual economic growth needed to guarantee an everlasting and unlimited increase in human well-being and economic prosperity, at least for part of the human population. There is no doubt that science and technology provide the essential support for better human health and living standards, economic prosperity, and increasing availability and diversification of goods and services. However, science and technology constitute a necessary but not sufficient condition for the viability of perpetual improvement. There are other factors on which it depends.

After two devastating world wars in the first half of the twentieth century, the warring countries engaged in a period of reconstruction and development, starting in about 1950, in which the USA assumed the role of leader of the free world in opposition to the communist Soviet Union and its satellite countries. This period, usually called the Great Acceleration, witnessed a remarkable increase in the global population, urbanization, global GDP, land use change, exploitation of natural resources, communications and mobility, scientific research, and technological innovation, and it set the stage for two waves of democracy that went round the world. In the first three decades of the Great Acceleration, known as *Les Trente Glorieuses*, middle class incomes in countries with advanced economies grew strongly, while socioeconomic inequalities were reduced. This growth resulted mostly from extensive industrial development, which created a high number of jobs in the manufacturing, construction, and service sectors for workers with middle level qualifications.

From 1978 onwards, China started to open up its economy to the rest of the world, following the economic reforms introduced by President Deng Xiaoping, and it joined the World Trade Organization in 2001. India and other emerging countries were also integrated into the global economy and began providing goods and services at low prices to consumers in advanced economies, thanks to their cheap workforce. This process of globalization, together with the increase in the price of oil and other commodities, exported by developing countries, increased the speed of economic convergence between the two groups of countries, and it freed hundreds of millions of people from poverty in Asia, Latin America, and certain regions of the Middle East and Africa.

The Great Acceleration also led to the global economic and financial system becoming the prime driver of planetary-scale changes, usually referred to as global changes to the Earth system. Currently, we are observing global anthropogenic

changes in atmospheric composition and circulation, ocean circulation, the climate, the polar regions, the global mean sea level, the water, carbon, nitrogen, and phosphorous cycles, pollution, land use and land cover, biodiversity, and the availability of natural resources, while we continue to produce various kinds of solid and liquid wastes and emissions at a rate at which they cannot be renewed or sequestered. In other words, humankind is overexploiting natural resources, polluting and degrading the environment, reducing biodiversity, and changing the climate at the planetary scale. These unintended but destructive changes, sometimes irreversible, are starting to backfire since they are affecting the well-being and economic prosperity of a large, indeed increasingly large, part of humankind, especially in the developing economies. Humans are intimately interconnected and dependent on the environment, much more than is usually admitted. If we interfere in this dangerous way with the various biogeophysical subsystems that compose the Earth system, we are in fact doing ourselves harm.

The solution to such global anthropogenic interference that one might expect from a rational and ethical point of view would be a progressive change in behaviour and a reform of the economic and financial system so that the relation with the environment, natural resources, and climate could reach a new and lasting equilibrium beneficial to the whole of humankind. The required changes are feasible with the help of the science and technology that is currently available. However, such changes will negatively affect a minority that has powerful vested interests in the current system, interests that are shared with most governments. That minority enjoys extreme economic prosperity and holds a disproportionate power over humankind. On the other hand, the required changes would allow the development of a sustainable model that would benefit the majority of people around the world.

The Earth system is like a large shared home to a group of people with very pronounced social and economic inequalities that consume more than is actually available and renewable, while more are arriving all the time. And the economic and financial system controlled by a powerful minority has succeeded in addicting people to a consumerism that is destroying this common home. In the absence of an effective response, the most easily available narrative takes the form of negating the science that would justify a transformational transition to a sustainable model, and of waging campaigns of disinformation and misinformation aimed at confusing and distracting people from the dangers of the developing situation. In the limit, an erroneous alternative is entertained, which would consist of terraforming Mars at a cost of many hundreds of trillions of dollars.

Attacks on what is considered to be politicized science or science classified by the state as “secret”, to prevent it from being shared by citizens, are proliferating. Furthermore, widespread information noise, misinformation, disinformation, and mass manipulation in the social media is increasing distrust in and scepticism about science, promoting charlatanism, conspiracy theories, and political polarization in democracies. On the other hand, the incapacity of democracies to deliver the increasing well-being and economic prosperity that their political party leaders systematically promise to all citizens is weakening them.

There is a disturbing tendency for democracies to acquire some of the characteristics of oligarchies and for their governments to look more favourably on authoritarian governments, favour mercantilist and protectionist economic policies, dismiss the importance of human rights, and promote nationalist and nativist policies. Moreover, the malfunction and decline of some Western democracies is opening new spaces for the advancement of authoritarian regimes in emerging and developing countries, inspired by China's state capitalism.

All these developments represent a partial regression in some of the remarkable civilizational achievements initiated by the Industrial Revolution, by the worldwide development that occurred subsequently, and in particular by the past 70 years of progress in human cooperation, science, and technology, without any major world war.

What are the origins of the present situation and how is it likely to evolve in the future? What are the main obstacles in the way of reaching some form of sustainability? To what extent do the present and future developments stem from essential features of human nature and what are the chances of somehow circumventing that condition? These are some of the questions that this book tries to answer, using the knowledge and understanding provided by the physical, natural, and social sciences. Science provides an understanding of the physical and natural world in the past and present, and it projects the future by means of scenarios that portray a range of possible future outcomes. It helps to discover and develop technologies that have revolutionised our ways of life. It has extraordinarily improved human health and it is used in association with technology to fabricate a great variety of products and devices with extremely diversified potential uses, such as helping to reach greater economic prosperity, better well-being, and quality of life, while providing ways to produce powerful and destructive weapons and increasingly efficient addictive drugs. Human curiosity continues to be the main driving force of science and the same curiosity can also lead some to use the scientific method to reflect on the future of the human endeavour in the medium and long term and its effects on the Earth system, and to warn that the risks due to unsustainability of the current model are rising dangerously.

The present book pays special attention to the subject of climate change. Anthropogenic climate change is one of the more paradigmatic challenges facing humankind in the twenty-first and following centuries since it is an inadvertent collateral effect of the intensive use of fossil fuels. These have supplied abundant energy since the Industrial Revolution and were essential to build our present modern world. The analysis of the way humankind has reacted to this challenge reveals the inner workings of our relation with the environment and is particularly instructive about how the future is likely to unfold. Throughout the book and wherever appropriate, the specific characteristics and challenges created by climate change are addressed and compared with other issues. Particular attention is paid to the similarities between the present anthropogenic interference with the climate system and natural intensive-flux carbon injections into the atmosphere in the form of CO_2 and CH_4 that occurred in the geological past.

The following paragraphs attempt to guide the reader through the book by explaining the rationale for the sequence of chapters and sections in each chapter. In most cases, the reader can find here a very short description of the contents and main results of each section. This synthesis should help to localize the sections that are more relevant to following the main argument of the book and those that may be of particular interest to the reader.

Chapter 1 is about time, the unifying theme of the book. The first three sections play a central role since they contain the definition of the concepts of operative social time and operative time structure that are used throughout the book. Sections 1.4–1.7 deal with intertemporal choices, meaning those that involve decisions with consequences that have repercussions in the future. These are choices that lead us to feel the challenge of time and its all-embracing power over our plans and expectations and help us become acquainted with the uncertainty of the future. They are frequent and essential choices in everybody's personal life, but also choices that must be made at the individual level to construct collective decisions with implications for the present and future, and regarding institutions and all types of social groups from the local football team to professional groups and political parties, from the local community, to the city, the region, the country, or even the whole of humankind. Sections 1.4 and 1.5 deal with the main concepts of intertemporal choices, while Sects. 1.6 and 1.7 are more technical and address various ways of determining the optimum social discount rate and how they are crucial for intergenerational justice.

Section 1.8 introduces the analysis of the evolution of operational social time and operational time structure and the contribution to this process made by the advances in the measurement of physical time. Section 1.9 also deals with physical time and addresses the way the observation of cyclical phenomena, those defining time cycles, influenced its conceptual development. This relation provides the opportunity to introduce the concept of element of operative social time and in particular the element of operative time corresponding to a human lifetime, which plays a crucial role in our relation to time. Section 1.10 introduces a central notion of the book, namely the operative time of a social generation. Section 1.11 also deals with the deeply challenging meeting point between the ascendancy of time over humans and their essential eusociality. Sections 1.12 and 1.13 deal with multigenerational operative social time and historical time. They also offer a brief overview of our knowledge of ancient civilizations and introduce the idea of accelerated operative social time. Section 1.14 addresses the relevance of the human lifetime as an element of operative time in our horizon of expectancy and explores its implications in terms of time discounting. Section 1.15 discusses the time of the *Homo* genus and also *Homo sapiens* time and different forms of their termination. Sections 1.16–1.18 analyse the first records of human awareness of the solar and lunar cycles registered in European Upper Palaeolithic cave paintings and discuss how the Egyptian and Maya civilizations dealt with time. Sections 1.19–1.23 deal with physical time and how it is conceptually evolving with the theory of relativity and quantum mechanics.

Chapter 2 addresses the question of how humans became conscious of their lifetime as an element of operative time and how they dealt with death throughout historical time. Sections 2.3 and 2.4 analyse the concepts of mortality and amortality in evolutionary biology and the different strategies that living organisms have developed to extend their lifetime. The last two sections return to the subject of human amortality and death, but from a contemporaneous viewpoint.

Chapters 3–5 present a narrative of *Homo sapiens* time that began with our primate ancestors in the Cretaceous, followed their evolution until the emergence of the *Homo* genus and of humans, and continues up to the present time. This narrative claims to identify the main driving forces of our success as a biological species in the Earth system and also the major successes of our cultural evolution. Naturally, not everything has turned out to be a success. There are sustainability shortcomings that stem either from the hardware of our biological heritage or from our cultural evolution during the past 100 centuries. The fact is that in the first quarter of the twenty-first-century humankind contemplates the future with increasing uncertainty and assailed by recurrent crises. The future was always uncertain, but over the past 250 years most people have always entertained a deep hope that progress is inevitable.

The three chapters do not follow a strict chronological order of events. Sections with conceptual discussions on topics that are considered especially relevant were included as appropriate, such as a section on altruism and cooperation at the end of Chap. 3. Chapter 4 deals with some of the fundamental conceptual pillars of modernity up to the contemporary operative social time, including economic growth, the irreplaceable role played by energy in making economic growth viable, and the origins and overpowering development of the digital information age. However, Chap. 4 also has three sections dedicated to the question of time that are relevant to understanding the advances of modernity. Section 4.3 addresses the acceleration of operative social time induced by modernity and Sect. 4.6 describes how humankind started to forecast the future with the help of probability theory and how the concept of risk was born and developed. Section 4.10 describes the various worldviews of human evolution in cyclical or linear time through successive ages provided by different religions. Finally, Sect. 4.11 deals specifically with the breakthrough of imagining a better future for humankind by means of the audacity and radicalism of the first utopias.

Chapter 5 plays a crucial role in the book since it describes the origin and development of the ideology of progress in its various forms of social, economic, political, ethical, and moral progress, as well as the overarching form of human progress. Special attention is given to scientific and technological progress in Sects. 5.8–5.11. Section 5.12 addresses the troubled encounter between the concepts of human economic progress and the environmental crisis and various solutions that have been proposed to relieve the stress. It is complemented by Sect. 5.13, which deals with the violent clash between indigenous environmentalism and economic progress. Sections 5.14–5.16 return to the issues of technological progress, but now applied to the military domain and the development of addictive drugs. Sections 5.17 and 5.18 consider briefly how the long awaited Fourth Industrial Revolution

promotes the human ego and analyses some of its possible consequences. Section 5.19 deals with some of the present difficulties involved in making technological and economic progress compatible with reducing socioeconomic inequalities and preserving Western ethical and political values. The three following sections are centred on the way the writers of dystopian novels at the beginning of the twentieth century imagined what future societies dominated by technology would look like and how these prescient societies conform to what is witnessed nowadays. Finally, Sect. 5.23 is dedicated to ecotopia, a farfetched US utopia.

Chapter 6 attempts to provide a framework for addressing the problems of the contemporary globalized civilization by analysing a variety of human experiences, emotions, conditions, and values, discussing the way they are usually appraised, and how preferences and ratings can evolve in order to "solve" those problems. The analysis is partly based on Amartya Sen's different lifestyles, characterized by the words "opulence" and "utility", and by new ways of flourishing, which were later used by Tim Jackson to define three concepts of prosperity. Sections 6.2–6.4 describe how humankind, through the current economic and financial system, is forced to implicitly, passively, or unwillingly accept and support the extraordinary progress of ultra high-net-worth individuals, the perpetuation and proliferation of tax havens, and increasing wealth inequalities. Section 6.5 delves into the origins of the concepts of individualism and egoism and Sect. 6.6 describes the success of ethical and rational egoism in the twentieth and twenty-first centuries, and the way it is influencing politics in some countries, in particular the USA.

Sections 6.7–6.9 present a contrasting point of view to the preceding sections by proposing different concepts of prosperity, and in particular sustainable prosperity, which privileges social capital and environmental factors, and by revisiting voluntary simplicity. Section 6.10 introduces post-cooperation, or cooperation between the members of the contemporaneous social generation and the members of coming social generations, as a necessary condition to achieve strong sustainability. Such a goal imposes costs on the current social generation in exchange for a benefit that, in most cases, will only be tangible for future generations. A simple model shows that, once sustainability has been reached, the post-cooperation required to maintain it is reduced to a minimum. However, if post-cooperation is not implemented, the sustainability deficit will increase for each future generation as time unfolds. Sections 6.11 and 6.12 describe how science and medicine are doing their utmost to extend human lifespan in good health conditions and to achieve human enhancement, superintelligence, and finally transhumanism.

Chapter 7 uses the physical and natural sciences to address in more detail the impacts of the Great Acceleration on the Earth system and the risks that global changes are imposing on humanity in the twenty-first century. Section 7.2 shows that anthropogenic climate change is rapidly driving the Earth system into a non-analogue state, which should be taken as an ominous sign that humankind should reverse the course of action. Section 7.3 describes the evolving controversy in defining the Anthropocene as a geological epoch. Section 7.4 gives a succinct description of the most important materials that are used in the technosphere and are

essential to maintain vigorous global economic growth, as well as the ways they may become scarce.

Section 7.5 deals with the biosphere and emphasizes that ecological systems are an example of complex dynamical systems. This condition implies that they can undergo critical transitions in which the system shifts abruptly and irreversibly from one stable dynamical regime to another at a critical threshold called a tipping point. Since the Cambrian explosion, the biosphere has undergone five critical transitions known as mass extinction events due to various types of global changes with either internal or external origin. The current pace of anthropogenic biodiversity loss is likely to transform itself into the 6th mass extinction if there is no significant change in our present relationship with the biosphere. If this mass extinction is allowed to proceed, it will take about 10 million years to return to the levels of biodiversity at the beginning of the Holocene. Section 7.6 discusses the various energy fluxes in the Earth system that are critical to humankind and sets the scene for analysing their future sustainability. In particular, it addresses the increase in the human appropriation of net primary productivity and the effect it has on biodiversity, the water and carbon cycles, and the capacity of ecosystems to provide essential services to humans. Section 7.7 displays the evidence for biodiversity loss and shows that healthy ecosystems supply services that underpin all aspects of human life.

Section 7.8 takes a different approach from the preceding sections by exposing the ecomodernist ideology, in which the deep anthropogenic transformation of the biosphere is assumed and promoted. From this point of view, the only solution now is to build an excellent Anthropocene supported by a technobiosphere that is also expected to be excellent. A better technobiosphere would involve direct human interference in the populations, genetic characteristics, and evolution of living organisms that are useful as sources of food and the evolution of other essential commodities, especially through genetic engineering and synthetic biology. Section 7.9 follows a closely related discourse and debates how genetic engineering can assure global food security up to 2100 and beyond. Finally, Sect. 7.10 readdresses the question of the human relationship with the biosphere and the technosphere.

Section 7.11 is dedicated to the question of energy, which plays a central role in the current model of perpetual global economic growth. It considers the energy fluxes, specifically in the technosphere and biosphere, and the concepts of exergy efficiency and energy sufficiency. Section 7.12 provides evidence that the biosphere and the technosphere have very different metabolic mechanisms and capacities. Furthermore, it shows that humankind has been using natural capital faster than the Earth system is able to renew it. The role of the circular economy, which tries to answer that challenge, is analysed.

Section 7.13 addresses one of the critical points of the present book. It starts by revisiting the conceptual debate about perpetual economic growth and moves on to the relationship between growth and debt. It then considers the likely possibility that current overexploitation of natural resources, environmental degradation, and climate change is already giving signs that perpetual economic growth will not be possible. It also presents some possible responses such as the circular economy,

green growth, the dematerialisation of the economy, and the decoupling of economic growth from the use of energy and natural resources. It revisits the up-to-dateness of ideas, analysis, and recommendations put forward by the Club of Rome and ends by illustrating the regenerative capacity of the biosphere.

Sections 7.14–7.16 discuss three of the currently most important secondary global processes with strong social, economic, financial, political, cultural, and environmental impacts, namely globalisation, urbanisation, and migration. Section 7.14 presents a brief history of globalisation processes, including the ascent of the second modern globalisation process, now under way, describing the resulting benefits and shortcomings and the recent tendency to discredit its value. Section 7.15 deals with urbanisation, the present trends, the growing number of megacities and the challenges they generate, the urban environment, pollution and climate, urban health, and the relations between cities, use of natural resources, and the global environment. Section 7.16 begins by revisiting humans' remarkable capacity for endurance running and briefly reviews *Homo sapiens*' migratory movements out of Africa, which populated all the continents in a relatively short period of time. The contemporary problems regarding voluntary migration and forced displacement are analysed, along with their political implications. This section ends with a brief review of the travel and tourism sector, which has had the highest economic growth at global level in recent years, up to 2019.

The next seven sections all relate to the challenge of anthropogenic climate change. Section 7.17 deals specifically with the connection between the use of fossil fuels and climate change, while Sect. 7.18 addresses the feasibility of a global energy transition from fossil fuels to renewable energies. Section 7.19 analyses the problem of an ever-increasing global energy demand. Section 7.20 describes the extraordinary history of ideas to modify weather and climate, especially for military purposes and more recently to countervail anthropogenic climate change, a technology called geoengineering. It also provides an instructive opportunity to analyse the conspiracy theory surrounding aircraft contrails. Sections 7.21–7.23 address the emerging field of geoengineering research. Section 7.21 deals with the techniques of carbon dioxide removal and Sect. 7.22 with solar radiation management, a more promising technology to decrease global warming. Section 7.23 discusses the future of geoengineering and in particular its governance in the multilateral framework of the United Nations.

The last stages of writing this book coincided with the beginning of the COVID-19 pandemic. This dramatic event has shown once again how fragile and globalized is humankind's civilizational model and the economic and financial system that sustains it. Section 7.24 presents a brief analysis of the pandemic and its possible outcomes as regards the main sustainability issues.

Lisbon, Portugal Filipe Duarte Santos

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Lisbon, Portugal
June 2020

Filipe Duarte Santos

Contents

Chapter 1
Time

Truth was the only daughter of Time

Leonardo da Vinci, *The Notebooks of Leonardo da Vinci* (started in 1508)

1.1 Human Evolution and Time

We are the only biological species that has the ability for self-awareness and self-knowledge through thought and symbolic language. We do not know what it is like not to have these abilities but we understand that they make interaction and relationships with others and the environment around us much more complex. In this context, the environment is understood as all the biotic and abiotic conditions, factors, and elements that involve and affect ecosystems, humankind, and all living things in the Earth system. We also know that self-awareness and self-knowledge have created apparently endless opportunities for us, some of which have been used to transform and extraordinarily improve the quality of human life since prehistory, throughout the last great civilisations of the past and, above all, over the last four centuries.

We do not know the future of humanity in the medium and long term but it is possible to imagine several scenarios for how it will evolve. The problem is to identify the essential elements that define *Homo sapiens* and the elements that enable us to look into our future as a group. The search for the direction to take in the future is one of the most fundamental forms of human rationality and will potentially contribute the most to the sustainability of our civilisation. It enables us to discover the challenges and risks that we may encounter, and it allows us to attempt to minimise them using practical reason.

The essence of a complex evolutionary system can be defined as a set of intrinsic properties and fundamental functions that uncover and encapsulate its past and present behaviour and build scenarios for the future. It is the set of properties that characterise the system's evolutionary process and are central to its complexity. It is the profound and determining nature of the direction its transformation takes.

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The evolutionary process discussed here is the evolution of humanity, although we must recognise that it is a process that cannot be separated from the natural evolution of the Earth system and, ultimately, the evolution of the Universe. The Earth system is a complex one that comprises, as well as the planet's core, the human subsystem and five subsystems—the lithosphere, the hydrosphere, the cryosphere, the atmosphere, and the biosphere—which form the ecosphere. The human subsystem is the functional system that groups together all our activities, processes, and products, including complex and diverse social, cultural, economic, financial, scientific, and technological structures, the renewable and non-renewable natural resources used, farming and forestry, material and energy flows, and all the systems and physical infrastructures we build. In other words, the human subsystem is the whole human enterprise recognised us a functional system anchored and integrated in the Earth system. This subsystem includes the technosphere, a concept defined by Haff (2014b) as part of the Earth system that has been transformed by different human technologies, including the means and infrastructures involved in those processes, such as the interconnected energy systems, systems for the production and consumption of goods and services, including industry, agriculture and food, communication systems, and transport and housing infrastructures, as well as services at the global level. The technosphere goes beyond the ecosphere, occupying part of outer space where spacecraft, satellites, and space debris can be found. The technosphere is gradually expanding into the Solar System and some space probes have even gone beyond. Furthermore, the exploration of mines has extended the technosphere to the greatest depths of the lithosphere. Despite the enormous complexity of the *Homo sapiens* population, its many actions and social relationships, its interactions with the environment, and the various successive stages in its journey, we may still reflect on the essence of the evolutionary process of humanity. This may lead us to discover the fundamental processes and essential features of our lineage that have determined our evolution from primordial times to the *Homo* genus.

The origin of the concept of essence can be found in Aristotle's (384–322 BC) *Metaphysics*. While trying to answer the question of what forms a thing's substance, Aristotle introduced the concept of essence through the expression *to ti ên einai*, which is, translated literally, "the what it was to be", although it is arguable whether this really gives the original meaning of the expression (Owens 1978). The translators who translated the text into Latin used the expression *esse*, which means to be and later gave rise to the word *essentia*. Since then, essence has been a concept that is frequently used in everyday speech, in literature, and in philosophy.

In philosophy, the concept of essence became the cornerstone of metaphysics and rationalism. Martin Heidegger (1889–1976) and Jean-Paul Sartre (1905–1980) stated that existence predated essence, to highlight that ways of being and acting are just choices that each person can make. Based on those choices, people acquire and project an identity that they claim is their essence. The essence that is sought here is not the essence of individual existentialism but the essence of the evolution of the *Homo sapiens* population as a biological species. Personal, subjective, and identity-based aspects of each human life are a few major manifestations of the complexity that surrounds the essence of evolution.

If we delve into the evolutionary side of the human process, we find one form of essence that is truly fundamental: time. Of course, everything related to humankind has happened and will happen in time. But the relationship goes deeper than that. Time influences and limits all human actions, each one of our lives and, ultimately, the evolution of humanity itself. We must find out how man has dealt with time and its relentless command to understand the history and future of the human condition. One of the central aspects of modern times is the acceleration in the evolution of technology and social and cultural changes which impose a different pace on life. This acceleration has generated time structures that restrict our time and force a larger proportion of it to be occupied, which leaves us in the perplexing situation of not having time. To analyse the origins and future consequences of this accelerated pace of time, we must start by reflecting on the notion of time and the different concepts of time that we have built throughout our history.

The word "time" has a clear operative sense but causes bafflement when we try to explain or define its meaning. In other words, we are able to use the word without hesitating but we find it extremely difficult to illustrate what time is from an ontological perspective. This was acknowledged by Augustine of Hippo (354–430) when he wrote in Book XI of *Confessions*: "What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not." We are aware that time is not something that we can escape from in order to analyse it from the outside, as we would an object. We also have no way of perceiving time itself independently from the perceptions that constantly allow us to be conscious and interpret the environment that surrounds us. However, time is real and can be understood in the intuitive sense defended by Henri Bergson (1859–1941) and Martin Heidegger. Time in an operative sense is an essential, unavoidable reality, the most important in human experience and evolution. Moreover, in its different forms and appearances, it is always a human construct, as recognised by the Dutch–American philosopher of science Bas van Fraassen in the context of his constructive empiricism, when he said "there would be no time were there no beings capable of reason" (Dowden 2009).

Time is a recurring and incredibly rich theme in philosophy. It was first explored by pre-Socratic philosophers in the 6th century BC in their search for the essence of things. Parmenides, who was active in the first half of the 5th century BC, was the first to conclude that time had something unreal about it, as Plato (c. 428–c. 346 BC), Immanuel Kant (1724–1804), and J.M. McTaggart (1866–1925) would later maintain (Hoy 1994). Discussion about the philosophy of time has been kept alive over the last 25 centuries and new life was breathed into it at the start of the 20th century.

We intuitively acknowledge that there is a flow of time that produces a past, a present, and a future. Here, the past is considered to be unchanging and the future undefined and uncertain. The passage of time consists of a constant transmutation of the present into a near past, accompanied by the transmutation of a near future into the present. Analysing in this intuitive, common way of interpreting time leads to the philosophical theory of presentism, according to which only sensations, perceptions, objects, and events that are temporally present exist. An analysis of time may also lead to the philosophical theory of eternalism, which argues that both past and future

events exist, even if we cannot experience them. In accordance with this point of view, the flow of time is an illusion of our consciousness, in other words, time does not flow because it is always present everywhere. A version of eternalism that comes closer to perceptions connected to psychological time is the theory of time called the growing block universe theory of time (Tooley 2000), according to which the past and present exist but the future does not, and is gradually uncovered by the flow of time. In this situation, the past block and the present block gradually increase, revealing the evolution of the Universe.

We can clarify, or even attempt to resolve, the dilemma of the flow of time by using an alternative form of analysis. The central idea involves focusing attention on ordering events by time, in other words, with approaches like event X happened two days before event Y or event X and event Y took place at the same time. In this case, we do not need to refer to the flow of time. Sentences that include references to the past, present, and future can be reformulated using relations of order in time. The two points of view—placing events in a past, present, or future that are constantly transmuting, or relating pairs of events using temporal relations, before, after, or simultaneously—correspond to McTaggart's A-theory and B-theory, respectively (McTaggart 1908). A-theory, which corresponds to a description of events as existing in absolute time and belonging to the past or the future, leads to contradictions that McTaggart interprets as being the result of an illusory conception of time. He therefore defends B-theory, according to which reality is non-temporal. Curiously, these two theories are relevant to relativistic theories of physical time, as we will see later. The concept of time can also be approached from a phenomenological perspective in which the consciousness and perception of time and use of the word "time" are analysed. The latter path is particularly relevant to the reflections proposed in this book.

1.2 Physical, Psychological, and Biological Time

Time is a central, constant theme in physics, psychology, philosophy, religion, and the social sciences but it is not possible to find a sufficiently broad-reaching and consensual definition that applies to all the fields in which it is involved. To start the analysis, we may use the perspective of the psychology of time. The perception of time fundamentally involves the concept of succession, the result of perceiving a relationship of order between two or more successive events, and the concept of duration, the result of perceiving two successive events (which could be two successive transitions, for example the moment when a sound is first heard and then the end of that sound) (Fraisse 1984). Duration does not exist in itself, i.e., independently of perception of the events that define it. The concept of duration requires the concept of succession. Succession, moreover, contrasts with simultaneity, and duration is extinguished when simultaneity occurs.

A full understanding of the concepts of succession and duration is only acquired at 7–8 years of age when children achieve the ability for abstract reasoning (Friedman 1982). It is also during that period that children begin to have an abstract awareness of

a certain type of time, namely that personal, private, non-transferable, and unyielding time that is normally called psychological, phenomenological, or mental time. It is important to remember that strictly speaking we do not perceive psychological time itself but only the changes and successive events that we later process in abstract forms of successions and durations until we build an awareness of psychological time.

The concept of psychological time is clearly distinguished from the concept of physical time. This is essentially the result of finding that duration can be measured consistently and universally. Physical time was constructed by measuring durations, first using calendars and later using different types of clocks, which are becoming more and more precise. Newton, in the *Scholium*, an introductory essay to his renowned book setting out the laws of motion and gravity (Newton 1687), begins by establishing the conceptual basis of the distinction he proposes between absolute and relative motion. That is where he introduces "relative, apparent, and common" time and space and "absolute, true, and mathematical" time and space. Relative time is time measured in cyclical durations linked to the uniform motions of objects, particularly stars such as the Sun and the Moon.

The problem was to know whether a motion was really uniform. Newton intuited that it would never be possible to prove such a property beyond all doubt. This underlies Newton's postulate: "Absolute, true, and mathematical time, of it self and from its own nature, flows equably without relation to anything external, and by another name is called 'duration"' (Newton 1687). Finding a reliable measure for time was actually a highly debated issue in the 17th century, especially among astronomers. It was known that the mean solar day was around four minutes longer than a sidereal day, and this led to diverging measurements of time. And it was not certain that the rotation of the Earth was uniform. Newton said that it was, but he considered that it was a contingent assertion that needed to be proved. Newton's model of physical time became deeply rooted in people's minds because it has a structure compatible with psychological time, for which it began to function as a support and reference.

The emergence of Einstein's theory of relativity (Einstein 1905a, b) broke that relationship and definitively shifted the concept of physical time away from the concept of psychological time. In the end, there is no absolute time and space in physics, and the spacetime of relativity theory is a structure that cannot be reached merely by directly processing the perception of successions, durations, and distances. It becomes necessary to use a physical theory expressed through mathematics and examine whether or not measurements of the spatial and temporal coordinates of events obey the equations that define the theory.

Perception of psychological time is not associated with any particular sensory organ. However, our brain gives us that ability via a complex, distributed system that involves the cerebral cortex, the cerebellum, and the basal ganglia. Using this system, which includes an internal clock based on time defined by regular neural impulses, we are able to place past events in time and assess and compare time intervals with durations that vary between milliseconds and several decades. Psychological time includes perception of what we call the present which, in terms of measuring physical time, is a relatively short time interval. E. Robert Kelly (1883), who used

the pseudonym E.R. Clay, called this limited and somewhat mistaken perception "specious present". William James described it as the short duration to which we are immediately and incessantly sensitive (Andersen and Grush 2009).

The limits of our ability to perceive duration, for instance the duration defined by two successive events, have been established by psychologists and neurologists. We are unable to perceive durations of less than 0.1 seconds for visual stimuli or durations under 0.01–0.02 seconds for audio stimuli. Below these limits, we interpret events as simultaneous even though from a physical perspective they are not. On the other hand, when perceptions of durations are compared with measurements obtained from clocks, we conclude that perceptions are subjective and vary according to emotional state and age, although they are on average reliable enough for most of our activities.

Psychological time can dilate and contract in relation to physical time. A day can seem longer to a young child than it does to an adult. In dangerous situations, when we are afraid, suffering, or under intense stress, time appears to run faster, while the outside world runs at a slower pace. In contrast, when we are absorbed in a rewarding or routine activity, time seems to run more slowly, while the outside world advances at a faster pace. Perception of the duration of past time intervals is also influenced by what we did at the time. Generally speaking, when a period of time is filled with varied, pleasant activities, experiences, or events, we feel like it went past quickly; when we assess its duration later, it feels like it was long. In contrast, a period of time with little to fill it takes longer to pass but in retrospect appears short (James 1918).

Michael Flaherty (1991) attempted to explain the variation in perception of the passing of psychological time compared with physical time. This variation is generally related to the density of experiences and conscious activities that require or force our cognitive attention, emotional involvement, or decision-making actions per unit of physical time, as a result of the circumstances the person finds themselves in. Problematic or difficult circumstances demand greater awareness and cognitive, emotional, or decision-making intervention, and this increases the density of experiences. As a result, time appears to pass more slowly and there is time dilation. Examples of this include intense pleasure, for example an orgasm, intense suffering, torture, violent combat, and situations of great danger. Psychological time also dilates during discovery, wonder, and pleasure at a feeling, sight, experience, or new knowledge, as well as during deep meditation or mental bliss. Forced inactivity, for example in prison or as a result of unemployment, can also cause time to dilate due to forced, concerned, and emotional introspection which fills time unhealthily. Tedium is the most benign way of perceiving time dilation.

On the other hand, if the density of experience and intense, interesting, or new activities per unit of physical time is low, time seems to go by more quickly, in other words it seems to contract. This is the case when we are doing something we like which occupies us without involving a high density of emotional states or different activities. It is also the case if we are involved in a routine, relatively pleasant activity that we are able to perform almost unconsciously.

The contraction of time is also found in our perception of the duration of past time intervals and its intensity depends on the density of significant, varied, and relevant cognitive, emotional, and decision-making experiences. We have an extraordinary

ability to selectively forget most of our past actions and experiences. This forgetfulness concerns above all things that are part of our everyday routines and that we consider to a greater or lesser extent irrelevant. Only the most important and relevant experiences, actions, and events remain in our memories. Due to this restructuring of time caused by such forgetfulness, past time tends to contract and that contraction tends to increase as the density of important memories decreases.

Despite the subjectivity of our perception of time, we frequently find ourselves in situations in which we feel like time does not go faster or slower than the physical time shown by clocks and watches. Under these circumstances, psychological and physical time are synchronised and we are able to assess the physical duration of the time periods we perceive relatively accurately. This ability is acquired by the practice of establishing equivalence between the units of physical time, particularly minutes and hours, and the duration of cyclical personal and professional actions, as well as environmental and social cycles and the physical infrastructures where we live.

Drugs also interfere with our perception of duration. Some, such as cocaine, interfere with the dopamine regulation system. When the dopamine concentration increases, our internal clock speeds up, psychological time moves faster and external events appear to last longer. Dopamine is the main neurotransmitter involved in processing psychological time in the brain. It is associated with pleasure, motivation processes, and learning from reward mechanisms, the inclination towards addiction to gambling, sex, and drugs, and certain neurological diseases, including schizophrenia, Parkinson's disease, and attention deficit disorder with hyperactivity.

As well as the ability to be aware of psychological time, our organism has involuntary cyclical behaviour lasting around 24 hours that includes biochemical, physiological and behavioural elements. This is known as the circadian rhythm, a name which comes from the Latin *circa*, meaning "near", and *diem*, meaning "day". It is a rhythm that is endogenous to our organism, regardless of the environment we find ourselves in, but it is relatively sensitive to some kinds of external stimuli, known as *zeitgeber* ("synchronisers" in German), of which the most important is sunlight. Circadian rhythms can be observed in most living organisms, including some bacteria, fungi, plants, and animals. There are other biological rhythms linked to the tides, the different seasons, and the year. During the evolution of life on Earth, the adaptation of living beings to some cyclical events in the external environment, such as the alternation between day and night, has generated cyclical behaviour equivalent to the biological clocks that have created biological time.

Circadian rhythms originated in the evolutionary process of adapting internal cell physiology to the diurnal cycle. Little is yet known about the mechanisms that first triggered this adaptation process. They may have evolved to stop the complex process of DNA replication from taking place in the daytime to protect it from solar ultraviolet radiation, which was initially much more intense at the surface, before the stratospheric ozone layer was completely formed. Later, when the concentration of oxygen in the air increased, the evolution of biological clocks probably resulted from mechanisms for protecting oxygen at the molecular level, involving oxidation–reduction cycles by way of antioxidant enzymes (Edgar et al. 2012).

In mammals, the primary centre for regulating circadian rhythms is the suprachiasmatic nucleus in the hypothalamus, in the central area of the base of the brain. If it is removed, circadian rhythms are completely destroyed in the organism, in particular the regularity of sleep and wakefulness periods. The genes that regulate circadian cell mechanisms in the human species are present not only in the suprachiasmatic nucleus but also in several organs and tissues, including the skin (Zanello et al. 2000). There are minuscule cellular clocks spread throughout our bodies that together consistently regulate our biological time.

1.3 Operative Social Time

The notion of time is not limited to the concepts of psychological time, physical time, and biological time. Time also has a social dimension that has been recognised by the founders of modern sociology. Max Weber (1864–1920) (Weber 1905) called attention to the importance of considering awareness of time when studying the evolution of mentalities and the development of the modern era. He defended the theory that the "spirit of capitalism" requires a special relationship with time. Emile Durkheim (1858–1917) (Durkheim 1912) went even further in his analysis by postulating a social time that transcends individual experiences of time. According to Durkheim, time is a social institution, i.e., an essentially collective phenomenon, a product of collective consciousness.

In other words, we are dealing with a structural construct that arises from the awareness of and ability to process psychological time together with the use of language and the fact we live in society. Pitirim Sorokin (1889–1968) and Robert Merton (1910–2003) (Sorokin and Merton 1937) conclude, in their methodological and functional analysis of social time and the relationship with physical time, that social time reflects the pace of activity in different societies. Calendars, for example, are systems for organising social time that express the pace of collective activities and at the same time have the role of ensuring that activities are regular. Hassan (2009) considers time to be social and believes that it fundamentally exists in the social sphere, although he emphasizes that, in this field, it does not in any way constitute an absolute and universal structure similar to the one Newton suggested for physical time.

The diversity and complexity of human perception, processing, analysis, knowledge, action, and communication capabilities in social settings have generated different concepts of time that are compatible with each other but impossible to place in a hierarchy. Physical time therefore essentially represents the ability to measure and compare the duration of various cyclical phenomena and the fact that the results of the measurements form a consistent set of data that makes it possible to structure and communicate intelligible, universal, falsifiable physical laws (Popper 1959) that can be expressed using the language of mathematics. That ability and the applications it produces do not necessarily imply the existence of an external physical time independent of humankind, to which all other concepts of time would be subordinate.