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The MANBRIC-Technologies in the Forthcoming Technological Revolution

Leonid Grinin, Anton Grinin, and Andrey Korotayev

Abstract In this chapter, we analyze the relationship between Kondratieff waves and major technological revolutions on the basis of the theory of production principles and production revolutions, and offer some forecasts about the features of the Sixth Kondratieff Wave/the Fourth Industrial Revolution. We show that the technological breakthrough of the Sixth Kondratieff Wave may be interpreted as both the Fourth Industrial Revolution and as the final phase of the Cybernetic Revolution. We assume that the sixth K-wave in the 2030s and 2040s will merge with the final phase of the Cybernetic Revolution (which we call a phase of self-regulating systems). This period will be characterized by the breakthrough in medical technologies which will be capable of combining a number of other technologies into a single system of new and innovative technologies (we denote this system as a system of MANBRIC-technologies—i.e. medical, additive, nano-, bio-, robo-, info-, and cogno-technologies).

Keywords Medical technologies • Additive technologies • Nanotechnologies • Biotechnologies • Robotics • IT • Cognitive technologies

1 Introduction: Cybernetic Revolution, Scientific-Cybernetic Production Principle, the Sixth Kondratieff Wave, and the Fourth Industrial Revolution

The production revolution which began in the 1950s and is still proceeding, has led to a powerful acceleration of scientific and technological progress. Taking into account expected changes in the next 50 years, this revolution deserves to be called

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'Cybernetic' (see our explanation below). The initial phase of this revolution (the 1950s—the 1990s) can be referred to as a scientific-information because it was characterized by the transition to scientific methods of planning, forecasting, marketing, logistics, production managements, distribution and circulation of resources, and communication. The most radical changes took place in the sphere of informatics and information technologies. The final phase will begin approximately in the 2030s or the 2040s and will last until the 2070s (note that many contributors to this volume denote this forthcoming technological breakthrough as the "Fourth Industrial Revolution"). We believe that it can be also interpreted as a phase of self-regulating systems of the Cybernetic Revolution (see below). We do not think that these interpretations are mutually exclusive; on the contrary, they are perfectly compatible. Now we are in the intermediate (modernization) phase of the Cybernetic Revolution which will last until the 2030s. It is characterized by powerful improvements and the diffusion of innovations made at the initial phase—in particular by a wide proliferation of easy-to-handle computers, means of communication, and the formation of a macro-sector of services among which information and financial services take center stage. At the same time the innovations necessary to start the final phase of the Cybernetic Revolution are being prepared.

Cybernetic Revolution is a great breakthrough from industrial production to production and services based on the operation of self-regulating systems.

Table 1 demonstrates the connection between three phases of the scientific-cybernetic production principle (which coincide with three phases of the Cybernetic Revolution) and three Kondratieff waves[1] (the fourth, fifth and sixth).

1.1 Peculiarities of the Fourth Kondratieff Wave in Connection with the Beginning of the Cybernetic Revolution

The fourth K-wave (the second half of the 1940s—1980s) fell on the initial phase of the Cybernetic Revolution. The beginning of a new production revolution is a special period which is connected with the fast transition to a more advanced technological component of economy. All accumulated innovations and a large number of new innovations generate a new system that has a real synergetic effect. It would appear reasonable that an upward phase of the K-wave coinciding with the beginning of a production revolution can appear more powerful than A-phases of other K-waves.

[1]See Kondratieff 1926, 1935, 1984, 1998, 2004 [1922]; Schumpeter 1939; Hirooka 2006; Devezas 2006, 2010, 2012; Korotayev et al. 2011; Grinin et al. 2012, 2014, 2016c; Korotayev and Grinin 2012; Grinin and Grinin 2015, 2016 for more detail on Kondratieff waves.

Table 1. The scientific-cybernetic production principle (initial phases) and Kondratieff waves

Phases of the scientific cybernetic production principle	The first phase (initial phase of the Cybernetic Revolution) 1955–1995 ≈ **40 years**	The second phase (middle phase of the Cybernetic Revolution)1995—the 2030s/40s ≈ **35–50 years**	The third phase (final phase of 'self-regulating systems' of the Cybernetic Revolution) the 2030s/40s–2055/70s ≈**25–40 years**	Total: ≈ **100–120** years
K-Waves and their Phases	The Fourth Wave, 1947–1982/1991 ≈ **35–45 years**	The Fifth Wave, 1982/1991–the 2020s. The beginning of the upward phase of the sixth wave (2020–2050s) ≈ **30–40 years**	The sixth wave, 2020–2060/70s. The end of the upward phase and downward phase (the latter ≈ 2050–2060/70s) ≈ **40–50 years**	About**110–120 years**
K-Waves and Their Phases	Upward phase, 1947–1969/1974s	Downward phase of the fifth wave, 2007–2020s	–	
K-Waves and Their Phases	Downward phase, 1969/1974–1982/1991	Upward phase of the sixth wave, 2020–2050s	–	
K-Waves and Their Phases	The fifth wave, 1982/1991–2020s, upward phase, 1982/1991–2007	–	–	

That was the feature of the upswing A-phase of the fourth K-wave (1947–1974) which coincided with the scientific-information phase of the Cybernetic Revolution. As a result, a denser than usual cluster of innovations (in comparison with the second, third and fifth waves) was formed during that period. All this also explains why in the 1950s and 1960s the economic growth rates of the World System were higher, than in the A-phases of the third and fifth K-waves. The downswing phase of the fourth K-wave (the 1970s–1980s) in its turn also fell on the last period of the initial phase of the Cybernetic Revolution. This explains in many respects why this downswing phase was shorter than those of the other K-waves.

1.2 The Fifth K-Wave and the Delay of the New Wave of Innovations

It was expected that the 1990s and the 2000s would bring a radically new wave of innovations, comparable in their revolutionary character with computer technologies, and therefore capable of creating a new technological paradigm. Those directions which had already appeared and those which are supposed to become the basis for the sixth K-wave were considered in position to make a breakthrough. However, it was the development and diversification of already existing digital electronic technologies and rapid development of financial technologies that became the basis for the fifth K-wave. Those innovations which were really created during the fifth K-wave as, for example, energy technologies, still have a small share in the general energy, and, above all, they have not developed properly. Some researchers believe that from 1970s up to the present is the time for the decelerating scientific and technological progress (see a discussion on this topic in Brener 2006; Khaltourina and Korotayev 2007; see also Maddison 2007). Polterovich (2009) also offers the notion of a technological pause. But, in general, the mentioned technological delay is, in our opinion, insufficiently explained. We believe that taking features of the intermediate modernization phase of a production revolution (i.e., the second phase of the production principle) into account can help explain this. Functionally it is less innovative; rather during this phase earlier innovations become more widely spread and are improved.

As regards the 1990s–2020s (the intermediate phase of the Cybernetic Revolution) the question is that the launch of a new innovative breakthrough demands that the developing countries reach the level of the developed ones, and the political component of the world catches up with the economic one (see Grinin and Korotayev 2010, 2014a, b; Korotayev and de Munck 2013, 2014; Korotayev and Zinkina 2014; Korotayev et al. 2011a, b, c, 2012, 2015).

Thus, the delayed introduction of innovations of the new generation is explained, first, by the fact that the center cannot endlessly surpass the periphery in development, that is the gap between developed and developing countries cannot increase all the time. Secondly, the economy cannot constantly surpass the political and other components, as this causes very strong disproportions and deformations. And the appearance of new general-purpose technologies, certainly, would accelerate economic development and increase disparities. Thirdly, introduction and distribution of the new basic technologies do not occur automatically, but only within an appropriate socio-political environment (see Grinin and Grinin 2016; Grinin and Korotayev 2014a, b; see also Perez 2002). In order for basic innovations to be suitable for business, structural changes in political and social spheres are necessary, eventually promoting their synergy and wide implementation in the world of business.

Thus, the delay is caused by difficulties of changing political and social institutions on the regional and even global scale, and also (or, perhaps, first of all) within the international economic institutions. The latter can change only as a result of the strong political will of the main players, which is difficult to execute in the framework of the modern political institutions. These institutions rather can change under the conditions of depressive development (and probable aggravation of the foreign relations) compelling them to reorganize and dismantle conventional institutions that are unlikely to be changed under ordinary conditions due to a lack of courage and opportunities (for our vision of the future of the world order see Grinin and Korotayev 2010, 2015a; Grinin et al. 2016a).

The above explains as well the reasons of different rates of development as regards the center and periphery of the World System during the fifth K-wave (for more detail see Grinin and Korotayev 2010, 2015a; Grinin et al. 2016a). The periphery was expected to catch up with the center due to the faster rates of its development and slowdown of the center development. However, one should not expect continuous crisis-free development of the periphery—a crisis will come later and probably in other forms. Without a slow-down of the development of the periphery and serious changes, full harmonization of the economic and political component will not happen. Consequently, it might be supposed that in the next decade (approximately by 2020–2025) the growth rates of the peripheral economies can also slow down, and internal problems will aggravate; this can stimulate structural changes in the peripheral countries, thus also increasing international tension.

The world order has already begun to change, and it will continue to change over the next 10–20 years and some visible results of this change may appear by the start of the new K-wave. We have called this change "the World System reconfiguration" (see Grinin and Korotayev 2012, 2015a: 159–166; Grinin et al. 2016a, b). Thus, we suppose that in the next 10–15 years the world will face serious and painful changes. The World System reconfiguration processes further explain the reasons for the very turbulent processes observed in the recent years.

2 Characteristics of the Cybernetic Revolution

2.1 What Are Self-regulating Systems and Why Are They So Important?

Self-regulating systems are systems that can regulate themselves, responding in a pre-programmed and intelligent way to the feed-back from the environment. These are the systems that operate either with a small input from human or completely without human intervention. Today there are many self-regulating systems, for example, pilotless electric cars, artificial Earth satellites, drones, navigation systems laying the route for a driver. Another good example is life-support systems (such as medical ventilation apparatuses or artificial hearts). They can control a number of parameters, choose the most suitable mode of operation and detect critical situations. There are also special programs that determine the value of stocks and other securities, react to price changes, buy and sell them, carry out thousands of operations in a day and fix a profit. A great number of self-regulating systems have been created but they are mostly technical and information systems (like robots or computer programs). During the final phase of the Cybernetic Revolution there will be a lot of self-regulating systems connected with biology and bionics, physiology and medicine, agriculture and environment. The number of such systems as well as their complexity and their autonomy will dramatically increase. These systems will also significantly reduce energy and resource consumption. Human life will become organized to a greater extent by such self-regulating systems (for example, by monitoring health, daily regimens, regulating or recommending levels of personal exertion, having control over the patients' condition, prevention of illegal actions, etc. [for more detail about self-regulating systems see Grinin and Grinin 2016]).

Thus, we designate the modern revolution 'Cybernetic,' because its main sense is the wide creation and distribution of self-regulating autonomous systems. Cybernetics, as is well-known, is a science of regulatory systems. Its main principles are quite suitable for the description of self-regulating systems (see, e.g., Wiener 1948; Ashby 1956; Foerster and Zopf 1962; Beer 1967, 1994; Umpleby and Dent 1999).

As a result, the opportunity to control various natural, social and production processes without direct human intervention (that is impossible or extremely limited now) will increase. In the fourth phase (of maturity and expansion) of the scientific cybernetic production principle (the 2070s and 2080s) the achievements of the Cybernetic Revolution will become quite systemic and wide-scale in its final phase (for more detail see Grinin 2006; Grinin and Grinin 2016).

Below we enumerate the most important characteristics and trends of the Cybernetic Revolution and its technologies. These features are closely interconnected and support each other.

2.2 The Most Important Characteristics and Trends of the Cybernetic Revolution

1. Increases in the amount of information and complexity in the analysis of the systems (including the ability of systems for independent communication and interaction).
2. Sustainable development of the system of regulation and self-regulation.
3. Mass use of artificial materials which previously lacked the appropriate architectural properties.
4. Qualitatively increasing controllability a) of systems and processes that vary in their constitution (including living material); and b) of new levels of managing the organization of matter (up to sub-atomic levels, as well as the use of tiny particles as building blocks).
5. Miniaturization as a trend of the constantly decreasing size of particles, mechanisms, electronic devices, implants, etc.
6. Resource and energy saving in every sphere.
7. Individualization as one of the most important technological trends.
8. Implementation of smart technologies and a trend toward humanization of their functions (use of a common language, voice, etc.).

2.3 The Most Important Characteristics and Trends of the Cybernetic Revolution

1. The transformation and analysis of information as an essential part of technologies.
2. The increasing connection between the technological systems and environment.
3. A trend toward automation of control is observed together with the increasing level of controllability and self-regulation of systems.
4. The capabilities of materials and technologies to adjust to different objectives and tasks (smart materials and technologies) as well as capabilities for *choosing optimum regimes in the context of certain goals and tasks*.
5. A large-scale synthesis of the materials and characteristics of the systems of different nature (e.g., of animate and inanimate nature).
6. The integration of machinery, equipment and hardware with technology (know-how and knowledge of the process) into a unified technical and technological system.[2]
7. Self-regulating systems (see below) will become the major component of technological processes. That is the reason why the final (forthcoming) phase of the Cybernetic Revolution is (or should) be called **the epoch of self-regulating systems** (see below).

2.4 Medicine as a Sphere of the Initial Technological Breakthrough and the Emergence of MANBRIC-Technology Complex

It is worth remembering that the (first) Industrial Revolution began in a rather narrow area of cotton textile manufacturing and was connected with the solution of quite concrete problems—at first, liquidation of the gap between spinning and weaving, and then, after increasing weavers' productivity, searching for ways to mechanize spinning. However, the solution of these narrow tasks caused an explosion of innovations conditioned by the existence of a large number of the major elements of machine production (including abundant mechanisms, primitive steam-engines, quite a high volume of coal production, etc.) which gave an impulse to the development of the Industrial Revolution. In a similar way, we assume that the Cybernetic Revolution will start first in a certain area.

Given the general vector of scientific achievements and technological development and taking into account that a future breakthrough area should be highly

[2]During the Industrial Epoch these elements existed separately: technologies were preserved on paper or in the engineer's minds. At present, thanks to IT and other technologies the technological constituent fulfils the managing function facilitating the path to the epoch of self-regulating systems.

commercially attractive and have a wide market, we forecast that the final phase of this revolution will begin somewhere at the intersection of medicine and a number of other technologies (we will provide reasons for this statement below). By the 2030s there can appear unique opportunities for a breakthrough in medicine (see below). However, when speaking about medicine, one should keep in mind that with respect to potential revolutionary transformations medicine is a very heterogeneous sphere. That is why the breakthrough will not occur in all spheres of medicine but in its one or two innovative fields. Perhaps, it has already formed (as biomedicine or nanomedicine) or it can form as a result of the introduction of some other innovative technologies into medicine. As for other branches of medicine, revolutionary transformations will begin there later. Moreover, some branches of medicine would be unable to transform due to their conservatism. Thus, more radical reforms will occur in these fields in the future.

In general, the breakthrough vector in medicine and associated branches can be defined as a rapid growth of opportunities for correction or even modification of the human biological nature. In other words, it will be possible to extend our opportunities to alter a human body, perhaps, to some extent, its genome; to widen sharply our opportunities of minimally invasive influence and operations instead of the modern surgical ones; to use extensively means of cultivating separate biological materials, bodies or their parts and elements for regeneration and rehabilitation of an organism, and also artificial analogues of biological material (bodies, receptors), etc.

This will make it possible to radically expand the opportunities to dramatically increase life expectancy and improve physiological abilities of people as well as health-related quality of life (HRQoL). It will be technologies intended for common use in the form of a mass market service. Certainly, it will take a rather long period (about two or three decades) from the first steps in that direction (in the 2030s and 2040s) to their common use (about some possible forthcoming medical technologies see Appendix).

On the whole, the drivers of the final phase of the Cybernetic Revolution will be medical technologies, additive manufacturing (3D printers), nano- and bio-technologies, robotics, IT, cognitive sciences, which will together form a sophisticated system of self-regulating production. We can denote this complex as MANBRIC-technologies (i.e. medical, additive, nano-, bio-, robo-, info-, and cognitive technologies). As is known, with respect to the sixth technological paradigm (known also as the sixth technological system or style) there is a widely used idea connected with the notion of NBIC-technologies (or NBIC-convergence) (see Lynch 2004; Bainbridge and Roco 2005; Dator 2006; Korotayev 2008; Akaev 2012). There are also some researchers (e.g., Jotterand 2008) who see in this role another set of technological directions—GRAIN (Genomics, Robotics, Artificial Intelligence, Nanotechnology). However, we believe that this set will be larger. And medical technologies will be its integrating part.

It should be noted that Leo Nefiodow has been writing about health as the leading technology of the sixth Kondratieff wave for a long time (Nefiodow 1996; Nefiodow and Nefiodow 2014a, b). He explains that health is much more than medicine and includes mental, psychosocial, environmental and spiritual aspects. He believes that medicine covers only a small part of the health problems we face today. We agree that health is more than medicine. However, we regard medicine as the most important business sphere connected with health care (note that the overwhelming majority of researchers in the health area work with medical technologies). We also agree with Nefiodow that business and profit far from always serve people. But we do not know any power beside medical business which has opportunities (in co-operation with such state agencies as the National Institutes of Health in the USA) to finance research and development in this area, to elaborate new ways to fight mortal diseases, to invest in prolongation of life expectancy. In Nefiodow's opinion, health area covers not only psychotherapeutic, psychological and psychiatric services, but also numerous measures of health improvement that, using his terms, will reduce social entropy. The problems with this argument, based on reducing social entropy (e.g., corruption, small and large crime, drug addiction, lack of moral guide, divorces, violence, etc.), is that social entropy (as Nefiodow himself points out) has always existed in society. Social changes can be really extremely important for the creation of starting conditions for a long-term upswing in reducing social entropy (see Grinin and Grinin 2013, 2015 for more detail). However, it is production and/or commercial technologies that represent the driving force of the K-Wave upswing phases. There is one more important point. The Nefiodows believe that it is biotechnologies that will become an integrating core of the new technological paradigm. However, we suppose that the leading role of biotechnologies will be, first of all, in their possibilities to solve major medical problems. That is why it makes sense to speak about medical technologies as the core of a new technological paradigm. Besides, we forecast a more important role of nanotechnologies than the the Nefiodows do (Nefiodow and Nefiodow 2014b: Chap. 3). Nanotechnologies will be of great importance in terms of the development of bio- and medical technologies (they are supposed to play a crucial role in the fight against cancer; at the same time nanotechnologies will play a crucial role in other spheres too, in particular in energy and resource saving).

Thus, we maintain the following:

1. Medicine will be the first sphere to start the final phase of the Cybernetic Revolution, but, later on, self-regulating systems development will cover the most diverse areas of production, services and life.
2. We treat medicine in a broad sense, because it will include (and already actively includes) for its purposes a great number of other scientific branches: e.g., the use of robots in surgery and care of patients, information technologies in remote medical treatment, neural interfaces for treatment of mental illness and brain research; gene therapy and engineering, nanotechnologies for creation of artificial immunity and biochips which monitor organisms; new materials for growing artificial organs and many other things to become a powerful sector of economy.
3. The medical sphere has unique opportunities to combine the above mentioned technologies into a single system.

4. There are also some demographic and economic reasons why the phase of self-regulating systems will start in medicine:

– Increase in average life expectancy and population ageing will favor not only the growth of medical opportunities to maintain health, but also allow the extension of working age, as population ageing will be accompanied by shortages in the working-age population.
– People, in general, are always ready to spend money on health and beauty. However, the growth of the world middle class and the cultural standard of people implies much greater willingness and solvency in this terms.
– Medical corporations usually do not impede technological progress, but, on the contrary, are interested in it.

Thus, today medicine is a very important sector of the economy, and tomorrow it will become even more powerful.

3 Global Demographic Factors

A number of global demographic factors explain why in particular in medicine the transition to the new technological paradigm should start.

This will be supported by a particularly advantageous situation developing by 2030 in economy, demography, culture, a standard of living, etc.—these will define a huge need for scientific and technological breakthrough. By advantageous situation we do not mean that everything will be perfectly good in the economy; just on the contrary, everything will be not as good as it could be. Advantageous conditions will be created because reserves and resources for prolonging previous trends will be exhausted, and at the same time the requirements of currently developed and developing societies will increase. Consequently, one will search for new developmental patterns.

Particular attention should be paid to the global population aging (see Figs. 1, 2, 3, and 4). As shown above, an especially rapid global increase in the number of age persons above retirement-age is expected to come in the next 20 years—their number will actually double during a short historical period, thus it will increase by almost 600 million and the total number will considerably exceed a billion.

However, a massive acceleration will be observed in particular of people aged 80 years or more. While by 2050 the number of persons of retirement age will approximately double, the number of elderly people aged 80 years or more will practically quadruple and, in comparison with 1950, their number by 2075 will increase almost by 50 times (see Fig. 4).

As we can see, over the next 35 years there will be a truly explosive growth of population over 80 years old. By the 2050s, the global population of this age group quadruple. A particularly rapid growth will occur in the 2030s and 2040s, when the number of very old (and hence having particular acute needs in medical care) people will grow from 200 to 400 million (by 200 million people) just within

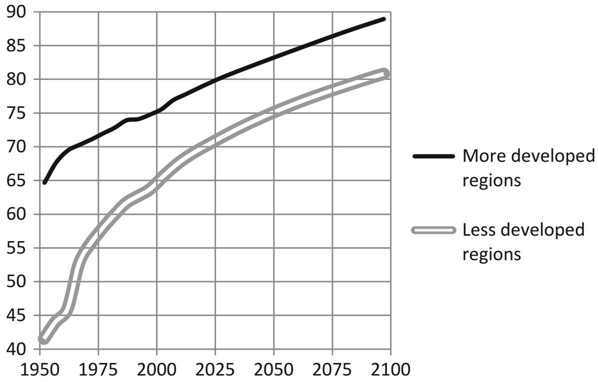

Fig. 1. Dynamics of the life expectancy at birth (years) in the World System core and global periphery, 1950–2015, the UN medium forecast to 2050 (*Source*: UN Population Division 2016)

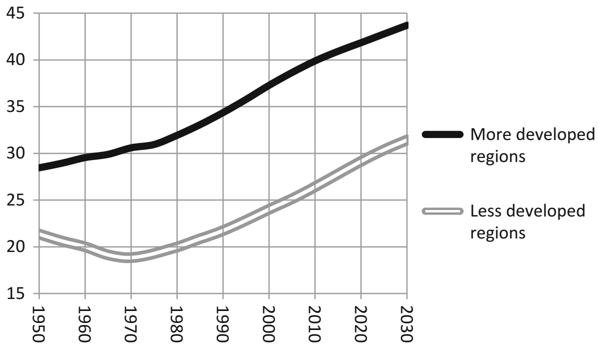

Fig. 2. Dynamics of the median age of population (years) in the World System core and global periphery, 1950–2015, with the medium forecast of the UN till 2030 (*Source*: UN Population Division 2016. We would like to remind the reader that if the median age of population of a given country equals, for example, 40 years, it means that half of the population of this country is younger than 40 years, and the other one is older)

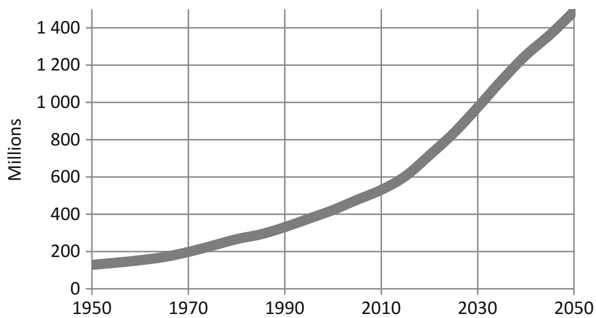

Fig. 3. Increasing number of persons of retirement age (over 65), 1950–2015, with the UN medium forecast till 2050 (*Source*: UN Population Division 2016)

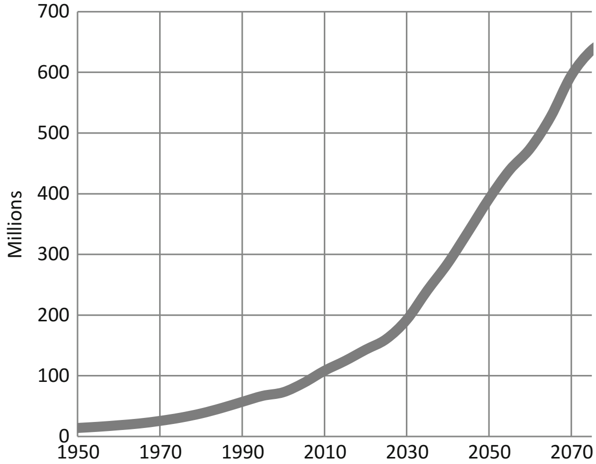

Fig. 4. Increase of global number of elderly people (aged 80 years+), 1950–2015, with the UN average forecast till 2075 (*Source*: UN Population Division 2016)

20 years. And this is the very period when we expect a technological breakthrough in medicine. As we can see, the UN forecast shows that the demographic conditions for such a breakthrough in those years will be extremely favorable. An explosive growth of the number of very old people will mean an equally explosive increase in demand for medical services that will serve as a powerful incentive to increase even more research and development in this area. On the other hand, it would mean a very rapid growth of the market for such services—which implies that new developments in this area will have brilliant opportunities for commercialization that will stimulate further growth in life expectancy, forming a positive feedback loop that can act as a powerful driving force of this technological breakthrough.

So by the 2030s, the number of middle-aged and elderly people will increase; economy will desperately need additional labor resources while the state will be interested in increasing the working ability of elderly people, whereas the population of wealthy and educated people will grow in a rather significant way. In other words, the unique conditions for the stimulation of business, science and the state to make a breakthrough in the field of medicine will emerge, and just these unique conditions are necessary to start the innovative phase of production revolution!

It is extremely important to note that enormous financial resources will be accumulated for the technological breakthrough, such as: the pension money whose volume will increase at high rates; spending of governments on medical and social needs; growing expenses of the ageing population on health (related) services, and also on health services obtained by the growing world middle class. All this can provide initial large investments, an appeal of high investment of respective venture projects and long-term high demand for innovative products, thus a full set of favorable conditions for a powerful technological breakthrough will become available.

4 Self-regulating Systems Phase and the Sixth Kondratieff Wave

4.1 The 6th K-Wave A-Phase: Take-off Run Before the Start of the Final Phase of the Cybernetic Revolution

The sixth K-wave will probably begin approximately in the 2020s. Meanwhile the final phase of the Cybernetic Revolution has to begin later, at least, in the 2030s or 2040s. Thus, we suppose, that a new technological paradigm will not develop in a necessary form even by the 2020s (thus, the innovative pause will take longer than expected—see Grinin et al. 2016c: Chap. 6). However, it should be kept in mind that the beginning of the Kondratieff wave upswing phase is never directly caused by new technologies. This beginning is synchronized with the start of the medium-term business cycle's upswing. And the upswing takes place as a result of the levelling of proportions in economy, the accumulation of resources and other impulses that improve demand and conjuncture. One should remember, that the beginning of the second Kondratieff wave was connected with the discovery of gold deposits in California and Australia, the third wave was linked with an increase in prices for wheat, the fourth one with the post-war reconstruction, the fifth one with the economic reforms in the UK and the USA, as well as oil price shocks. And then, given an upswing, a new technological paradigm (which could not completely—if at all—realize its potential) facilitates overcoming of cyclic crises and allows further growth.

Consequently, some conjunctural events will also stimulate an upward impulse of the sixth K-wave. And, for example, the rapid growth of the underdeveloped world regions (such as Tropical Africa, the Islamic East, and some Latin American countries) or new financial and organizational technologies can become a primary impulse. Naturally, there will also appear some technical and technological innovations which, however, will not form a new paradigm yet. Besides, we suppose that financial technologies have not finished yet its expansion in the world. If we can modify and secure them somehow, they will be able to spread into various regions which underuse them now. One should not forget that large-scale application of such technologies demands essential changes in legal and other systems, which is absolutely necessary for developmental levelling in the world. Taking into account a delay of the new generation of technologies, the period of the 2020s may resemble the 1980s. In other words, it will be neither a recession, nor a real upswing, but rather somehow accelerated development (with stronger development in some regions and continuous depression in others—see Grinin et al. 2016c: Chap. 3).

Then, given the favorable conditions as they had been mentioned above, during this wave the final phase of the Cybernetic Revolution will begin. In such a situation it is possible to assume that the sixth K-wave's A-phase (the 2020s–2050s) will have much stronger manifestation and last longer than that of the fifth one due to more dense combination of technological generations. And since the Cybernetic

Revolution will evolve, the sixth K-wave's downward B-phase (the 2050s–the 2060/70s), is expected to be not so depressive, as those during the third or fifth waves. In general, during this K-wave (the 2020s–the 2060/70s) the Scientific and Information Revolution will come to an end, and the scientific and cybernetic production principle will acquire its mature shape.

4.2 There Is Another Scenario

The final phase of the Cybernetic Revolution can begin later—not in the 2030s, but in the 2040s. In this case the A-phase of the sixth wave will terminate before the beginning of the regulating systems revolution; therefore, it will not be based on fundamentally new technologies and will not become so powerful as is supposed in the previous scenario. The final phase of the Cybernetic Revolution in this case will coincide with the B-phase of the sixth wave (as it was the case with the zero wave during the First Industrial Revolution, 1760–1787—see Grinin et al. 2016c: Chaps. 2 and 6) and at the A-phase of the seventh wave. In this case the emergence of the seventh wave is highly possible. The B-phase of the sixth wave should be rather short due to the emergence of a new generation of technologies, and the A-phase of the seventh wave could be rather long and powerful.

4.3 The End of the Cybernetic Revolution and Possible Disappearance of K-Waves

The sixth K-wave (about 2020–the 2060/70s), like the first K-wave, will proceed generally during completion of the production revolution (see Grinin et al. 2016c: Chap. 6). However, there is an important difference. During the first K-wave the duration of the one phase of the industrial production principle significantly exceeded the duration of the whole K-wave. But now one phase of the K-wave will exceed the duration of one phase of production principle. This alone should essentially modify the course of the sixth K-wave; the seventh wave will be feebly expressed or will not occur at all (on the possibility of the other scenario see above). Such a forecast is based also on the fact that the end of the Cybernetic Revolution and diffusion of its results will promote integration of the World System and a considerable growth of influence of new universal regulation mechanisms. It is quite reasonable, taking into account the fact that the forthcoming final phase of the revolution will be the revolution in the regulation of systems. Thus, the management of the economy should reach a new level. K-waves appeared at a certain phase of global evolution and they are likely to disappear at its certain phase.

5 Conclusion: Some Possible Future Medical Technologies

5.1 Constant Health Monitoring as a Self-regulating Supersystem

Nowadays the boundary between medical diagnosis and treatment already becomes more and more imperceptible. Diagnostics is a constant necessary measure for disease controlling and drug dosage. During the final phase of the Cybernetic Revolution we expect breakthroughs in many fields of medical care. Thus, a very important direction of self-regulation can be associated with the development of the health monitoring system that will allow an early diagnosis and prevention of diseases. The key compounds of such devices are biosensors.

Biosensors are a good example of self-regulating systems and development of individualization (e.g., Cavalcanti et al. 2008). One can easily imagine that in the future biosensors will be able to become an integral part of human life fulfilling the function of a constant scanner of the organism or its certain organs and even transmitting the information about it to medical centers in case of potential threats or serious deterioration in the state of health. Built-in sensors will allow for controlling and regulating all vital processes, as well as prompting the time of drug intake and their dosage, time of physical activities and required exercises taking into account different circumstances, and recommending the most appropriate diet, etc.

Respectively, such mini-systems can be integrated into a large system which monitors a large number of people, for example in medical centers, therapeutic facilities, hotels, etc. We can forecast the decreasing number of hospitals, and such monitoring and remote online access can significantly relieve hospitals. One can imagine that such systems will be able to detect potentially dangerous situations and quickly respond to critical situations. That is a good example of prognostics and prevention of problems. We suppose that it will take much time to create such systems. Besides, there are complicated ethical and legal problems as regards to such monitoring as there always exists the danger that a watching 'Big Brother' will take advantage of this.

5.2 Artificial Antibodies and Growing Opportunities to Use the Immune System

There will never be any universal drug against all diseases. But strengthening the immune system is one of the universal directions which can transform this situation and help the struggle against different diseases. There is a special instrument of the human immune system—antibodies.

Antibodies are the molecules synthesized to fight against certain cells of foreign origin—antigens. The damage done by antigen usually leads to the destruction of foreign organisms and to recovery. Specific antibodies are produced for each antigen. They are produced by special immune cells—lymphocytes, which accumulate and circulate in the blood over the period of a lifetime. Thus, everyone has his own protective system based on the 'history of diseases'. It is one of the most important directions of development of individualization. Medicine is always connected with a patient's individuality. However, in the twentieth century there was a tendency towards mass medicine (connected with mass vaccination, preventive examinations, etc.). At present there are some signs of transition from mass medicine to personal/individual medicine, which is related to the general tendency of the Cybernetic Revolution towards individualization. But individualization to an even greater extent will be manifested when based on the unique characteristics of the organism, one of which is the immune system. Artificial antibodies can strengthen the tendency towards the individualization of medicine.

Scientists have repeatedly attempted to produce artificial antibodies. In 1970, Cesar Milstein and Georges Köhler found the method of producing the antibodies of a certain type, that is of monoclonal antibodies. Nowadays a focus of much medical research is into the production of antibodies by other means (Schirhagl et al. 2012) and also the creation of chemoreceptors (Dickert et al. 2001). Antibodies have already become widely used in pregnancy tests, in the diagnostics of many diseases, in laboratory experiments.

We suppose that during the final phase of the Cybernetic Revolution there will be a considerable progress in the creation of artificial antibodies and their acceptance by the organism. There is no doubt that progress in this field will lead to a breakthrough in medicine. The formation of artificial antibodies will play an important role in the prevention and treatment of many serious diseases, they will prevent the rejection of transplanted organs, etc. This will help make controlling the course of a disease easier and will help in suppressing the disease and defeating the disease if it is possible. Progress toward the creation of artificial antibodies will mean a significant growth of opportunities to control processes previously inaccessible for controllable interference and formation of self-regulating systems for regulation of such interference.

Control of programmed cell death (*apoptosis*) is one of the promising methods to defeat serious diseases including cancer. The researches into this field have been carried out since the 1960s. They show that some cells often die in strict compliance with the predetermined plan. Thus, the microscopic worm nematode's embryo consists of 1090 cells before hatching but later some of them die and there remain only 959 cells in the adult worm organism (Raff 1998; Ridley 1996). The mechanism of apoptosis is associated with the activity of signaling molecules and special receptors which receive the signal, launch the processes of morphological and biochemical changes, and as a result lead to the cell death.

An opportunity to trigger the self-destruction of pathogenic cells can make the struggle against diseases controllable. Besides, it would secure a rapid recovery without a long period of rehabilitation which is necessary after surgical intervention, chemotherapy or radiation treatment (it is an example of economy of energy and time for a patient). We suppose that during the final phase of the Cybernetic

Revolution medicine will be able to make progress in this direction and in the mature stages of the scientific-cybernetic principle of production to control it. In this case the movement toward creation of self-regulating systems will occur on the basis of the influence on the key elements of these subsystems of the organism in order to select the optimum regime in the context of certain goals and tasks. So in some cases it will be possible to cause the death of unwanted cells deliberately and in other cases to block the mechanism of death of necessary cells.

Also switching off the mechanism of cell self-destruction will help to save an organism from some diseases and, probably, to control the process of ageing. But it is only one of the possible ways to slow down the ageing process. On the processes determining ageing and opportunities to 'fight' ageing also see the monograph by Aubrey de Grey and Michael Rae (2007).

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