Facing the challenges of the Third Revolution in Biology

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ABSTRACT

In this article, it is proposed to revise research approaches in the field of biological sciences in Cuba, according to the international trends of technological convergence. New views are debated concerning to the Third Revolution in Biology and advantages of its implementations. Fundamental aspects of the Cuban higher education system for scientific careers and for the functioning of the national scientific system are revisited, also debating on the risks that inadequate strategies would imply for the future of national scientific development.

Keywords: Third Revolution in Biology, technological convergence, higher education, Cuban scientific system, biotecnology

Biotecnología Aplicada 2017;34:3411-3413

RESUMEN

De frente a los retos de la Tercera Revolución de la Biología. En este artículo se propone un redimensionamiento en el abordaje de las investigaciones en el campo de las ciencias biológicas a escala nacional en Cuba, a tono con el reciente fenómeno de la convergencia tecnológica en el contexto internacional. Se introducen los enfoques concernientes a la Tercera Revolución de la Biología y las ventajas que pudieran traer sus desarrollos futuros. A su vez, se tocan aspectos relacionados con las fortalezas actuales del sistema de educación superior para las carreras de ciencias y del sistema de ciencias en Cuba, y los riesgos que significarían en detrimento del posible desarrollo científico del país en caso de no implementarse estrategias acertadas en esta dirección.

Palabras clave: Tercera Revolución de la Biología, convergencia tecnológica, educación superior, sistema de ciencias cubano, biotecnología

Introduction

An additional challenge for Cuban Biotechnology and Medicine, in order to maintain the outstanding position achieved, is getting inserted in the Third Revolution in Biology, under full development [1-6].

As is well known, the discovery of DNA by James D. Watson and Francis Crick in 1953, considered the birth date the First Revolution in Biology, marked a significant turning point. This allowed mankind to understand the molecular and cellular bases of the most complex biological processes, with the DNA molecule as a support for biological information, its application to the study and modification of the biology of living systems and the analysis of their anomalies. Therefore, in the early 1970s, the handling of DNA from different organisms at cellular level served to produce new processes and products, as the basis of contemporary Genetic Engineering and Biotechnology.

The Second Revolution in Biology is universally accepted as the revolution in the field of Genomics, with emphasis on the sequencing of the Human Genome in 2000. On the one hand, the First Revolution laid the foundations of molecular biology, where the DNA molecule, the support of biological information inside cells (‘the hardware’ of processes), allowed to understand more deeply the biology of living systems and their anomalies. On the other hand, in the Second Revolution, the bases for understanding and manipulating the codes of the transmission of biological information (‘the cellular software’) were consolidated [2].

The conquests of the Cuban Life Sciences (mainly in Medicine, also includes veterinary sciences, agricultural sciences, and those related to the preservation and development of the environment, and in particular Biotechnology), are the consequence of the adequate and simultaneous combination of several factors: the political will and vision of the Cuban Leader of the Revolution Fidel Castro Ruz, the traditions of the Cuban biomedicine, the existence of a critical mass of experts committed to this great project and the effective and dynamic performance of outstanding scientific leaders; coinciding with the First and Second Revolutions in Biology. Knowledge revolutions (gnoseological character), with the process of social transformations and the real existence of political will have been factors supporting the success of Biotechnology.

Third Revolution of Biology

The Third Revolution in Biology consists, essentially and succinctly, in the convergence of Life Sciences with Physics, Engineering, Computing and Mathematics [1-3].

This convergence does not only lie in transferring tools and methods from Physics, Engineering, Computing and Mathematics to Biology, but also, it is presented with new approaches and paradigms. It is a deeper interrelation between these sciences to address the complex problems of biological systems where the converging sciences with Biology also benefit from that interaction.

At the same time, with the Third Revolution in Biology, other technological revolutions are taking place, accelerating and complementing it, among them are: the quantum revolution [4], nanotechnology;

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information technology, with prominent sites for data-intensive science or Big Data; and artificial intelligence, with the so-called Deep Learning. Due to this, quantum clocks, computers and sensors for biomedical uses are being developed, of higher sensitivity, resolution and accuracy of the measurements in several orders of magnitude. Another example is the increase in the variety and precision of biomedical images and living matter. New methods have been developed for modeling and quantum simulation; to generate, transmit and store energy; materials with new and surprising properties [4], or even new and improved versions of natural processes for the generation of fuels or the exploitation of renewable sources of energy.

Many of the regularities and tendencies of this accelerated inflection in development have been developing for only 10 years [1-3, 5]. Some distinctive features of the scientific and technological transformations that make up the Third Revolution in Biology are:

- Impetuous development of information technologies. Increase in capacities for the storage, processing and analysis of large volumes of information in databases, both of experimental information and their metadata.

- Design, synthesis and remote control of intelligent nanosystems. Manufacture of new molecular engineering tools at nanoscale.

- Increase in sensitivity, accuracy and resolution of quantitative measurement systems allowing the visualization of processes at all scales of the organization of matter, with a renewal of the arsenal of existing imaging methods and the creation of platforms for new ones.

- Convergence at the molecular and instrumental levels of diagnostic and therapeutic methods (Theranostics), for the evaluation and modification of biological systems [5, 6],

- Obtention and production of new materials, metamaterials and nanomaterials, with properties and characteristics compatible with new applications. Design, modification, structuring, creation and production of microfluidics and systems composed of few atoms, molecules or cells.

- Understanding of the kinetics of complex processes and their integration for the (re)creation, management, simulation and modeling of new complex systems.

- Dynamic controls of technological processes at molecular and cellular level, through the generation of new devices that replace, correct or complement biological functions.

Of each and every of the abovementioned points, and of others not addressed, there are many concrete and successful achievements that are currently pushing forward to change the approaches, paradigms, possibilities and the 'know how' and procedures in technological research and development (R&D) systems and healthcare in the area of Life Sciences.

The effectiveness of this depicting process of convergence of the Third Revolution in Biology is determined, to a large extent, by the effectiveness of the interconnections between universities and research institutes to rapidly progress from new discoveries into products [1-3, 5]. In this context, the inter-institutional links and the technical level of the scientific communities, together with the identification of projects and opportunities, the balance between applied research and basic developments, acquire a transcendental connotation for the generation of goods and services for all society.

However, the transdisciplinary nature of this recent Revolution in Biology and the traditional university structures in Cuba also pose challenges of organizational nature to the Higher Education System. Moreover, it demands to achieve visions beyond isolated disciplines and the flow of results to increase according to the most current global dynamics; and making optimal use of the available resources.

Advantageously, the Cuban Universities and other national Science, Technology and Innovation system comprise a number of research teams and scientific centers with high-value results in the fields of Biophysics, Bio-Engineering, Biomaterials, Bioinformatics, Bio-mathematics and medical equipment. In this line, care must be taken to avoid a relative dispersion in research lines, which could make them incoherent with the most far-reaching purposes and limiting them to low or medium impact objectives, ultimately reducing the R&D performance. Therefore, those centers and groups of experts constitute the nucleus for the design of an adequate organizational strategy, to create a more effective convergence between Natural Sciences, Mathematics, Engineering and Life Sciences, according to the most modern tendencies.

At the same time, it is imperative to increase the investments that benefit the R&D activities in the Life Sciences, that strengthen their qualitatively superior connections with Engineering, Physics and other Natural and Exact Sciences. Such inversions cannot be governed by classical canons or based on traditional concepts, neither in quantity nor in rhythm.

So, what impact could be expected in the medium and long term on health systems and society?

- A substantial increase in the effectiveness of access to health systems.

- An increasingly personalized medicine, shifting the center of attention from treatment to prevention more expeditiously. Also providing a continuous real-time diagnosis using micro- and nano-smart sensors, connected remotely for a more effective and dynamic preventive action.

- A more efficient management of all healthcare information and in a more integral way, as soon as it is generated in the National System of Public Health and among the different scientific activities. In this way, the functional connections of cause and effect between all the levels of biological organization from molecules and cells up to the organism, and from these to the environment, would be established; from research or clinical laboratory information towards its introduction in the surveillance and the epidemiological control.

- A better understanding of the quantitative differences between normal and abnormal conditions for the functioning of living systems at all levels of organization (molecule-cell-tissue-organ-organism-ecosystem-environment), with a systemic approach.

- Greater participation of healthy individuals and patients in decision-making about the therapeutic modes and behaviors in response to adverse events.

There would increase the connection and better inform healthy subjects and patients to health systems.

- Obtaining and applying new compounds, materials and substances to increase the dynamic control and local treatment of diseases. New medical treatments, nano-scale drug release mechanisms, and new abilities to modify genetic disorders. Decrease in toxic and secondary effects of treatments.

- A more sustainable and lower cost agrofood and agricultural production system.

- Greater systematic environmental monitoring at a massive scale of the ecosystem, with a better understanding of the dynamics of crops and biological and natural resources.

- Better conditions for the production and maintenance of farm animals, their protection against the occurrence of epidemics, adaptation to climatic conditions and the increase of productive yields in a sustainable manner.

- Generation and use of new sources of renewable energy, new systems carrying energy charges and their rational use, with power generation at micro and nano-scale.

- Use of waste and productive remnants with a contaminating load for their recycling, use as sources of renewable energy and reduction of their pollutant load for the environment.

Experts assert that this Third Revolution implies unusual advances not only in biomedicine but also in agricultural production, new forms of energy, environmental sustainability and national security [1-3], as well as the study and adaptation to climatic conditions. The convergence is a new paradigm that will produce cardinal advances in a large number of sectors of the society.

Hence, it is essential to weigh, quickly and deeply, the processes that take place as a result of these revolutions, and to design a course of action. Some of them could be:

1. Evaluate and discuss scientifically and at all levels of the National System of Sciences (projects, Scientific and Management Councils of research and innovation institutions, Scientific Societies and Academic Committees) the regularities, trends and opportunities that derived from the full insertion as part of the Third Revolution in Biology. The realization of action plans in the short, medium and long term, with a focus on sustainability and technological sovereignty.

2. Strengthen the existing links in a systematic way, both qualitatively and quantitatively, and generate new ones between the Universities, the companies linked to the research activity (for example: BioCubaFarma) and the entities linked to the activities of innovation, rationalization, and knowledge management at national level, for its coordinated action in the areas of biological sciences and engineering.

3. Increase the funding dedicated to R&D, by including basic projects duly substantiated, that favor the strategic insertion of wide scope technology platforms and of feasible implementation in the medium and short term, and oriented to the establishment of proofs of concept that could derive in long-term strategic projects. This, in turn, would result in a sustainable financing cycle to bring together multiple actors at society level and achieve the necessary productive chain of research programs in biological sciences, biotechnology, pharmaceutical sciences and biotechnology and biomedicine.

4. Modify the undergraduate and postgraduate curricula in the careers of Physics, Mathematics, Chemistry, Biology, Engineering and Medicine, focused on their strengthening through multi-disciplinary and transdisciplinary approaches to achieve the required technological and scientific progress.

5. Increase and sustain actions of communication, dissemination and debate on these issues at society scale, starting from the scientific community itself and ramified towards the educational environments.

Otherwise, the implementation of slow-running strategies or their absence could compromise the opportunity brought by this Third revolution of the Life Sciences, further risking the relative excellence achieved by the Cuban biotechnology sector in the pharmaceutical and biomedical fields, and a foreseeable drop in the added value of products and services and their competitiveness. Therefore, the aim is to preserve the technological independence and autonomous development in these areas. We have the oportunity to face this new challenge.

Declaration of conflicts of interest

The author declares the absence of conflicts of interest. The ideas and opinions expressed here are personal views and should not be considered as official or institutional statements.