BASIC SCIENCES FOR SUSTAINABLE DEVELOPMENT

Discovery of the DNA: impact on health, water quality, nutrition and food security

March 15, 2023

Hybrid-mode | Via Zoom and at the Academy of Sciences of Lisbon, Portugal

At a time when scientists are urged to develop high technologies, a question immediately arises – What technology can be developed/improved without the contribution of basic sciences? It is impossible to run without putting one´s feet on the ground. Likewise, it is impossible to develop new and reliable technologies without the knowledge derived from basic sciences, including the basic principles underlying the different technologies. However, the universal access to the discoveries made by basic sciences, to new and promising technologies and to the desired progress towards sustainable development, equity and well-being, is far from being achieved.

Acesso Zoom

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ACADEMIA DAS CIÊNCIAS DE LISBOA

IYBSSD2022 Ano Internacional das Ciências Básicas para o Desenvolvimento Sustentável

DNA: from the discovery to applications

Considering the need to emphasize the role of basic sciences in technology development and it's seminal contribution to human development and well-being, the Institute of High Studies of the Academy of Sciences of Lisbon will address the impact of the DNA double helix elucidation, one of the greatest scientific discoveries honoured by the Nobel Prize in Physiology or Medicine in 1962. When this research was performed, no one could imagine what would be the impact on diverse scientific domains, generating the knowledge necessary for the development of technologies relevant to Human health, Agriculture, Biodiversity, Food security, Nutrition and Water quality. This meeting aims at bringing together scientists to illustrate how basic sciences contribute to emerging technologies with impact on sustainable development and human well-being.

10h00 - 10h10 *Opening Ceremony*

10h10 - 10h30 *Discovery of DNA*
- Alexandre Quintanilha (ACL, PS)

10h30 - 11h00 *Messenger RNA and new vaccines*
- Miguel Prudêncio (ACL, FM-ULisboa, iMM)

11h00 - 11h30 *Bacterial genomes and resistance to antibiotics*
- Raquel Sá-Leão (FCT NOVA/ITQB)

coffee break

12h00 - 12h30 *Synthetic biology and food sustainability*
- Maria Salomé Pais (ACL)

12h30 - 13h00 *Human identification*
- Francisco Côrte-Real (FMUC)

lunch

14h30 - 15h00 *DNA alterations in diagnosis and treatment of cancer*
- Manuel Sobrinho-Simões (UPorto, i3S, Ipatimup)

15h00 - 15h30 *Water: the challenges of the cradle of life*
- Nuno Brôco (CEO AdP Valor)

coffee break

16h00 - 17h00 *Round table*
Moderator - Jorge Soares (ACL)

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Opening Words

Maria Salomé Soares Pais (ULisboa, ACL)

On behalf of Mr. President of the Academy of Sciences of Lisbon and as President of the Institute of High Studies of this Academy, I welcome you to Cumpriment Greetings to all participants. I greet and say a very special word of thanks to our speakers who agreed to participate in this seminar commemorating the international year of basic sciences for the development and sustainability. The United Nations 2030 agenda constitutes a global challenge for sustainable development, believing that this is the way to Transform our World. The sustainable development goals (SDGs), are of crucial importance for the humanity and the planet. As far as humanity is concerned, it is important to eradicate hunger and poverty so that every human being can have a dignified life, be able to use their abilities in equality and live in a healthy environment. As for the Planet, it is urgent to protect it from degradation resulting from unsustainable consumption and production or from extreme phenomena due to climate change. If it is not the case, the needs of present and future generations are compromised. Every human being has the right to a prosperous and full life from the economic, social and technological point of view. A prosperous, inclusive, enlightened society is a society capable of building the present and the future and living in peace. Without peace there is no development and without development there is no peace.

The changes resulting from globalization require social, political and economic organizations based on scientific and technological progress that can only be achieved with the decisive contribution of basic sciences. These are crucial to respond to the global challenges, namely access to food quality, basic health care, understanding the effects of climate change, to the accelerated extinction of biodiversity and natural resources. Without the contribution of basic sciences, technological development and innovation, are difficult to understand this dependency being often misunderstood.

The basic sciences associated with the social sciences and Humanities constitute a strong basis for the formation of informed citizens, professionals, policy makers and entrepreneurs capable, in conscience and free of prejudices, make decisions that positively affect their future in the world. The basic sciences constitute the base of support for the 2030 agenda of the United Nations (People, Planet, Prosperity). Having in mind the humanity, the planet and the prosperity, the eradication of poverty - a purpose to which can join peace- is an absolute requirement to transform our common world for the well-being of future generations. The use of basic sciences is the challenge for building sustainable development, believing that's the way to transform our World. The United Nations General Assembly in 2021 drew attention to the importance of basic sciences, emphasizing that these and the technologies emerging from them intend to respond to the needs of humanity and provide more health and well-being to individuals, communities and societies.

In this seminar will be presented the enormous contributions of the DNA discovery (resulting from basic science) for Human development and sustainability in the Planet.

I wish you a great day and invite everyone to participate in the round table that will take place after the conferences.

I give the floor to Professor Jorge Soares.

Abstracts

DNA discovery

Alexandre Quintanilha

(UPorto, ACL, Parliment Deputy)

It was in 1869 that Friedrich Miescher isolated and described a new molecule, which he named nuclein, later identified as DNA.

Understanding the function and structure of DNA involves two fascinating stories separated by nearly a century.

The first has to do with two of the most important figures in biology in the 19th century, namely Charles Darwin and Gregor Mendel.

The second, around the unavoidable names of Francis Crick, James Watson and Rosalind Franklin.

Darwin presented his work to the Linnean Society in 1858 along with that of Alfred Wallace on the same subject, publishing “The Origin of Species” the following year. Gregor Mendel presented his work on the laws of heredity to the Brno Natural History Society in 1865, publishing these results in 1866.

Today we know that Mendel read and annotated “The Origin of Species”, but everything indicates that Darwin never got to know the work that Mendel had sent him, probably because it was published in German.

It was the "rediscovery" of Mendel's Laws, independently, by Hugo de Vries, Carl Correns and Erich von Tschermak-Seysenegg in 1900, which allowed Ronald Fisher to publish in 1918 the work that we now call the modern synthesis of Evolution theory. More than half a century had passed since the seminal contributions of Darwin and Mendel.

The second story results from a fertile “marriage” between physics and biology. The idea that X-ray diffraction could be the technique of choice for studying the structure of biological molecules emerged in the first decades of the 20^{th} century as a result of the work of William Henry Bragg and his son Lawrence Bragg.

Dorothy Hodgkin was one of the first to use this technique to clarify the structure of cholesterol and penicillin. John Kendrew, Max Perutz and Linus Pauling are part of a growing number of investigators who followed the same strategy.

The "race" to decipher the structure of DNA was intense in the late '40s, early '50s. Linus Pauling put forward the (wrong) idea of a triple helix in 1952. But it is the image (nicknamed “Photo 51”) that Rosalind Franklin and Raymond Gosling were able to obtain from X-ray diffraction by the hydrated DNA molecule, which allows Watson and Crick to propose the correct model of the double helix. Watson and Crick's article as well as that of Franklin and Gosling's were published in the same issue of Nature in 1953.

I would like to end by emphasizing the enormous importance of the Cavendish Laboratory in the so-called “marriage” between physics and biology. Founded in 1874, as the physics department of the University of Cambridge, it had the brilliant idea of attracting physicists, chemists, biologists and mathematicians to work together, work which has already resulted in three dozen Nobel prizes.

Messager RNA
and new vaccines

Miguel Prudêncio
(ACL, FM-ULisboa, iMM)

Despite stark warnings by much of the scientific community, when the SARS-CoV-2 pandemic hit, most of the world was caught by surprise. Almost overnight, one country after another was forced to implement measures to restrict the propagation of the infection. “Flatten the curve” came to be an expression known to all, as it became apparent that only by keeping infection rates under control would health services be able to cope with the needs of their citizens. The scientific community became actively engaged in a race to efficiently diagnose, treat and protect against COVID-19. Funds became readily available for researchers to seek these crucial objectives, and scientists started working around the clock to meet them. It soon became clear that effectively curbing the pandemic situation would largely depend on the availability of effective vaccines against the disease caused by SARS-CoV-2, particularly against its more sever forms. A plethora of vaccine candidates were created, some of which pushing the boundaries of the vaccination field beyond what used to be its state-of-the-art. Within only a few months, a continuously evolving constellation of vaccine candidates against COVID-19 emerged, employing “classical” approaches to vaccine development, as well as emerging methodologies. Among the latter, mRNA-based vaccines were developed and clinically tested with unprecedented swiftness, and soon became a pivotal tool in the fight against COVID-19, particularly in the so-called Western world. However, the technology that made this possible was not developed overnight. Quite on the contrary, mRNA vaccines were made possible by decades of previous research on the RNA molecule, and by an understanding of its potential for medical interventions including, but not limited to, vaccination. The administration of billions of doses of mRNA vaccines against COVID-19 clearly confirmed their very high safety and efficacy, arguably constituting the widest real-world validation of a medical intervention in the shortest time ever. The importance of this achievement can hardly be overestimated. In fact, not only did this constitute a decisive tool in the fight against COVID-19, decisively contributing to leading the world away from the pandemic situation it found itself in, but it also paves the way for the development of future medical interventions. Although the exact scope of these achievements is hard to predict, it is safe to say that scientists will build upon the accumulated knowledge on RNA built over the years that preceded the COVID-19 pandemic, as well as on the scientific advances brought about by the latter, to deliver not only new mRNA-based vaccines against infectious diseases for which they still do not exist, but also mRNA-based therapeutics against cancer and ageing-related diseases that may truly revolutionize medicine.

Bacterial genomes and resistance to antibiotics

Raquel Sá-Leão

(FCT-NOVA/ITQ)

Antibiotics are viewed by many as the greatest therapeutic revolution in the history of medicine. They are largely responsible for the 10-year extension in longevity witnessed in 1940's. When antibiotics were introduced in clinical practice infectious bacteria were generally susceptible to them. However, its intensive use led to emergence of antimicrobial resistance. Global travelling, in addition, contributed to the dissemination of the most successful antibiotic resistant bacteria. Today, the problem of antimicrobial resistance is a serious threat to human health often compromising treatment of infections. In this communication, I will give an overview of how antimicrobial resistance is acquired and "imprinted" in bacterial genomes. I will also illustrate how DNA-sequencing technologies are contributing to fight the problem of antimicrobial resistance.

Synthetic biology and food sustainability

Maria Salomé Soares Pais

(ULisboa, ACL)

The humanity is facing constrains and challenges. Biodiversity is drastically declining; world resources are under tremendous pressure.

Extreme weather events (droughts, heat, flooding, tropical storms and wildfires) impact on soil, plant and livestock health and drastically compromise agriculture and goods production. By 2050, humanity likely have grown to around 10 billion people that demands a 50% increase of agricultural products, causing high pressure on agriculture and natural resources.

The global ecological footprint continues increasing faster than global biocapacity particular in Asia. 5,2 billions of people is expected to face water stress by 2025 thus a shift to sustainable agriculture is needed. The 2022 report jointly published by FAO, IFAD, UNICEF, WFP and WHO, revealed that around 2.3 billion people in the world (29.3 percent) were moderately or severely food insecure in 2021;almost 3.1 billion people could not afford a healthy diet in 2020; estimated 45 million children under five years were suffering from wasting, increasing children's risk of death up to 12 times; 149 million children less than five stunted growth and development due to chronic lack of essential nutrients, while 39 million were overweight; 11 million people die every year due to unhealthy diets and rising food prices will get worse.

Although the green revolution played an important role on increasing agriculture production through increased land, irrigation and agro-chemicals use, it is commonly recognized its long-term negative effects namely land degradation, over-use of ground water, soil and water pollution and biodiversity erosion.

The discovery of DNA structure by Watson and Crick (1953) opened avenues to further genome sequencing of plants and animals including man.

The need for increasing productivity, resistance to biotic and abiotic stresses, and better foods able to satisfy consumers, moved scientists to use genomic approaches as a way to cope with plant and animal diseases, decreased food production and development of food well accepted by consumers. These expectances were made possible due to a number of success stories achieved through biotechnology (maize, cotton resistant to pathogens among others) included in the category of genetically modified crops (GMOs). Citizens resistance to biotechnology played a significant role in limiting the use and spread of the obtained products.

Considering the increase in food supply, it appears that by now the world produces food more than enough to satisfy the dietary needs of global population. It looks like good. But in 2020 almost 3.1 billion people could not afford a healthy diet and estimated 45 million children aged less than five suffered from wasting.

The data available for developed and developing countries reveals inequality in incomes and other means of subsistence which explains large differences in access to food with hundreds of millions of undernourished people. Many other constrains like access to facilities for food storage, cooking equipment and clean water should be added to understand this reality. Food production must be accompanied by increasing demand, equitable food access and adequate food utilization. There is a need for education of consumers from developed and developing countries in order to promote healthier food consumption patterns.

According to Ghebreyesus (WHO Director-General) We must work together to achieve the 2030 global nutrition targets, to fight hunger and malnutrition, and to ensure that food is a source of health for all 9,7 billion population by 2050.

How to achieve Food Sustainability?

Food sustainability became a topic of more and more public concern. A significant amount of resources is spent for the global food system. Resource-intensive farming systems, responsible for massive deforestation, water scarcity, soil depletion and high levels of greenhouse gas emissions, can no more deliver sustainable food and agricultural production.

Food sustainability implies producing food by making efficient use of natural resources without compromising the quality of communities, life and environment.

Food sustainability concern is feeding the world today and tomorrow, without increasing the world’s agriculture system. To answer the challenges agriculture is facing, major transformations in agricultural systems, rural economies and management of natural resources are needed.

Agriculture and synthetic biology have a tremendous potential to ensure food supply for healthy diets of people living in our planet.

The challenge is to take profit of scientific advances to transform or bring novelty to agriculture.

What about food sustainability?

Agriculture, the base of food production, is responsible for soil and water contamination with fertilizers and pesticides and needs high water consumption. Science and innovation, latus sensus, are crucial to find solutions for food sustainability Biotic and abiotic stresses negatively impact agricultural productivity and health. There is an increasing need to achieve yield and sustainable production, reducing the consumption of fertilizers, and pesticides, land resources and water. At the same time there is an increased demand for nutrient-rich and healthy foods.

Synthetic biology constitutes an important tool to nourish growing populations with more and better-quality food without increasing the impact of climate change.

Gene editing and synthetic biology are promising technologies for food sustainability since they can be used to reduce chemicals enabling soil quality improvement with immediate impact on food quality and human health. Gene-editing technology, widely applied in synthetic biology, can quickly, efficiently, and accurately create organisms more suitable for the production of high value-added products.

How can synthetic biology contribute for food sustainability?

According to Khalil and Collins (2010) Synthetic biology is bringing together engineers and biologists to design and build novel biomolecular components, networks and pathways, and to use these constructs to rewire and reprogram organisms. These re-engineered organisms will change our lives over the coming years, leading to cheaper drugs, 'green' means to fuel our cars and targeted therapies for attacking 'superbugs' and diseases, such as cancer. The promises of synthetic biology ten years after its beginning only depends on human imagination and on societal problems of its applications.

Since the discovery of DNA structure and the capacity for genome sequencing of near every organism, synthetic biology is responsible for a third biotechnological revolution.

Design /re-design of proteins, design and production of DNA sequences, manipulation of microorganisms is having impact on different industries namely food industry. Great acceleration can be foreseen in the production of new enzymes and products important as food and food supplies.

Synthetic biology for more and better food

The use of synthetic symbiotic bacteria and fungi may enhance the capacity of plants to use phosphate and nitrate from the soil and decrease the need of water supply. It also increases yield production decreasing soil contamination which results on more food with better quality preserving nature.

The knowledge of bacteria and fungi responsible for nodule and mycorrhizal associations in plants can be used to select microbial strains with desired functions and combine them to form synthetic microbiomes for engineering plant microbiome. Synthetic root-associated microbiota may reduce plant diseases, promote growth and resistance to environmental stresses. The production of synthetic microbiomes enables the control of its microbial composition. Since the bacteria and microbes currently modified are a very small amount of the total biodiversity, increasing knowledge of the microbial species and their features is needed to make them more suited for the purpose.

An important contribution is from Pivot Bio Comp. that launched in the market a biological nitrogen fertilizer for corn (PROVEN). This product is based on a γproteobacterium (KV137) engineered to switch on the genes necessary to fix nitrogen. This bacterium with modified genome is the active ingredient of the liquid fertilizer PROVEN. This synthetic bacteria strain attached to the roots of the plant converts atmospheric nitrogen into ammonia. There is no release of nitrates to groundwater which decreases soil water pollution. N2O emissions to the atmosphere are also decreased. The use of this bacteria reduces the need for chemical fertilizers and increase yields of around 211 litters.

South et al. (2019) introducing synthetic glycolate metabolic pathways in tobacco chloroplasts, succeed to increase photosynthetic quantum yield by 20% and stimulate crop growth and productivity.

Increased yield production, essential for food supply, contributes for feeding a growing population with better quality food, preserving biodiversity.

Synthetic biology and plant diseases

The increased impact of global changes on agriculture economic losses due to biotic and abiotic stresses was a driver for the application of gene editing technologies to different crops. Genome editing, particularly through CRISPR-Cas2, has been used to improve resistance namely of tobacco, rice, cotton, Arabidopsis, cassava, banana, cucumber, grape, wheat, apple, orange, papaya, cocoa to virus, fungi and bacteria. Direct targeting of viral genomes by CRISPR-Cas2 was developed as a way to provide flexible and durable resistance to different pathogens. In rice, researchers used this technology to modify pathogen genes responsible for pathogen growth in the host.

Engineering stress tolerance holds substantial promise for increasing disease resistance. The resistant plants showed improved yield which brings hope for use in different food crops to enhance yield production, a promise to achieve the zero-hunger goal of MDGs.

Scientists believe that CRISPR-Cas2 can also be used to quick domesticate wild plants and make them suitable as food; edit genomes for de novo speciation and edit mitochondria and chloroplast genomes to improve photosynthesis, which will contribute for increasing yield production.

Synthetic biology and changing diets

Meat rich diets, in particular from ruminants are associated to high environmental costs (clearing of forests for pasture) and greenhouse gas (methane and nitrous oxide) emissions. Synthetic biology plays an important role in finding meat substitutes.

Several companies are launching products derived from synthetic biology into the market. An example is the production of soy leg-hemoglobin by yeast Pichia pastoris engineered with DNA of soy LegH enabling the large scale production of this colorant that added to plant based hamburgers give them a more meaty flavour and aroma. According to ImpossibleFoods, compared to a beef patty, the Impossible Burger requires 96% less land and decreases 89% greenhouse gaz emissions.

Conservation and sustainable use of biodiversity

Search for food ingredients and supplies is responsible for biodiversity degradation. Synthetic biology can help in reducing use of plants for production of oils or food supplies. An example is the production of palm a coconut oil. Palm oil, a versatile vegetable oil used in frozen products like pizzas and biscuits, shampooing or lipsticks is obtained from the oil-palm tree fruits. It is a major driver of deforestation worldwide.

Companies like C16 Biosciences and No Palm developed a next generation palm oil produced by synthetic microorganisms cultured in fermenters and described it as ‘conflict-free’ and ‘deforestation-free’ product.

Ginkgo bioworks engineered yeasts with synthetic sequences of gene from plants flavors metabolic pathway to produce flavors in fermenters, without spoiling biodiversity.

Synthetic biology, transforms enzymes, bacteria, yeasts, fungi or algae, into ‘cell factories’ by instructing the organism’s DNA to express molecules of interest that can be produced by controlled fermentation. Can be used to develop new biologically based systems for addressing environmental needs and food sustainability.

Synthetic biology aims at making food industry more sustainable by changing the way ingredients are produced resulting on deforestation-free products.

Benefits versus constrains of synthetic biology

The potential benefits of synthetic biology are tremendous. But could sourcing ingredients from labs instead of farms have a negative impact on sustainable social development?

Although Synthetic biology present opportunities for raising food production to decrease hunger and poverty and meet new challenges to protect life in the planet, it also carries the risk of increasing disparities between low- and high-income countries at the same time that significant ethical concerns are being addressed.

Human identification

Francisco Corte Real

(FMUC)

Human identification based on genetic markers was started in 1984 by Alec Jeffreys when he found that some regions of the genome were different among different people. This way of identifying people was applied, for the first time, in an investigation related to an immigration process. A rape and murder investigation of two young women in Leicestershire, England, also benefited from the application of this new form of human identification, having contributed to the initial exclusion of a suspect and the subsequent conviction of the author of the crimes. Thus, the forensic application of genetic markers began, which constituted a real revolution in the process of criminal investigation and identification of unknown bodies, also greatly benefiting the processes of kinship investigations.

This new methodology was quickly accepted by the scientific community and the judicial system of many countries, although many questions were raised about the statistical interpretations presented and the technical methodologies on which it was based.

A very significant step forward in the process of human identification was also the development of the polymerase chain reaction methodology by Mullis and Faloona, in 1987, by enabling the successive duplication of DNA chains and, consequently, the obtaining of millions of copies of the original sequence, even in situations where the DNA was degraded or in very small quantities.

In the 1990s, after several attempts, the use of microsatellites, regions of the genome with a variable number of tandem repeats, began to be the preferred methodology. Throughout this decade and the next, there was a very significant effort by the scientific community towards the harmonization and dissemination of the best methodologies for analysis and interpretation of the results obtained not only with microsatellites but also with other types of markers that meanwhile began to be used. In the context of biological investigations of kinship, individual genetic identification or investigations in criminalistics, it is now common not only to study autosomal or sexual chromosomes microsatellites, but also to study single nucleotide polymorphisms, among others, not only of nuclear DNA but also of mitochondrial DNA.

Informative markers of ancestry (geographical origin) and phenotypic markers (eye color, hair color, etc.) can be very useful tools for forensic genetics. Also, epigenetics, allowing the discrimination of true twins, knowledge of the type of sample 3 under analysis, its age, among many other aspects, has brought new possibilities to forensic genetics. New equipment and new methodologies, such as massively parallel DNA sequencing, are providing extremely relevant information to this area of forensic sciences. All this evolution naturally raises many important ethical and legal issues, which must be carefully analyzed before introducing new methodologies in forensic practice.

Among all forensic sciences, forensic genetics is, in recent decades, the one that has undergone the greatest evolution, the one that has achieved the greatest methodological harmonization and the one that has most contributed to the security of the human identification process possible today.

DNA alterations in diagnosis and treatment of cancer

Manuel Sobrinho Simões

(UPorto, i3S, Ipatimup)

The discovery of the DNA structure has made a major impact in human health for innumerable reasons including the progress towards the understanding of many diseases due to the establishment of a genetic basis for pathologic conditions. This assumption is particularly true regarding hereditary disorders caused by germline mutations, and neoplastic diseases, namely malignant tumours (cancers) caused mostly by somatic mutations.

The aforementioned assumption is summarized in two sentences: "Cancer is a genetic disease" and "More than 90% of cancers are caused by (associated to) environmental factors".

Following the usual approach, neoplastic diseases, like many other "phenotypes", are the end product of the interaction of environmental factors (tobacco, obesity, microbiota, …) with the respective genotypes. In practical terms, most (if not all) interactions, involving always the tandem environment and genotype, lead eventually to cancers via inflammation(s) including immunological reaction and tissular microenvironment that requires space and time.

In order to present and discuss DNA alterations in diagnosis and treatment of cancer, we will start by defining precisely (and well documented as far as possible) the concept of cancer – "Highly regulated, successful, invasive clone of our own tissues". Together with this definition, we will address the different steps of oncology development – neoplastic transformation, progression, invasion and generalization – having DNA alterations underneath genetic instability leading to clonal selection and clonal expansions which are crucial to reach the final genotypic and phenotypic heterogeneity that is typical of cancer.

Besides approaching the etiopathogenesis of cancer through the study of DNA alterations in order to clarify, two main questions – Why and How? – we will also address diagnosis (How? Namely through histopathology) and treatment of cancer(s). The last point epitomizes the importance of DNA alterations in Precision Medicine in the context of Personalization.

Water: The challenges of the cradle of life

Nuno Brôco

(CEO AdP Valor)

Water, a natural resource essential to the genesis of life on our planet, remains, billions of years later, as a key resource for ecosystem services. Today, however, we face multiple and complex challenges in the sustainable management of this resource, the authentic cradle of life.

The management of water by mankind emerged with the transition from the nomad to sedentary life mode. Although irregular, there have been periods of great evolution, such as in ancient Greece, where major water storage and transport infrastructures appeared, but also the awareness that water on the globe is a singular resource and that it is renewed cyclically. In the Middle Ages, in Europe, the evolution of water and sewage management strategies was minimal, culminating directly, or indirectly, in the emergence and prevalence of devastating pests and waterborne infectious diseases. By contrast, in South America, and before colonisation by Europeans, the Aztecs had significant water and wastewater transport infrastructures in place, using wastewater to fertilize agricultural crops, which promoted remarkable demographic expansions.

It is in the 18th century, with the evolution of life sciences and microbiology in particular, that the first treaties highlighting the link between public health and water quality are established and that the relationship between the growth of cities, poor health conditions and the emergence of various diseases, especially cholera, is recognized. In the 19th century, benefiting from the industrial revolution, technological solutions applied to the water sector appeared, focusing on wastewater treatment, using environmental microorganisms for the removal of organic matter and subsequent limitation of the circulation of pathogens in the flows generated by water use.

In the 20th century, although in an empirical way and without integration nor informed manipulation of microbial metabolic pathways, there was a proliferation of different biological treatment solutions and the control of pathogenic species in water for public supply.

In Portugal, the importance of the access to water and the evolution of water services have been well documented since the founding of the nation. There was historical concern about the scarcity of water in the Lisbon region, with different solutions evolving over the years. At the time, the country's poor preparation in wastewater treatment also resulted in successive and numerous outbreaks of waterborne diseases. Since 1974, the evolution of water and sanitation services and underlying indicators has been exponential, more marked after 1990, and today they are benchmark references at the world level.

Water is now more recognised than ever as a circular resource with multiple interfaces with other sectors. The reuse of water and derived products also calls for a connection with the One Health paradigm. In this context, microbiology is a central linking element and a guarantee of balance in the various dimensions with which the water manager maintains a relational balance, using knowledge of the basic life sciences to establish partnerships or barriers with the vast microbial ecosystems.

This balance in water management faces today a set of disruptive new challenges, imposed by the exponential growth of the world's human population, the increasing access to water, the agglomeration of populations in megacities, the mobility of people and animals, social inequalities, the invasion of natural, pristine areas, but also the emergence of antibiotic resistance and the effects of climate change. The collective awareness of the value of water combined with inter-sectoral collaboration, with close links to life sciences, which today benefit from very powerful tools (omics, computational biology, artificial intelligence), promise empowerment in the management of water resources.

However, in some fields of cooperation, the value-added synergies established between water management and the life sciences domain have been little exploited. For example, more than a century after the discovery (Ardern and Lockett, 1914) and implementation of activated sludge technology on an industrial scale, the biological treatment of wastewater using this technology remains empirical, poorly grounded in mechanistic knowledge of microbial community interactions and metabolic pathway engineering.

In counter-cycle, the areas of knowledge related to wastewater epidemiology had a major accelerator in the last three years, related to the SARS-CoV-2 pandemic, which created fertile ground for the explosion of knowledge and partnerships in this field. In fact, it is now recognised that wastewater treatment plants (WWTPs) hold unpredicted potential that far exceed the basic functions of environmental protection, being a powerful tool for monitoring biomarkers with public health interest. In the case of the COVID-19 pandemic, it has been amply demonstrated, via national and international efforts, that wastewater can be used in addition to syndromic/clinical surveillance to monitor viral circulation in the community, as an early warning system for new outbreaks, and to investigate the genetic diversity of SARS-CoV-2.

In the COVIDETECT project, we developed new methodologies for the detection, quantification and identification of SARS-CoV-2 variants/lineages in wastewater treatment plants located in the large urban centres of Lisbon, Cascais, Gaia and Guimarães, monitoring about 20% of the national population and covering regions with high disease prevalence.

Additionally, the circulation of the virus in the drainage networks of the effluents from the Hospital Curry Cabral, in Lisbon, the Hospital Eduardo Santos Silva, in Vila Nova de Gaia, and the Hospital Senhora da Oliveira, in Guimarães, was monitored, enabling the establishment of correlations with the epidemiological indicators generated by clinical surveillance.

In the SARS-Control project, the scope of the studies was broadened to assess the efficiency of wastewater treatment plants in removing the genetic material of the virus, and the effect of different treatment schemes, with particular attention to the points of interconnection with natural systems (discharge of treated water, reused water and sludge). The taxonomic and functional characterization of the different flows by metagenomic approaches allowed the identification of diagnostic biomarkers and also useful biomarkers for informed WWTP operation purposes.

The knowledge and experience generated were openly shared within the national ecosystem and with the European Commission (EC) and helped to define the moulds of EC Recommendation no. 2021/472, which calls for the implementation of a SARS-CoV-2 monitoring system in the European population. In this context, a third project was developed involving the systematic monitoring of SARS-CoV-2 in sewershed covering more than 30% of the national population, in a partnership extended to a wide range of utilities, national authorities (APA and DGS) and academia. The information is automatically reported and shared with the competent authorities and the European Commission, in a network that will cover the EU space.

Basic life sciences will be at the centre of several partnerships among academia, utilities, government sectors and water quality regulators, being critical in the sustainability of water services, in the promotion of more robust and integrated One Water and One Health strategies, ultimately contributing to a more resilient and sustainable planet.