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The Role of Scientists in a Human-centered Society

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Abstract

Scientists have an important role not only in avoiding inappropriate and dangerous decisions, but also advising policymakers and other stakeholders about the best and wiser moves to make towards a human-centered society, thereby fomenting scientific knowledge and enhancing cross-cultural connections and joint research. They should also not forget the objective limitations of Science, which is always incomplete. With this purpose, we stress the importance of transferring knowledge among all scientific disciplines, using a transdisciplinary cross-talks approach. A few examples of how this may be done are presented in the paper.

1. Introduction

Science and technology are essential tools for innovation. To reap their fullest social potential, we need to articulate and solve the many aspects of today's global issues that are rooted in the political, cultural, industrial and economic realities of the human world.

> *"There are some objective limitations to Science itself. Science is still faraway from its goal of knowing the truth, which it always finds to be incomplete; also, science is not the only way to search for Truth."*

Our society is witnessing an era of ever-faster growing revolution at all levels, in an exponential spiral pace that sometimes may awaken a feeling of vertigo. It doubtless goes towards objective improvements in humanity and nature.

However, the society is not immune to eventual serious unintended consequences. Scientists have to be alert, therefore, in not only avoiding inappropriate and dangerous decisions, but also advising policymakers about the best and wiser moves to make, since having a human-centered society is advantageous to everybody.

We should not forget that there are some objective limitations to Science itself. Science is still faraway from its goal of knowing the truth, which it always finds to be incomplete; also, science is not the only way to search for Truth. There are other valuable ways, such as philosophy, ethics, and religion, which are unfortunately limited too, because we always arrive at concepts of reality which are unintelligible to reason. Now or later, we will always find unintelligible mechanisms that are "left face to face with the awful mystery which is reality" (Dampier, 1971, p 501).

Before elaborating on these points, we will start clarifying some conceptual generalizations of interest in this context.

2. Conceptual Generalities

What do we understand from Science? Etymologically, the term "Science" comes from the Latin *scientia* (*scire* = to learn, to know), meaning a process of studying and knowing the fundamental laws of nature, through a dialogue between theory and experiment. It is one of the most remarkable inventions of humankind, a source of inspiration and understanding, which lifts the veil of ignorance and superstition, is a catalyst for social change and economic growth, and saves countless lives.

The function of science is to expand continually our knowledge of the phenomena of nature, giving us an insight into the complex interrelations of phenomena, or rather between the concepts used to interpret those phenomena.

Whereas in other languages, like German (*Wissenschaft* = *Naturwissenschaft* & *Geisteswissenschaft*), the extension of the concept coincides with the extension in the classical Greco-Roman times, in English the word "science" is limited to natural sciences, also known as "hard sciences", something done in a laboratory; which involves taking measurements with instruments, accurate to several decimal places; and controlled, repeatable experiments where you keep everything fixed except for a few things that you allow to vary. Areas that often conform well to these stereotypes include chemistry, physics, molecular biology...

This divide between natural sciences on the one side, widening our knowledge of the phenomena of the nature and the relation between the different concepts used to interpret them, and philosophy and arts, on the other side, focused more on human origin and destiny, the project of life, the *Weltanschauung*, even when it realizes its impossibility of achieving this purpose because there is no human way of solving everything, started in the 19th century (indeed, the word "scientist" was not coined until 1833) and according to Richard Holmes (2016), it was destructive as it was neither a natural nor a necessary divide.

They are traditionally divided between a primarily **basic** science, which studies the fundamental laws of nature: in a free search for progress of pure knowledge, from microcosms (atoms) to macrocosms (universe), and a secondarily **applied** science on how the power of thinking can be increased by pursuing useful purposes and eventual specific practical advantages like medicine, engineering, industry, cyberspace, economics, quality of life, environmental and climatic changes…

A new call to abolish this traditional division came from Venkatesh Narayanamurti, former Dean of Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS), in 2008, who described it as artificial, as it assumes a linear relationship that does not always exist—discovery goes both ways, while inventions draw on scientific knowledge and scientists gain insight from new devices and applications. Narayanamurti proposes organizing science as a cycle that moves from discovery to invention and back again, a highly nonlinear model, because they must feed on each other, in a cross- and interdisciplinary work that breaks down disciplinary walls and encourages collaboration, which has been successful in some of the top scientific institutions. Some of the world's most important inventions were made not by basic scientists and applied scientists working sequentially in isolation, but by those who teamed up, sharing ideas and insights and even sometimes switching roles in cross- and interdisciplinary work. For instance, Bell Labs, home to many important discoveries, such as the development of the transistor in 1947, which laid the foundation for modern electronics and earned eight Nobel Prizes, blurred lines between disciplines, talented personnel, ample resources, and leadership (Powell, 2017).

"No single discipline can capture reality fully or claim to have the complete knowledge."

There are other disciplines such as social sciences (sociology, economics, political science, history…), and human sciences (philosophy, ethics, theology, art, psychology, anthropology…), usually known as **soft sciences**. Do they really constitute science at all, and do they deserve to stand beside the hard sciences? A key problem is that the task of operationalizing intuitive concepts is inevitably more difficult and less exact in the soft sciences, because there are so many uncontrolled variables (Lang, 1975). Far from colonising social science under the banner of natural science, some social scientists consider their disciplines as science, and others want to think that the robustness of the philosophical approach is even more intense and transcendent than the so-called natural sciences, say, nuclear physics, because they offer achievements of great importance. Philosophy is forced to consider science as the best available evidence. In its intention of achieving a complete construction of reality, philosophy focuses on human origin and destiny, and its *Weltanschauung*, or project of life, even if it realizes the impossibility of achieving this purpose—solving all problems, because there is no human way of solving everything (see: Ramirez, in press).

3. Towards a Transdisciplinary Approach in the Natural & Social Sciences

The science of the 21st century is in most areas far too complex to be understood, let alone experimentally verified, by any one person. This necessity of knowing something in depth reveals how the different specialties of knowledge become continuously more specialized, erecting barriers between disciplines, even if, in the end, these barriers between disciplines may block the possibility of judging and of doing better. This is why we need an interdisciplinary approach, a cooperative integration between all the branches of sciences, with each branch competent in a restricted field, but in contact with the rest, keeping all the subjects in permeating touch with each other, for better answers about being human and our single common Universe, because no single discipline can capture reality fully or claim to have the complete knowledge. “The moment a problem of any kind is encountered, recourse is always made to interdisciplinary solutions” (Giarini, 2002, p. 148). Moreover, conclusions from different disciplines cannot contradict one another. [Tooby & Cosmides, 2017].

> *“Sciences and humanities are actually not independent, but interdependent ways of getting to know the world.”*

These interconnections and comprehensive approaches are becoming more and more apparent at different levels: a) within a discipline, as the translational approach in medicine shows, “from field to bench, and from bench to bedside”, i.e. before applying the adequate therapy (pharmacology or surgery), we have to know its pathology (abnormal) and, even prior to that, its physiology and structure (normal); and b) between all different disciplines of sciences and humanities, transferring knowledge gained in one discipline to others, with the very desirable goal of the integration of the human sciences, at some level, rendering coherent the areas where various disciplines overlap.

Sciences and humanities are actually not independent, but **interdependent** ways of getting to know the world. Both share a sense of reality that transcends time and place; hence their common interest in a fixed ‘human nature’. This is tied to a way of thinking and a sense of knowing that are largely contemplative. As it may seem self-evident, and was regarded as important by Einstein, Bohr and the founders of quantum theory a century ago, and by Karl Popper, who argued that falsifiability was a hallmark of good science, “all our theorising and experimentation depends on particular philosophical background assumptions” about the world (Koch, 2004).

An especially good example of transferring knowledge gained in one discipline to others is the Viennese school, one of the most important intellectual schools of the 20th century, which had a mixture of classes and nationalities, faiths and worldviews, amid a babble of peoples and languages. It was known as the *Wiener melange*. It found universal forms of communication, discovering what people had in common. For instance, a) Ernest Dichter, author of *The Strategy of Desire*, used the tools of psychoanalysis to revolutionise business; b) Paul Lazarsfeld, the founder of modern American sociology, applied his expertise in data and quantitative methods (he studied maths in Vienna, completing his doctorate on Einstein’s gravitational theory) to examine public opinion, or market “field research”; and c) political economy, where the “Austrian school” of economists like Joseph Schumpeter, Ludwig von Mises and his student Friedrich Hayek, strongly influenced the revival of liberalism and conservatism in the West, overwhelmed by the collectivism and totalitarianism of the right and the left during the interwar years.

We would like to mention specially the greatest contribution of Hayek, who combined technical expertise in economics with a global breadth, publishing on law, sociology and more, to restore intellectual rigour to the free-market school, expositing in detail the "price mechanism" to show that socialist economics would not possibly work in theory, let alone in practice. In 1947, he founded the Mont Pelerin Society (MPS), along with Milton Friedman & Karl Popper (the "Chicago school" of economists was made up largely of MPS members) and his ideas were taken up again by a subsequent generation of politicians in the mid-1970s, including Margaret Thatcher and Ronald Reagan, He was the recipient of the 1974 Nobel Prize in Economic Sciences.

Why has the Viennese school produced ideas so influential in the West? Because it articulates a more convincing defence of freedom, placing the life experience of individuals—rather than the abstractions of class, race and nationalism favoured by their opponents—at the heart of its intellectual enterprises. "I suddenly realised that Keynes and all the brilliant economic students in the room were interested in the behaviour of commodities, while I was interested in the behaviour of people," Peter Drucker, the founder of modern management theory, clearly stated after attending a lecture by John Maynard Keynes (The Economist, 2016).

We are aware that bridging disciplinary divides cannot be easily done. As the various disciplines model human behavior in distinct and sometimes incompatible ways, the task requires a common underlying model of individual human behavior, specialized and enriched to meet the particular needs of each discipline (Gintis, 2003). There is a lack of shared language between disciplines; insights from one field can be lost on researchers in another because of terminology differences, incompatible standards of evidence. And we may also find practical differences in funding different disciplines, and strong incentives created by the academic promotion process to do disciplinary, rather than interdisciplinary work. As Silk (2004) explains, "drawing the line between philosophy and physics has never been easy. Perhaps it is time to stop trying. The interface is ripe for exploration."

Consequently, a new transdisciplinary approach among all scientific disciplines, philosophy, art and theology included, can bring some badly needed insights probing into the meaning of our very existence. As MIT President L. Rafael Reif said, solving the great challenges of our time will require multidisciplinary problem-solving—bringing together expertise from science, technology, the social sciences, arts, and humanities. "We use the term the collective wisdom of MIT to solve a problem; now we're talking about collective wisdom of the world… working together to solve global problems" (Berglof, 2012).

4. Towards an Integrated and Comprehensive Technological Revolution

We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has ever experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society, as Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, exposes in *The 4th Industrial Revolution* (2016).*

* The First Industrial Revolution used water and steam power to mechanize production; the Second used electric power to create mass production; the Third used electronics and information technology to automate production; a Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century.

This Fourth Industrial Revolution is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres: ubiquitous, mobile supercomputing, artificially intelligent (AI) robots, self-driving cars, neuro-technological brain enhancements, genetic editing… The evidence of dramatic change, which is happening at exponential speed, is all around us.

"The desire to know the unknown is what inspires humankind's search for knowledge."

We cannot close our eyes to the information technology (IT) challenge, when diffusion is continuously spreading throughout the scientific world and everybody is investing more in it and in high-tech, and each time more intelligently. IT is an authentic revolution, with higher efficiency, more productivity and less transport expenses, resulting in an increase in quality of life.

a. Internet, a ubiquitous and an exponential growing web, has become the first global social organization, linking and bringing together different people into a single global cultural community, affecting international relations (Choucri, 2013) and forging a common sense of humanity;
b. mobile phone usage and internet access have exponentially risen: social media has become important and fundamental, connecting families across vast distances, the internet is now quintessentially helpful for e-banking, education or medical reasons, or for market trading (80% smartphones; smart cities…); in the case of migrants and refugees their importance goes well beyond staying in touch with people back home—phones have become a lifeline, suggesting where they should go, and whom they should trust. They even help us in dealing with important risks too, such as rumors leading to misinformation, or sensitive data falling into the wrong hands
c. artificial intelligence may help improve our decision-making capacity, and unravel the complexity of biology (producing drugs) and advanced human health (diagnose), given that living organisms are complex systems which process information using a combination of hardware and software (The Economist, 2017)
d. Internet of Things (IoT) is going to change business more than the industrial revolution did one century ago, encouraging innovation and offering prediction and prevention as one of its most valuable assets; it requires interoperability among all the different systems and kinds of applications; for instance, a smart city with a digital ecosystem including citizens, universities, hospitals, companies, government…

Even if we cannot live without IT, we should not forget that its use is not free of risk: social media webs, so efficient for agglutination of attention, are not appropriate for a public discourse, given their volatility: they are uncontrollable, unstable, short-lived and amorphous, appear suddenly and disperse with the same speed, showing a lack of stability, consistency and credibility, as the Korean philosopher Byung-Chul Han (2017) argues: digital communication enables instantaneous, impulsive reaction, being in fact responsible for the disintegration of community and public space. Suspicions about security have also risen, given the vulnerability of the present digitally connected cyber world (Ramirez & Garcia-Segura, 2017).

The most important comment, however, is that the last decision belongs to humans, because we are the ones who have to know how to use these new concepts adequately, knowing how to discriminate in the event of eventual risks inherent to their above described whirl.

5. Limits of Sciences

The continuous appearance of new scientific discoveries—some by serendipity, like the usefulness of some drugs or the law of gravity, which was discovered after Newton observed the fall of an apple—shows that **science has no borders**. Once, when Max Planck went to Munich to study Physics in 1875, somebody advised him not to do so because "there was nothing left to be discovered", when it is probably Physics that shows better the living continuity of knowledge (Zichichi, 1990; Weatherall, 2016). The desire to know the unknown is what inspires humankind's search for knowledge; the more we know, the more questions we ask. We want our understanding to be completely harmonious, which is never totally accomplished.

"What is important is not the objective reality, but subjective perception."

Science's quest for knowledge about reality presupposes the importance of truth, both as an end in itself and as a means for resolving problems. When we are using science, we are trying to arrive at the truth. In many disciplines, we want the truth to translate into something that works. But if it is not true, it is not going to speed up computer software, it is not going to save lives and it is not going to improve quality of life. However, experience says that science can only disclose certain aspects of reality, but not the whole truth. Universal truth is beyond the scope of any scientific enterprise. **Science is not synonymous with truth**. Let us base this assertion on a couple of arguments: the tentative nature of Science, by definition, the subjectivity of the perception, and the undeniable fact of the existence of many scientific studies subject to error and to fraud.

a. The **nature of Science is tentative** by definition, by a scientific self-limitation to believe only what is empirically verifiable, and the emphasis that reality is measurable (Dupré, 2001); scientific concepts are not realities, but just models: Science is a hypothesis which produces laws which, to be universally acceptable, do not need to have an overall contradiction, even when described from different coordinate systems. Examples of common assumptions, which have played significant roles in pursuit of truth: the laws of energy conservation and of entropy increase, causality, constant light velocity in vacuum… Science expands our knowledge of nature, giving us an insight into the complex interrelations of phenomena, or rather between the concepts in which phenomena are expressed.

   But these generalizations, even if they are universally accepted as ultimate scientific concepts, have often proven to be mistaken; they are just inductions, which may be useful, only working hypotheses, drawing more or less probabilistic conclusions.

Science, thus, is only a guide to what is probable, an affair of probability; even if the odds in favor of much of it are very high, it is impossible to reach the exact complete knowledge. There are **no scientific dogmas**, there are no certainties in science: all scientific theory is open to challenge; scientific findings cannot be ignored, nor treated as mere matters of faith.

b. **What is important is not the objective reality, but subjective perception**. Even when we accept the old scholastic dictum *nihil est in intellectu quod prius non fuerit in sensu*, science only gives information about what is apprehended by the senses. This does not imply that all we perceive is an objective reflex of the physical reality: we can never know what things are like 'in themselves', independent of how our minds format what we perceive, as Immanuel Kant's quite sensible contention asserted. This implies, for example, that what is true of the world for humans is probably different from what is true for an elephant or an *E. coli*.

Our own experience tells us that the subjective perceived phenomena, the human sensations, are not reliable, because what is perceived cannot be separated from the perceiver. Knowledge is inevitably constructed by the knower in interaction with his nervous activity, and we should never forget that each scientist has his own values, priorities and may also have all sorts of cognitive biases, prejudices or unfounded speculations (Popper, 1932). Much of the public hears what it wants to hear. Thus, although science attempts to unify different ideas, prejudice and self-righteousness, it bases itself on an illusion from a particular viewpoint, and there may be struggles. Many things have to be scientifically understood. We are far from understanding the truth (Ameniya, 2017).

The same things may look different if our viewpoint is different, as it is evident from the quite well known Indian tale about six blind men who touch an elephant to learn what it is like: The one who feels the leg says the elephant is like a pillar; the one who feels the tail says the elephant is like a rope; the one who feels the trunk says the elephant is like a tree branch; the one who feels the ear says the elephant is like a hand fan; the one who feels the belly says the elephant is like a wall; and the one who feels the tusk says the elephant is like a solid pipe. The different interpretations of the elephant imply that one's subjective experience is inherently limited by its failure to account for other truths or a totality of truth. At various times the parable has provided insight into the relativism, opaqueness or inexpressible nature of truth, the behavior of experts in fields where there is a deficit or inaccessibility of information, the need for communication, and respect for different perspectives. We cannot thus ignore the subjective experiences and the limitation of our faculties of perception, given that the human cognitive capacity is limited.

c. The daily experience also tells us that many scientific studies are **subject to error**: for instance, wine testers have more sophisticated sensations than ordinary people; the visual field does not perceive any blind spot, even if there is one, known as *optic papilla*, in the area of the retina where the optic nerve arises; the *phi phenomenon* takes place when two successive lights are turned on, a sensation of movement of light is perceived, even if in reality nothing moves; or take *cryptomnesia*, the capacity of remembering something we are not conscious of remembering, mixing real and imaginary memories.

d. Many aspects of scientific progress may also be inhibited by **fraud,** not unusual at all, since that the scientific system is based on trust: some 14% of scientists say that they have witnessed it (Clark, 2017). For instance, given the logistical difficulties of providing visual evidence or replicating precisely remote field work, there may be a number of irreproducible (and often poorly conducted) studies, which may foment dishonesty, when scientists or researchers invent data, but which in reality may have come from major manipulation to outright fabrication of data.

6. Reality goes beyond the Limits of Science

We have just asserted that science only gives information about what is apprehended by the senses, but these senses do not reveal the Reality. This does not necessarily have to be restricted to physical terms, by suppressing its subjective dimensions, even if—we have to admit it—these observations are subtler. If we want to understand the human being and the universe, science has a lot to say, but it is not the only test of validity. The uniqueness of a human mind is its ability to think about things which do not fall under the senses. There are other ways of knowledge, but to see life steadily and as a whole, we need something that will overpass the limits of science, ethics, philosophy, art and theology, all of them equally valid and limited in isolation, like science.

Science has plenty to say about many aspects of the world—about art, drawings, paintings, poetry, sports, anything you mention…, but it has nothing or very little—to say about many other basic questions, such as: What was the beginning of the universe[*]? What is the universe made of[†]? Might an alternative model of gravity remove its *raison d'être*? What is the origin of life on Earth? Are we alone in the universe or is there a probability of life elsewhere in the universe? What is human nature? How much can human life span be extended? How do organisms know when to stop growing? Can cancer be cured or ageing be stopped? What genetic changes made us uniquely human? Is "consciousness" present outside of organisms? Is morality hard-wired into the brain? What are the limits of learning by machines? and so on (Weiss, 2005).

Given the enormous complexity of reality, there will always be things unintelligible to the human mind. For instance, the existence of moral values, social institutions, God… cannot be subject to experimental tests, but it does not mean that they do not exist. We need them as pilots of our life and our social relations. The **vision of the human being** searching for a purpose in life thus **transcends scientific knowledge**. *Ignoramus, Ignorabimus!*

[*] All we have are theoretical assumptions which have not been tested by experiment

† Until last century it was thought that the universe was composed of atoms and light; now we know that, besides the atoms, composed of protons, neutrons and electrons, dark energy exists, which has a gravitationally repulsive effect (without it, the experimental facts of the universe expanding at an accelerating speed cannot be explained), and dark matter, composed of one or more species of sub-atomic particles that interact very weakly with ordinary matter, too (without dark matter, the revolting galaxy in which the solar system exists would be disintegrated by centrifugal force) (NASA, 2014; Ameniya, 2017)

Faith (belief in what we don't know) is a normal part of human cognition, founded on our direct experience. Belief is a decision rationally as fundamental, and consequently at least as respectable, as no belief. We dare to say that **everybody has faith**. Obviously, 'believers' may feel religious needs, seeing life in a transcendent world: "we need the apprehension of a sacred mystery, the sense of communion with a Divine Power, that constitute the ultimate basis of religion" (Dampler, 1971, XXII). Others, even if we are color-blind and have no religious sense, still use faith in acceptance of science, because, otherwise, we would not accept any science that we have not personally studied ourselves and get convinced of the evidence presented.

We would like to add to these considerations that there is a need for a **bridge between science and religion**, because both have things to say about the same subject matter. They are different ways of studying the same territory; they have different kinds of things to say; they are different phases in humanity's attempt to understand the world, and they each have a strong contribution to make to the efforts of humans to cope with life. Some aspects of the world can be known through empirical observation; others, through religious thought. Science tells us more and more about how things work. Why they work, and what is the overarching reality, are issues of an evolving religion. Science without religion is soulless. Religion without science is superstition, or, as Einstein stated, "science without religion is lame; religion without science is blind" (Ake, 2001). Consequently, science and religion should not be seen as conflicting forces; on the contrary, they have to progress and share the same pedestal: science has to be inspired by values such as love for Creation, respect for life and promotion of human dignity.

In sum, recognizing the limits of scientific knowledge—science does not have the last word—includes an explicit recognition of the tentative nature of science, combined with the fact that some things are, theoretically, unknowable scientifically. In the end, we seem to be brought to the theologian dictum of Tertullian, *credo quia absurdum.*

7. How Scientists can help create a Human-centered Society

In spite of their limitations, scientists can play an important role in favouring a human-centered society. We suggest a few simple examples of how this may be done.

7.1. An international team of experts, after estimating that as much as 85% of the US biomedical research effort is wasted, has recently produced a manifesto with a master plan to improve the quality of scientific research, "to perform good, reliable, credible, reproducible, trustworthy, useful science" (Ioannidis, 2017). Its goal is to increase the speed at which researchers get closer to the truth, taking into account four major categories: methods, reporting and dissemination, reproducibility, and evaluation and incentives. Who are responsible for improving the quality of science? Not just the researchers, but also other stakeholders, such as research institutions, scientific journals, funders and regulatory agencies. Fomenting scientific knowledge and enhancing cross-cultural connections and joint cooperative research have to be their main goal.

7.2. **Scientific cooperation in easing relations between governments:** Science is fundamentally an interactive, cooperative pursuit, which allows us to expose the results of research to review and critique through a common language to more easily cross cultures and borders.

Rachel Rothschild, analysing centers on The European Monitoring and Evaluation Programme (EMEP), which was designed to investigate the pollutants causing acid rain and began operations under the United Nations Economic Commission for Europe in 1977, notes that the creation of the EMEP is an evidence of how addressing global environmental concerns can pave the way for easing geopolitical conflicts. "EMEP's formation illuminates the importance of developing technological networks and international research projects on acid rain in furthering both détente among European countries as well as international research and policies for environmental protection" (Rothschild, 2016).

The impetus for cooperating across the Iron Curtain on air pollution monitoring came from a group of scientists and environmental officials in Norway working on acid rain. Despite security concerns over disclosing power plant locations and resistance on placing pollution monitoring stations within the Soviet Union, the Scandinavian scientists were eventually able to secure the commitment of the Communist bloc to a Europe-wide environmental research program—a breakthrough that resulted in limited technological cooperation. This development helped ease Cold War tensions, fostering subsequent political relationships, which culminated in the 1979 UN Convention on Long-range Transboundary Air Pollution.

Another example is how science brought Americans and Russians together, just after the dissolution of the Soviet Union and the end of Cold War, in late 1993, a US-Russian collaboration into sensitive areas, like the safety and security of nuclear weapons and materials. The Russian Federal Nuclear Center VNIIEF and Los Alamos National Laboratory conducted a ground-breaking joint experiment to study high-temperature superconductivity in ultra-high magnetic fields, sharing each other's previously highly secret sites on nuclear weapons programs. VNIIEF sent to Los Alamos explosive magnetic flux compression generators from Russia, which were charged with US-supplied explosives and stationary pulsed power machines to produce ultra-high electrical currents and magnetic fields that, in turn, produced a wide range of high-energy density environments needed to pursue a unique approach to civilian nuclear fusion. This joint collaboration resulted in over 400 joint publications and presentations between 1993 and 2013, and opened the door for joint work in other areas (Hecker, 2016).

These stories clearly demonstrate that countries can achieve some scientific collaboration by working together, although it is less evident whether scientific cooperation can become a precursor for political collaboration, i.e. whether science would be a driver for peace, bringing peace to the region or the whole issue is just wishful thinking. We hope science would play its part.

7.3. **Improving the public's understanding of socially relevant science:** The ubiquitous impact of science-based information and technologies in everyday life suggests that misunderstanding how science works can have serious consequences. Although the fake news phenomenon in the context of science is not at all new, social media disseminates this kind of news much faster among online social networks. There is an increasing need for the scientific community to have a more prominent role in social media, because people's decisions and strongly held beliefs are often at odds with the conclusions and recommendations of empirical studies and scientific consensus; they can be influenced by unscientific mass media and widely publicized campaigns providing inaccurate information via disconnections between human emotion and rationality. Surrounded by like-minded friends and followers, opinions are reinforced and become more extreme, because simply presenting facts is unlikely to change beliefs when those beliefs are rooted in the values and groupthink of a community. It should bring us a necessary shot of humility: be sceptical of your own knowledge, and the wisdom of your crowd (Regan, 2017; Sloman & Fernbach, 2017).

People often have strong opinions about issues they understand little about. In some cases, the implications of misunderstanding or rejecting science are more or less harmless, because what the public admires is a sense of wonder and fun about the world, or answers to big existential questions, such as the popularization of physics, of animal behaviour, of how brain works; or if someone believes the Earth is the centre of the Universe or if there are other planetary systems, like the TRAPPIST-1 that was recently announced by NASA. Does it really matter to our daily life?

In other cases, however, the issues that people face in their lives can be socially relevant or even critical, like when they are focused on uncertainty perhaps under the label of environment, health or food. Here are a few examples:

a. **Vaccination** is a particularly important issue to think about here, given the rise of the anti-vaccination (anti-VAX) movement that has the potential to reverse the health gains achieved through one of the most powerful interventions in medical history. Researchers estimate that between 1963 and 2015, in the U.S. alone, nearly 200 million cases of polio, measles, mumps, rubella, varicella, adenovirus, rabies and hepatitis A and approximately 450,000 deaths from these diseases were prevented, thanks to the development of a human cell strain that allowed vaccines to be produced safely, with Leonard Hayflick's discovery of WI-38, in 1962, to safely grow the viruses needed to produce vaccines against more than 10 diseases. The anti-VAX is an emotionally-charged phenomenon distrusting healthcare, undervaluing many vaccine-preventable diseases that have become much less common, like smallpox and polio. It is based on a flawed debunking of a chronological (but not causal) relationship between vaccination and autism, based on a falsified and discredited study by Andrew Wakefield in 1998, that has since been shown to be fraudulent but often highly cited. Vaccine refusal is not just a problem for unvaccinated children (measles outbreaks), but for everybody because it endangers the health of an entire generation of children, lowering local herd immunity.* But if enough people forego vaccination, vaccine-preventable disease outbreaks can

* Local herd immunity means that when almost everyone in a community is immunized against a disease, if an unimmunized person becomes infected, the disease has little opportunity to spread because there are very few unprotected hosts.

occur since the disease spreads among unprotected individuals, as the recent emergence of some diseases that were previously considered dormant in Western countries, such as a revival of measles, pertussis, mumps and rubella demonstrates (S. Jay Olshansky & Leonard Hayflick, cited by Parmet, 2017).

b. Another example of myths and not medically validated alternative therapies may be found among cancer patients. After an endless series of eventually not-so-efficient **oncotherapy** of some kinds of cancer, and the inherent feeling that death may be close, the despair of many patients is quite understandable, which may lead them to look for any type of alternative assistance *agarrándose a cualquier clavo ardiente,* as we say in Spanish, like grasping at straws, as a last resort, even if most of them have not been proven to be efficient. In the '60s-'70s of the last century, the public opinion seemed to consider nuclear energy as a panacea, as a healer of illness such as cancer, heart insufficiency, lung emphysema… Top class restaurants were offering highly radioactive bottled water; we do remember a Bohemian spa in Joachimsthal, next to a uranium mine, offering thermal water, radioactive from uranium mines. Nowadays we know that, used in high amount, they can be cancerogenous. We may also find other alternatives: Gerson diet, reflexology, chiropractics, neurolinguistic programming…[*] Leaving aside the quite unacceptable chrematistics abuse of these situations by some "practitioners", however, this decision may be understandable in certain cases when one cannot find any other solution. Is this not reason enough for resorting to homeopathic therapy?

c. There is an increasing trend among many people to favor "clean", healthy diets, even if they have not been diagnosed with any intolerance. These people prefer ecological and sustainable agriculture, choose containers or smoothies with the words "bio" or "detox", and eat foodstuff without lactose, sugar, flour or palm oil just because it seems healthy to them, and, on the other side, they worry about eventual toxins or artificial ingredients in processed frozen or junk food, which may reduce its nutritional value, lead to overweight, or even enhance the risk of diabetes or cancer, demonizing them as "pure poison". A few decades ago, the 'danger' was the saturated or trans fats; nowadays it seems sugar has become the main 'devil'; it was quite advisable to eat the blue fish not long ago because of its omega-3 acids, but now, the issue is quite dubious given the presence of too many heavy metals in it; whereas some people suggest that coffee may be 'a bomb' within our organism, others, on the contrary, say that caffeine even might cure cancer; are eggs good or bad?; quinoa is quite in (it has become a good source of income for South American farmers), because it seems to be the panacea: it leads to lower cholesterol and less body weight, due to saponines that alterate the permeability of intestines, but when you wash it, before eating, the saponine goes away.

Similar comments may be made on another scientific myth according to which antioxidants are good and free radicals are bad. By the 1990s, many people were taking antioxidant supplements, such as vitamin C and carotene, based on the theory that free radicals cause

[*] For instance, the Spanish Group of Cancer Patients (GEPAC) has published a manual where "78 myths" are mentioned. GEPAC (2016), *Mitos y pseudoterapias*.

ageing as proposed by Denham Harman (free radicals would be reactive molecules that build up in the body as by-products of metabolism and lead to cellular damage), assuming the corollary that molecules that neutralize free radicals, such as antioxidants, were good for human health. Yet in the early 2000s, scientists trying to build on the theory encountered bewildering results: mice genetically engineered to overproduce free radicals lived just as long as normal mice (Doonan, et al., 2008), and those engineered to overproduce antioxidants didn't live any longer than normal (Pérez, et al. 2009). It was the first of an onslaught of negative data, which initially proved difficult to publish. David Gems started to publish his own negative results in 2003, and then, one study in humans (Ristow, et al., 2009) showed that antioxidant supplements prevent the health-promoting effects of exercise, and another associated them with higher mortality (Bjelakovic, Nikolova & Gluud, 2013). Today, most researchers working on ageing agree that free radicals can cause cellular damage, and that this seems to be a normal part of the body's reaction to stress. And the idea still holds back publications on possible benefits of free radicals (Ristow, et al., 2009). Some researchers also question the broader assumption that molecular damage of any kind causes ageing. "There's a question mark about whether really the whole thing should be chucked out," says Gems. The trouble, he says, is that "people don't know where to go now" (Keaney & Gems, 2003; Scudellari, 2015).

All this is going out of our hands, leading towards what is known as **orthorexia**, which is the term for a condition that includes symptoms of obsessive behavior in pursuit of a healthy diet: if certain diets were previously rejected because of certain elements, considered prohibitive, these days the main problem is with conservatives or colorants, antioxidants, additives which pretend to conserve the life of products, avoiding mold or micro-organisms which destroy the food, emulsions which prevent the food from sticking to different surfaces, and thickeners which give body to sauces and stews. All food has chemicals; even milk contains thiamine and riboflavin, i.e., vitamins B1 and B2; and those called "functional foods"—because they affirm to have more nutrients like calcium or Omega-3—keep adding chemicals to the original product. All this does not make much sense to a world that flees from the "artificial" searching for the 100 % pure and natural (Quintas, 2017).

The main aim of dietetic guidelines, rather than being red nutritional advice, should be to help keep an ordered meal, adapted to each local cultural habits; f.i. 5 fruits/day, eat every 3 hrs, no carbohydrats after 5 PM, one glass of wine or beer… In few words, just follow common sense!

How can scientists influence what is being presented in social platforms? By articulating how this kind of science works when they talk to journalists, or when they advise policymakers. For instance, since as humans, we have all sorts of cognitive biases that come into play when we try to evaluate the risks posed by any decision, scientists should offer an alternative to bias-based decisions, enabling leaders to create more effective policies and avoid a "cure" which may be worse than the disease. We are aware that using inaccurate and false information in the context of science is much murkier and unclear, because usually there is no clear dichotomy between fake news and real news, it challenges the position of science as a singular guide to decision-making, and because it involves owning up to not having all of the answers all the time while still maintaining a sense of authority.

"Scientists cannot neglect the ethical responsibility concerning their work."

But if we want "to inoculate" the public against popular sticky misinformation campaigns, including the damaging influence of some fake news that circulates on scientific matters propagating myths on whatever topic, we cannot risk leaving this task in the hands of journalists because, besides not being well-trained to assess the validity of all studies (many of you may have already heard the difference between a scholar and a journalist: a scholar is somebody who knows a lot about very few things, whereas a journalist knows very little about a lot many things), they are attracted by the human interest of a news and the hope of creating an attractive headline. Scientists, therefore, need to "break the echo chambers as much as we can", as Dominique Brossard (2017) says, engaging toward better science communication, talking to journalists and people about real facts, to help explain and contextualize the news and to stop the dissemination of fake news or bad reporting because people are going to use science stories that fit better what they want to believe, improving the way that socially relevant science is presented to the public in popular media, providing a cognitive capacity to evaluate it in a coherent way that helps build up resistance to misinformation, and presenting them with accurate scientific statements and well-known facts (Klymkowsky, 2017; Makri, 2017; Nielsen, 2017; van der Linden et al., 2017).

8. Ethical Values of Science

We do not wish to close our presentation without a brief comment on one of the most important issues a scientist must face in his contribution towards a human-centered society: the relationship of science with ethics.

Science has been a catalyst for social change and economic growth, and saved countless lives. But, even if *in se* science is not good nor bad, it is evident that there is always an eventual danger or evil concerning its application. For instance, a new anti-malaria drug dispenser of a drug called ivermectin kills *Anopheles* mosquitoes, the sort that transmit malaria. But, in addition to helping in the eradication of this illness, protecting the people indirectly, by making their blood poisonous to *Anopheles,* it may also cause other obvious ill effects in the digestive system, turning human beings into chemical weapons.

The atomic research, besides its deadly applications we all know about (nuclear weapons), may also lead to peaceful applications, like the "tracer elements", which can be applied as a radio-active method of diagnosis, in cancer radiotherapy or as effective fertilizers.

Besides the above-mentioned invention of nuclear weapons, other discoveries have also done far more harm than good. To name just a few: massive blunders like fossil fuels, CFCs (chlorofluorocarbons), leaded petrol and DDT, and tenuous theories and dubious discoveries like luminiferous aether, the expanding earth, blank slate theory, phrenology…

But, even if choosing good or bad is not a scientific choice, **scientists cannot neglect the ethical responsibility concerning their work**. Society wants clear guidelines as to how these technologies have to be managed, but the factors that drive much of public sentiment are largely based on ethical and social concerns, rather than safety or efficacy. For instance, human genome editing raises a lot of questions related to the implications of new technologies, such as CRISPR-Cas9, that can alter the genome of living organisms, including humans. The fact that they can potentially be used by almost anybody either for beneficial or harmful purposes, has raised fears that CRISPR could become a weapon of mass destruction. Many countries, such as Austria, Italy, Spain and the Netherlands, have decided to ban the use of technologies to modify the human germline. In this context, The National Academies of Sciences, Engineering, and Medicine (NASEM) recommends that at least a series of stringent conditions should be met before authorizing this use. So while clinical trials for modifications of somatic cells are given a green light, the use of genome editing for enhancement purposes is given a red light for the moment and should be subject to further and wider discussions. The modification of reproductive cells (eggs, sperm and embryos) which would lead to germline modifications has raised fears about a brave new world of "designer babies". The report concluded that it would only be fine if three requirements are met: to prove that there are sufficient prospective benefits relative to the risks of using these techniques before starting clinical trials; to involve experts in a broad dialogue about the use of these technologies; and to guarantee that germline genome editing will be used only to prevent a serious disease, where no reasonable alternatives exist, under strong supervision.

In the NASEM report on gene editing, which he co-authored, Gary Marchant draws parallels between the public's concerns on that technology and how best to proceed incorporating social, ethical and religious aspects into regulations. "As biotechnologies grow more powerful and increasingly raise more profound ethical issues, we can no longer leave these ethical and social dimensions off the decision making table" (Marchant 2017). International scientific cooperation and dialogue seem to be essential components of good governance for new technologies. Otherwise, it would be profoundly detrimental to the success of those technologies.

9. Conclusion

All stakeholders have to be conscious of the importance of investment in Science, fostering scientific knowledge through the interconnections between all its branches with an open mind, transdisciplinary approach, enhancing joint research and cross-cultural connections, and providing funds not only focused on real life problems, but also on the fundamental tenets that will underpin the future of a human-centered society.

If development of science is important, what is even more important is human development, i.e. development of human beings themselves, which is all about "growing up truly to human beings, capable of governing themselves and the universe through the well-balanced development of science, art & religion" (Amemiya, 2017).

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Bibliography

1. Ake, S.E. (2001). Metanexus: Views 2001.10.15 Dual Magisteria: Louis Martin.
2. Amemiya, Y. (2017), Overall view of science, and the ideals of human civilization. 23rd ICUS, Seoul, February 4-5, 2017.
3. Berglof, A.M. (2012). At home: Rafael Reif The Financial Times, November 9, 2012.
4. Brossard, D. (2017). *How science should respond to fake news*. Annual meeting of the American Association for the Advancement of Science. February 18, 2017 https://phys.org/news/2017-02-expert-science-fake-news.html.
5. Chandrasekaran, M. (2016). Unifying Subjectivity & Objectivity", *Cadmus*, 3 (1): 93-104, 2016.
6. Choucri, N. (2013). *Cyberpolitics in International Relations*. MIT Press.
7. Clark, T.D. (2017). Science, lies and video-taped experiments. *Nature* 542, 139 (09 February 2017) doi:10.1038/542139a http://www.nature.com/news/science-lies-and-video-taped-experiments-1.21432?WT.ec_id=NEWSDAILY-20170209%20.
8. Dampler, W.C., (1971). A History of Science, Cambridge University Press, 4th edition.
9. Doonan, R. et al. (2008). Against the oxidative damage theory of aging: superoxide dismutases protect against oxidative stress but have little or no effect on life span in Caenorhabditis elegans. *Genes Dev*. 22, 3236-3241.
10. Dupré, J. (2001) *Human Nature and the Limits of Science*, Oxford University Press.
11. Economist, (2016) How Vienna produced ideas that shaped the West, *Economist*, Dec 24th 2016).
12. Giarini, O. & Tuzzi , U. (2002) Itinéraire vers la retraite à 80 ans, Economica, Paris, 2002.
13. Gintis , H. , (2003). Towards a Unity of the Human Behavioral Sciences February 24, 2003.
14. Han, Byung-Chul (2017). *In the Swarm: Digital Prospects (Untimely Meditations)* Stanford University Press.
15. Hecker, S.S. (*2016) Doomed to Cooperate: How American and Russian Scientists Joined Forces to Avert Some of the Greatest Post-Cold War Nuclear Dangers, Los Alamos Historical Society's Bathtub Row Press, 2016.* http://www.losalamoshistory.org/doomed-to-cooperate-ad.htm.
16. Holmes, R. (2016). *This Long Pursuit: Reflections of a Romantic Biographer***.** William Collins.
17. Ioannidis, J. (2017). Nature Human Behavior, Jan. 10, 2017 http://phys.org/news/2017-01-master-science.html.
18. Keaney, M. & Gems, D. (2003). No increase in lifespan in Caenorhabditis elegans upon treatment with the superoxide dismutase mimetic EUK-8. *Free Radical Biology & Medicine* 34, 277-282.
19. Klymkowsky, M. (2017). What can the anti-vaccination movement teach us about improving the public's understanding of science? *Plos Blogs*, January 10, 2017.
20. Koch, C. (2004). review of Searle's Mind: a Brief Introduction, *Science.*
21. Lang, S. (1975. *Diaphontine Approximation on Abelian Varieties with Complex Multiplication*. Advances in Mathematics, Elsevier.
22. Makri, A. (2017). Give the public the tools to trust scientist, *Nature* 541, 261 (19 January 2017) doi:10.1038/541261a.
23. Marchant, G (2017). *Governing Ethical, Social and Religious Aspects of Biotechnologies.* Annual meeting of the American Association for the Advancement of Science, Boston, February 17, 2017 https://phys.org/news/2017-02-advanced-technologies-social-ethical-lines.htm.
24. Narayanamurti,V. & Odumosu, T. (2008). *Cycles of Invention and Discovery*.
25. NASA (2014). What is the Universe made of? https://map.gsfc.nasa.gov/universe/uni_matter.html.
26. NASEM (2017). National Academy of Sciences and Medicine report on Safe and ethical ways to edit the human genome, February 14, 2017 https://phys.org/news/2017-02-safe-ethical-ways-human-genome.html.
27. Parmet, S. (2017). Ten million lives saved by 1962 breakthrough. *Medicine & Health / Diseases, Conditions, Syndromes* March 3, 2017 https://medicalxpress.com/news/2017-03-ten-million-breakthrough.html.
28. Pérez, V. I. et al. (2009). The overexpression of major antioxidant enzymes does not extend the lifespan of mice. *Aging Cell* 8, 73-75.
29. Popper, K. (1932, 2008). *Die beiden Grundprobleme der Erkenntnistheorie.*
30. Troels Eggers Hansen (Editor) The Two Fundamental Problems of the Theory of Knowledge. Routledge Classics.
31. Powell, A. (2017). The false choice of basic vs. applied research, *Harvard Gazette*, January 4, 2017, http://phys.org/news/2017-01-false-choice-basic.html.
32. Quintas, A. (2017). *Adelgaza para siempre. De forma fácil, saludable y definitiva*. Planeta.
33. Ramirez, J.M. (in press). The Limits of Science and the Benefit of Unified Values. In: Earth's Environmental Crisis, and the Role of Science.

34. Ramirez, J.M. & Garcia-Segura, L. (2017). *Cyberspace: Risks and Benefits for Society, Security and Development*. Springer.

35. Regan, A. (2017). Can social media connect science and society? *TResearch* April 5, 2017 https://phys.org/news/2017-04-social-media-science-society.html www.teagasc.ie/media/website/publications/2017/TResearch-Spring2017.pdf.

36. Ristow, M. et al. (2009). Antioxidants prevent health-promoting effects of physical exercise in humans. Proceedings of the National Academy of Sciences USA 106, 8665-8670.

37. Rothschild, R. (2016). Environmental cooperation in 1970s helped ease Cold War tensions*, Technology and Culture*, November 17, 2016 http://phys.org/news/2016-11-environmental-cooperation-1970s-ease-cold.html.

38. Schwab, K. (2016), *The Fourth Industrial Revolution,* World Economic Forum, Davos.

39. Scudellari, M. (2015). The science myths that will not die. *Nature*, vol 528, issue 7582, 16 December 2015.

40. Sloman, S. and Fernbach, Ph. (2017). *The Knowledge Illusion: Why We Never Think Alone.* Riverhead. Pan Macmillan.

41. Tooby, J. & Cosmides, L. (2017). *Evolutionary psychology: Foundational papers*. Cambridge, MA: MIT Press.

42. van der Linden, S. et al. (2017). *Global Challenges*, DOI: 10.1002/gch2.201600008 January 23, 2017 https://phys.org/news/2017-01-psychological-vaccine-immunize-fake-news.html.

43. Weatherall, J.D. (2016). *Void: The Strange Physics of Nothing***.** Yale University Press.

44. Weiss, R. (2005) Scientists far from knowing all the answers *Washington Post*. Jul. 18, 2005.

45. Zichichi, A. (1990). From Galilei to Dirac**,** *Europhysics News*, 21.

46. Zichichi, A. Dirac, Einstein and Physics, (2000]. *Physics World*, March 2000.