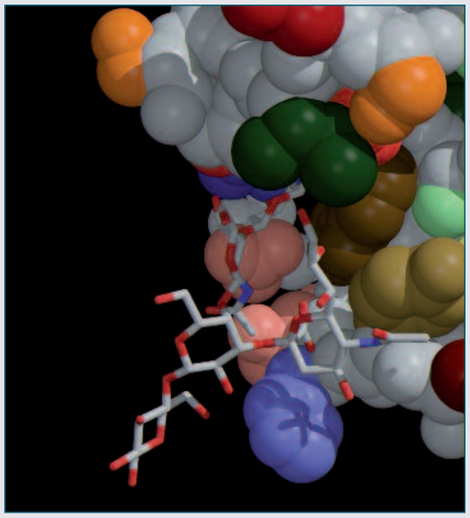

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THE ADVANCEMENT OF SCIENCE: SHARING OR EXCLUDING? THE "NEW BIOTECHNOLOGY DIVIDE": AN ALARMING PERSPECTIVE OF SCIENTIFIC DUAL USE

The role of scientists is of paramount importance in understanding and predicting the impact of their research in issues related to the threat of conflicts inherent in a polarized society. They must increase their own awareness of these issues as well as better informing the political community by advising and helping assess programs of cooperation that will lead to more equitable access to benefits and reduce inequalities driven by the technology divide. This article will focus on the use distribution, and accessibility of research outcomes in one particular area of biotechnology that is the technology related to health care.

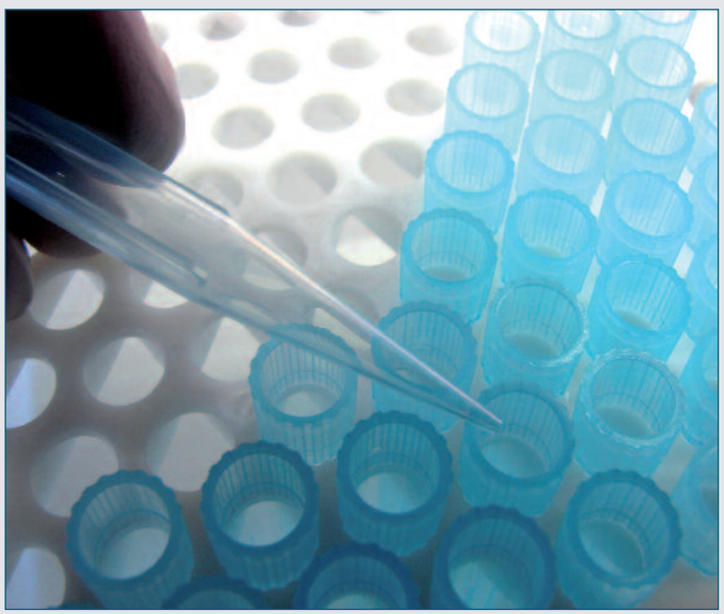
When we refer to biotechnology, the most important impact on society is from the burgeoning field of molecular biology and its evolved sciences such as for examples genomics, proteomics (and omics in general), cell and tissue engineering, regenerative medicine and stem cell research. These are indeed some of the most rapidly expanding areas of biotechnological research.

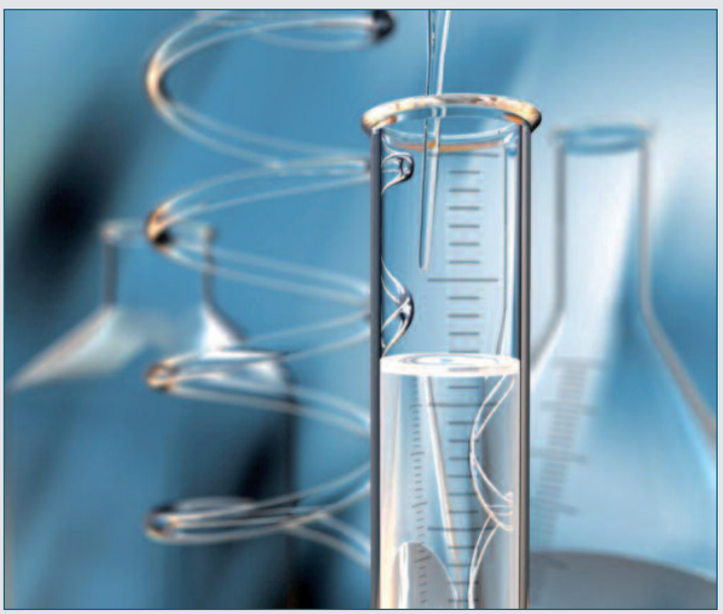
This report is intended to focus on the areas of biotechnological research related to biomedical application. Many other important opportunities such as food and agriculture are outside of the scope of this report and are more frequently discussed in numerous publications. Research in genetic engineering has numerous beneficial applications in medicine. An outstanding example has been the amazing success of the International Genome Project (HGP). The large, multi-

disciplinary HGP is revolutionizing our future so deeply that the 21st has been named the "biology century". Without exception, virtually everyone will be affected by the information and resulting applications of technologies derived from the HGP. New approaches are being implemented in biological research and in the practice of medicine. This knowledge will be of immense value for improving human health, by enabling better diagnosis of disease and early detection of genetic pre-disposition to disorders such as cancer or, for example, recognition of individual sensitivity among workers exposed to occupational risks. It will also lead to improved methods of treating diseases, e.g. by either providing personalized drugs or by therapeutic cloning, in which stem cells are used to repair organs damaged by degenerative diseases or accidents. Another dream is to prolong the human lifespan as much as possible. In addition, we see the benefits of genomic research in such areas as forensics, anthropology, human migration and evolutionary sciences. Among the fields that HGP research will impact are computer science, engineering, mathematics, counselling, sociology, ethics, law, agriculture, education, pharmaceuticals, nuclear medicine, forensics, bioremediation, biofuels, journalism, communication science and much more. In addition, the benefits related to HGP are also important in economical and industrial fields. Commercialization of a myriad of applications in genomic science may fuel the new life sciences economic sector. Legislation and litigation increasingly will be concerned with genetics and the intellectual-property issues pertaining to genetic information and technologies. Educators and the media need a good understanding of this "genetics" and its implications to inform the public.

From this somewhat abbreviated report it is not difficult to understand the momentous impact of this type of biotechnology on health and wealth. Concomitant with the remarkable beneficial effect, there are potential alarming possibilities of dual use. Obviously, the health and environmental risks implied in the biotechnology research itself (production, storage and transportation of genetic material) are the most relevant issues. However, analysts are also rightly concerned with the risks related to issues that divide opinions and result in friction regarding the ethics of such research. Some fundamental issues subject to open and heated debate are briefly reported: Fairness in the use of genetic information by insurers, employers, courts, schools, adoption agencies, and the military; Privacy and confidentiality of genetic information; Psychological impact due discrimination based on biological characteristics; Psychological implication due to discrimination based on uncertainties associated with gene tests; Reproductive issues, clinical issues including the education of doctors and other health service providers; Philosophical implications related to human responsibility; Commercialization of products including property rights (patents, copyrights, and trade secrets) and accessibility of data and materials; Vulnerability of biotech consumers exploited by the power of marketing and excessive cost of biotech products; Political decision whether money should go to biotech research or rather to more immediate needs and prioritizing how it should be spent.

Apart from the above reported highly sensitive and dividing questions of a fundamental nature, serious concerns are increasingly arising that health-related biotechnologies could potentially lead to a polarization of human society, mainly resulting from the unequal access to the benefits of research outcomes, creating "social exclusion". The technology required to access the advantages might be very costly and thus available only to the affluent. Will members of society who are *"left behind"* by ICT (information and communication technology), standing on the wrong shore of the "*Digital Divide*", find themselves once again gazing across a "*Genetic Divide*"? Such a divide would affect intra and inter national relations more profoundly than the digital divide did because it would affect fundamental areas of human health and welfare. This might create a medical apartheid with unequal and iniquitous segregation of care such as the typical example of the alarming situa-





tion of HIV/AIDS in Africa discussed below. It is well known that social, cultural and economic factors already cause substantial inequalities in traditional health care, but the approaching new "cutting edge" technological heath care is more seriously perceived as a potential threat of exacerbating discrimination among people and of supporting eugenic uses. There is the fear of the possibility of creating a disadvantaged biotech underclass as opposed to an advantaged "*Gen-Rich*" class.

What can and should scientists do?

The fundamental issue of how to mobilize world scientific and technological knowledge in order to both reduce discrimination and increase the welfare of human kind world-wide demands that we acquire a consciousness of the reality of such divides and a desire to reduce their impact.

Crossing the bridge

While much of this document has pointed out negative issues regarding the separation of technology between haves and have-nots, it is also possible to use technology as a transformation tool to help bridge the gap created by itself. In highly advanced countries we consider technology advances to be to a large extent inevitable but also desirable. An example of the potential positive impact of technology can be seen with its specific role in the AIDS epidemic of Africa. Currently biomedical technology is vital for measurement of CD4-T cell subsets in HIV/AIDS patients. The current technology of choice is flow cytometry, a highly complex and expensive technology utilizing laser based single cell analysis of blood cells. Without the measurement of CD4, patients may be excluded from life-saving antiretroviral therapy. These tests are readily available in the Western healthcare system but there has been an alarming failure to achieve ready-access in resource poor countries, particularly those heavily impacted by HIV/AIDS in Africa. Below are two examples of scientific and industrial involvement.

A recent program has been established that could potentially change the lives of millions of HIV/AIDS patients by bringing low cost CD4 technology to patients in the most remote regions of Africa. This program, known as "Cytometry for Life" - C4L (www.cytometryforlife.org), represents a paradigm shift in the modern high-tech environment. The program aims to use innovation rather than invention to achieve its aims. For example, by designing a modern minimalist implementation of a mature technology, costs are lowered, the parts are smaller and more reliable, and by bringing together *state-of-the-art* off-the-shelf components, a very low-cost diagnostics instrument can be created. This innovative use of off-the-shelf components such as cell phone chips to distribute data, GPS chips for tracking the location of portable instruments, and advanced processing chips to reduce data complexity to instantly identifiable results creates a unique bridge across both the digital and genetic divide. Without the rapid advancement of modern technology such as diode lasers made for CD and DVD players, cell-phone chips, GPS chips used in consumer products, and advanced processors used in modern computers, economic creation of this minimalist diagnostic technology would not be possible. The primary beneficiaries will be the most remote and inaccessible people in Africa who otherwise wouldn't be able to access life-changing therapy. Presently, a noteworthy example of industrial commitment to bridging the diagnostic barrier with low cost tests and suitable instruments is the approach developed by Partec company (www.africahealth.com/articles/july_2010/Publishing%20Partners.pdf, www.partec.com/cms/upload/PAR_Brochure_Image_EN_150dpi.pdf) This approach has changed the CD4 field in the past few years in terms of wide-spread use and affordability of the required patient diagnostics.

A further example from the same company (Partec) of appropriate technology translation in the creation of low cost, user-friendly devices is in the field of diagnosis malaria. This has traditionally been a labour-intensive, and expensive test because of the high cost of quality microscopes. Recently, efforts have been made to utilize the latest LED (light-emitting diode) technology as low cost, low-energy consuming lights for microscopes. A program of significant impact was set up by Partec company which developed a very low cost, high quality battery operated, fluorescence microscope using these approaches and made it available to communities in Africa where malaria diagnosis was most needed (www.ncbi.nlm.nih.gov/pmc/articles/PMC3118144/?tool=pubmed).

What are the criteria that must be applied when determining if a new technology is appropriate for this bridge function? On one hand, one always desires to bring the latest and best technologies to the table; on the other hand, any advanced technology has significant drawbacks such as cost, difficulty in implementation and failure. Thus, a careful evaluation must be made to ensure that the most appropriate tools are applied for a specific task.

Another example of social concern in science is that related to patenting and how to balance the right of the intellectual property and the respect to the weaker communities. How much scientists are available to diffuse our research results, even if their content is possible objects of patents? Is it acceptable that the results of researchers concerning drugs or devices for health are patented? Several scientists are opening a debate on these issues.

Conclusion

The authors maintain that scientists should advert the need to justify their work in terms of its positive social and economic impact and the need to direct more effort to benefiting human beings and nature. Every effort must be made to ensure that everyone-regardless of race, gender, citizenship, or national origin-enjoys the benefits of science and its subsequent applications, including life improvement and career possibilities. Scientists play a key role in this. In this paper we have identified some biotechnological barriers, given some specific examples of positive action in the field of our expertise in bridging such a divide and highlighted the direction we believe should be followed.