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From the Editor's Desk

Science and Technology in the 21st Century: Phytomedicine in Focus

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Abstract

The 21st century, from the stand-point of science and technology can aptly be described as the era of undeniable craves, zero limitation, absolute possibilities but, insatiable quests. Many scientific and technological advances have had their origins in research that could not have been predicted to have those outcomes. With all this scientific promise, there are myriad risks that could be provoked or exacerbated by plausible technological innovations. This paper focuses on science and technology in the 21st century with phytomedicine (plant medicine) in perspective. It brings to bear the historical overview, strides as well as challenges of science and technology in the 21st century. Improved policies and plausible projections were also critically examined. It also gave insight into the history and practice of Plant medicine. Also highlighted are relevant advances and challenges of science and technology in phytomedicine with possible solutions.

Keywords: Science, technology, 21st century, phytomedicine

Introduction

The 21st century, from the stand-point of science and technology can aptly be described as the era of undeniable craves, zero limitation, absolute possibilities but, insatiable quests. Technology is the use of scientific knowledge to solve practical problems or improve a preexisting solution to a problem. The fundamentals behind all scientific and technological inventions and discoveries derive from an inherent desire to live with the principle of least action. Also to be noted is an inherent desire to be in control of nature rather than the reverse.

Research is defined by Webster's New World Dictionary as "the careful, systematic, patient study and investigation in some field of knowledge, undertaken to discover or establish facts or principles". Research not only produces new knowledge, it deepens and broadens the experience of scientists and engineers who will go on to apply that experience in many productive ways. The interaction of scientists with each other and with others in society is a particularly effective way of transferring and enlarging new knowledge and technologies[1]. As we move further into the 21st century, we are facing a confluence of three factors that will shake up the interface between society and science. Nanoscale science and technology are enabling unprecedented control over matter, allowing living and non-living systems to be manipulated and used in radical new ways. Innovative new approaches to communication and networking are facilitating the emergence of virtual partnerships that transcend geographical, organizational and social boundaries. And society is now so closely coupled to the biosphere that our actions are stressing the system to a greater extent than ever before in human history. This confluence of control, communication and coupling raises major challenges for society in the 21st century[2].

Historical Perspective

The origin of modern science has been traced to 1687 with the publication of Newton's *Principia*, which showed that nature observes beautifully precise laws which man can aspire to comprehend. This beginning of modern science led to revolutionary developments of astronomy, mathematics and physics in the next century, but did not lead to technological developments with important economic benefits.

Many scientific and technological advances have had their origins in research that could not have been predicted to have those outcomes. For example, modern communications is founded on research into the fundamental properties of electromagnetism and electron flow in semiconductors, which resulted in the transistor. Recombinant-DNA technology arose from studies of unusual processes in bacteria. Mathematics, a contributor to engineering and technical arts for more than a century, continues to be at the core of applications as diverse as aircraft design, computing, and predictions of climate change[1].

Scientific information now moves quickly around the world, both through information technologies and through the movement of students and researchers across borders. The complexity of new technologies increases the importance of interdisciplinary knowledge transfers and the pace of change intensifies worldwide[1].

Strides in the 21st century

Most science and technology advances are governed by a structure of a connected triad - basic research, technology development, and the involvement of society. In this cycle, both pure and applied sciences become an integral part of a successful endeavor. Take the case of cloning, a current subject of significant relevance to the definition of species. Cloning began as a laboratory experiment on the genetic material of our cell's DNA. But these experimental achievements would not have been possible without scientific research and advances over a half century of development in many areas: the discovery of the genetic code, molecular structure of DNA, recombinant DNA, and other related studies. Moreover, a century of development of new techniques and tools provided the means: x-ray crystallography, polymerase chain reaction (PCR), genetic engineering, as well as computer data processing. Moreover, then came the first successful cloning of a higher organism - Dolly, the sheep – an act that transformed laboratory research into an enterprise with possible benefits to human medicine. But the third element of the triad, the society, must now be involved to develop a full perspective of the moral, ethical, and religious implications of cloning. With rational thinking, the benefits of cloning and other developments, such as stem cell research, to society will undoubtedly feed back to the support of basic research, and the cycle of the triad continues[3].

Challenges in the 21st century

With all this scientific promise, there are myriad risks that could be provoked or exacerbated by plausible technological innovations. As has been the case ever since technologies were employed not only for survival but also for conflict, these tools often have a double edge. Technological advances *per se* provide no foregone conclusions about how they will be used. With a retrospective look, challenges such as food security, disease control, global warming, accessible and affordable health care which has lingered still pose greater challenges to us today.

Indeed, looked at purely from the perspective of technical feasibility, three broad dangers had been forecasted concerning today's technological advances.

First, technologies contain destructive potential that will be both powerful and difficult to control. They could pose threats to the natural and human environment. Either by accident or through malevolence, the advances and diffusion of genetic engineering could give rise to unintended, unanticipated diseases, ecological vulnerabilities, and weapons of mass destruction. Dependence on computers, networks and the software that runs them could leave critical parts of society's life-support systems, from nuclear power plants and medical systems to security and sewage treatment facilities, open to both inadvertent yet catastrophic crashes and intentionally debilitating attacks. Less deadly but still pernicious risks might emerge as the spread of information technology makes it easier to violate basic privacy or civil rights and to engage in criminal practices ranging from fraud and theft to illegal collusion.

A second set of purely technological risks involves the possibility of greater vulnerability to system-wide breakdowns in, for example, the air-traffic control infrastructure. Some people fear that as the world becomes more diversified, decentralized and dependent on technology, there will be a higher risk of unmanageable failures in either the physical or social systems that underpin survival.

Lastly, the third danger relates to ethics, values and mindsets. Even the initial steps in the long-term development and diffusion of radically innovative technologies such as human cloning or computer-based intelligence (or even life-forms) could pose unusually strong challenges to existing ethical and cultural standards, and put greater burdens on people's tolerance of the unknown and foreign. The risk is that the shock induced by certain technological breakthroughs could end up generating serious social unrest.

Fortunately, the extent to which technology advances and actually poses such threats is fundamentally shaped by forces other than pure scientific feasibility. The emergence of these risks will depend not only on the extent of the actual and perceived dangers of new technologies but also, and crucially, on social and political choices. Such matters, however, lead to the broader debate on the enabling conditions for realizing technology's potential.

Looking ahead

Like it or not, society is dependent on science and technology. Indeed, our dependency on science and technology is accelerating. Take our technology-based infrastructure away and civilization as we know it would collapse. The world's population continues to grow, lifestyle expectations are going up, and supporting technologies are becoming increasingly sophisticated. But this "progress" can only be sustained through increasing the rate with which new discoveries are made and new technology innovations are implemented.

At some point this cycle of technology addiction probably needs to be broken if society is to avoid a rather nasty crash. And it is entirely plausible that the solution for avoiding such a crash will itself arise from technology-based innovation. This means that if global society is to continue to mature and prosper, we have to get the whole science and technology enterprise right.

The only alternative is to face a radical "recalibration" of society, leading to a population level and demands on resources that are more in keeping with the Earth's load-carrying capacity. Assuming that we want to avoid a rapid and potentially catastrophic reduction in the world's population, we need to ask whether the way we currently "do" science and technology is good enough. And if it isn't what needs to change?[2].

For the developing nations, there are barriers for progress, but I see no way out of investing in science education and science development. A look at global science and technology is illuminating. The total number of scientific papers published worldwide over the past five years is 3.5 million. The European Union's share is 37%; the United States, 34%; Asia Pacific nations, 21%. The United States contributes 30% to 40% to the world economy and the strong correlation between the advanced state of science and technology and the advanced state of the nation is clear. Asian Pacific countries are showing exponential growth in science and technology papers and this too explains their increased position in the world economy. Other correlations of gross domestic product (GDP), health status, life expectancy, and illiteracy show the critical role of science education and scientific research in the global positioning of nations.

The lack of a solid science and technology base is not always a result of poor capital or human resources. It sometimes stems from a lack of appreciation of the critical role of science and technology in development, an incoherent methodology for establishing such a base, and an absence of a coherent policy addressing national needs, and human and capital resources. Some countries consider scientific progress to be a luxury, as measured against other demanding concerns. Others believe that the base can be built by buying technology from developed countries. These beliefs translate into poor or, at most, modest advances that are based on the efforts of individuals, not institutional teamwork.

These issues point to three essential ingredients for progress. First is the building of human resources by eliminating illiteracy, ensuring active participation of women in society, and reforming education. Second is to rethink national constitutions, allowing for freedom of thought, minimizing bureaucracy, developing a merit system, and creating a credible - and enforceable - legal code. Third is the building of a science base. The foundations of a science base are investment in special education for the gifted, the establishment of centers of excellence, and the chance to apply knowledge in the industrial and economic markets of the country and, eventually, the world. This must go hand-in-hand with a plan for general education at state schools and universities. With such a vision, a scientific culture will emerge that enhances a country's ability to follow and discuss complex problems, rationally and collectively. Scientific thinking becomes essential to the fabric of the society.

Developing countries need centers of excellence, not only for research and development, but also for training experts in advancing technologies and so reducing the brain drain experienced by many such countries. It is important that these centers are not just exercises in public relations: They should be limited to a few areas of research in order to build confidence and recognition.

In the coming fifty years, knowledge-based and skill-based societies will have the lion's share of the world market and high status. Without science and technology how can the have-nots participate in current world issues such as stem-cell research, cloning, human genome sequencing, artificial intelligence, manipulation of matter, molecular medicine, and cosmology? Without science and technology how can they actively contribute to the world market in technologies such as microelectronics information and communication, new materials, and the revolutionary biotechnologies?

The challenges require a new system of education and a new outlook on technologies. Technologies fall into three categories, those that are 'simple' but relevant to services, solving domestic problems of everyday life, from traffic lights to desalination of water; those that are 'innovative', which make participation in the world market possible, such as microelectronics; and those that are 'frontier', which are concerned with research into the unknown, representing an investment in the future. To be effective, a new system of education and research and development in the first two categories are required and, at the least, there must be serious engagement with the issues of the third, frontier category - where the world is going to be. This implies that adequate caution must be employed in the issue of policy formulation.

Science and Technology Policy

The knowledge networks that emerged during the 1990s and early 2000s now dominate relationships in international science and technology. Traditional policy approaches based on national systems of innovation and research, using a linear concept of knowledge creation are inadequate to manage science and technology[4]. Because science and technical knowledge and guidance influences public policy decision making on many other issues, some think that science and technology policy does not need to be a separate field of inquiry. Science and technology policy has been considered in four facets: *science for policy, technology for policy, policy for science*, and *policy for technology*[5]. *Science for policy* and *technology for policy* are when scientists, engineers, and health professionals provide analysis, knowledge, and data to inform policymakers with the goal of enhancing their ability to make wise decisions. This scientific and technical guidance is available for almost any public policy arena. A classic example is global climate change[6].

Policymakers debate questions such as at what point actions, if any, should be taken to mitigate greenhouse gas emissions. If no action is taken, what are the possible impacts of global climate change? If policymakers decide to take action, what policy steps could taken to mitigate greenhouse gas emissions or to adapt to global climate change? Policymakers are the ones who decide what steps should be taken to manage these risks. They can base their decisions on the guidance provided to them by the science, engineering, and health communities.

In contrast, *policy for science* and *policy for technology* are when policymakers take actions that influence the science and technology community or the actions in which they engage such as research or science and technology business related activities (e.g., patent law). In the case of climate change, for example, these same policymakers make decisions such as the degree to which the government should invest in climate change related research, whether or not to establish programs and organizations that set priorities for this research, and what technologies government agencies should investigate further as possible mechanisms to mitigate greenhouse gas emissions[6].

Epilogue

Undoubtedly, the torrential wave of science and technology has brought with a mix of exhilaration and trepidation. It is practically impossible to suggest that we have had enough, particularly as the present state can only be sustained by yet further innovations. Perhaps the most throbbing challenges confronting science and technology in the 21st century revolves around issues of morals and sovereignty of individuals, groups or states. It is however pertinent that improved science and technology policy be advocated. These will include developing research agendas that are driven by social challenges, engaging citizens through building constituencies, and cultivating scientists with a clear sense of civic responsibility. Perhaps our inventions will not only gratify us, but posterity will applaud our legacies.

Science, Technology and Phytomedicine

Science and technology has played tremendous roles in the investigation and uses of plants which is one of the most primary human concerns that have been practiced by all cultures for tens, if not hundreds, of thousands of years[7]. The history and practice of phytomedicnie (plant medicine) is as old as man himself. According to World health organization, phytomedicines are herbal preparations produced by subjecting plant materials to extraction, fractionation, purification, concentration or other physical or biological processes which may be produced for immediate consumption or as the basis for herbal products. Phytomedicine can also be said to be naturally occurring substances, usually of plant origin in the prevention and treatment of diseases[8]. Generally, phytomedicines or herbal drugs have a myriad of therapeutic effects and are said to be safe and consumed over a long period of time without side effect[7]. This address will not be complete without making an attempt to define the main ingredient/ constituent of phytomedicines that has been the source of inspiration to several pharmaceutical drugs. These major ingredients are medicinal plants. Medicinal plants are plants that have in one or more of its organs active substances that can be used as therapeutic agents or as precursors for the manufacture of synthetic drugs. Roughly 50,000 species of higher plants (about 1 in 6 of all species) have been used medicinally. This represents by far the biggest use of the natural world in terms of number of species[8].

Trends in Phytomedicine

The history and development of Phytomedicine is as old as human civilization. But in order to survive and then for civilization to develop, people needed to learn what plants were useful for foods, fuels, medicines and fibers and how such plant resources could be mined or managed for human benefits. Historically, plants have not only provided man with food but also with means of healing. The use of plants as medicine was practiced by our ancestors, a process which must have started by trial and error[9]. Over the years traditional societies world over, by living close to nature acquired unique knowledge about the use of wild flora and fauna, most of which are not known to the people who live far away from such natural ecosystems(forests). The culture of plant use continues and it is estimated that about 80% of the people in the rural areas depended solely on herbal doctors for their healthcare need[10]. In the past, the traditional healers in an attempt to make the practice more appealing, included magic, rituals and sacrifices in their method of treatment. Today these practices have become part and parcel of the traditional healing system. It should be noted however that the apprentice or his teacher do not have any text book to refer to since these things were not written in any record, but depend on their wonderful memories. It must be noted that the lack of record in any form may not be overwhelming enough to discredit this healing system[11].

Interest in medicinal plants as a re-emerging health aid has been fuelled by the rising costs of prescription drugs in the maintenance of personal health and well being. An increasing reliance on the use of medicinal plants in the industrialized societies has been traced to the extraction and development of several drugs and chemotherapeutics from these plants as well as from traditionally used herbal remedies[12]. Today, plytomedicine has played a key role in World health care[13]. Presently, there is a trend of improvement in the development of phytomedicine in the world, though much of its values/importance is yet to be fully harnessed.

There is today established institutes and schools of learning in the areas of phytomedicine. Examples include the National College of Natural Medicine and the Nigerian Institute for Pharmaceutical Research both in Nigeria. Currently, there is an upsurge in research and development using science and technology in phytomedicine. Today research and development in phytomedicine has gone beyond documentation to screening of medicinal plants for bioactive agents, potency, pharmacological effects, toxicological activities, antimicrobial activities as well as development of drugs and dosage forms for natural products of merit.

Relevant information on medicinal plants are now available in a number of scientific and technological data bases, like Napralert, Pharmel, Napreca and the Traditional knowledge Digital Library (TKDL) been undertaken by the Nigeria Natural Medicine development Agency (NNMDA) in Nigeria, Africa.

Advances of science and technolgy in phytomedicine

Owing to the enormous progress of specific high-tech analytical methods, we are able today to analyze even complex composed extracts and phytopreparations and to quantify the major active compounds, which are supposed to be responsible for the efficacy of an extract. The successful three-dimensional high-performance liquid chromatography (HPLC) fingerprint analysis of a multiple extract combination of Kampo medicine prepared from eight herbal extracts and the quantification of their major constituents, illustrate the effectiveness of these modern tools. At the same time, these methods meet the quality standards of drug authorities and the reproducibility of pharmacological studies, along with the performance of good clinical practice (GCP) and conforms to clinical trials requirements.

Again science and technology have made giant strides in phytomedicine research particularly in the application of biotechnology. One of such technique is micro propagation which is said to increase the multiplication and permits the production of pathogen free herbal materials. This bio-technique has lead to the regeneration of plants from shoot and stem meristems yielding positive results in medicinal plants like *Catharanthus roseus*, *Rauvolfia serpentine* and *Digitalis* spp. Combinatorial biosynthesis have also emerged as a new biotechnological tool in the production of novel natural products as well as generation of rare and expensive natural products. The combinatorial biosynthesis of important classes of natural products such as alkaloids (vinblastine, vincristine), terpenoids((artemisinin, paclitaxel,carotenoid) and flavonoids have been done[14]. Other scientific and technological advances include organogenesis via callus mediation, somatic embryogenesis, genetic transformation and cryopreservation of medicinal plants[15].

Challenges of Science and Technology in phytomedicine

Several factors militate against development of science and technology in the production of phytomedicines: i. Improper documentation. There is inadequate scientific record as well as requisite technology to document available medicinal plants and as a result many species are becoming extinct. Also no straight record of the phytomedicine practitioners and the traditional healers who are of advancing age and are dying. ii. The development of a drug from its natural source is a very tedious task and more difficult than the development of synthetic drugs. Phytomedicine formulation biotechnologicaly from its crude stage requires trained and experienced specialised experts which are not readily available[16]. iii. Disparity in the duration of treatment using herbal medicine. iv. Lack of collaborative research among Phytomedicine practitioners, Traditional Medical Practitioners (TMP's), Orthodox medical practitioners and the Scientists. As a result of this, there is no robust development of the needed scientific knowledge and technology in the research carried out by the practitioners. v. Lack of standardization and quality control of herbal drugs used in clinical trials and even in occultic practices. vi. The development of science and technology is still lacking behind in terms of imprecise diagnosis and dosage forms for phytomedicine. vii. Unfavourable legislation. The practitioners, their practices and their herbal products are not well legislated for just as the indigenous knowledge and intellectual rights are not legally taken care of. This has also to a large extent affected the development of science and technology in phytomedicine. viii. Absence of scientific and often difficult to explain practices. ix. Communication problem. It is a big obstacle between the TMPs and the scientists. x. The risk of side effect due to over-dosage, toxicity and interaction with conventional drugs. xi. Wrong/improper manufacturing procedure such as misidentification of plants, lack of standardization, failure of good manufacturing practice, contamination as a result of field microbial activities, poor packaging, the environmental condition (temperature, light exposure), substitution and adulteration of plants, incorrect preparation and dosage. xii. Large variation in clinical methods between any two traditional medicine practitioners. xiii. Lack of adequate conservation and storage facilities for medicinal plants. There has been a very poor attitude towards developing the requisite science and technology to sustain the sensible utilization of medicinal and aromatic plants. xiv. Lack of coherent national health policies and development plan that will include phytomedicine research and developmental allocation of financial and other resources for the development of science and technology in phytomedicine research.

Recommendations

Phytomedicine is in the midst of renaissance and for years, there has been an increased public interest for natural therapies[17,18]. This interest in natural therapies have also increased international trade in phytomedicine and had attracted most pharmaceutical companies interested in commercializing Phytomedicines. The need for Phytomedicines is gaining ground and increasingly becoming recognized. However, as medicinal plants are going global with increasing demand in the phytotherapeutic market, there is the need to bear in mind certain scientific and technological factors in order to meet the world herbal medicine's standard of safety, efficacy, quality and stability of phytomedicines.

It is therefore, important that we emphasize and consider the following factors/issues in order to meet up with future challenges.

Protection of Intellectual Property Rights (IPRS)

The protection of intellectual property rights (IPRs) must be a priority item for the effective development of science and technology for phytomedicine in the future. It will be appropriate if we continue to uphold the IPR of persons who have sufficiently contributed in the discovery of new drugs from natural product sources. It is therefore, unwise and counter-productive to tap age-long knowledge and tradition without extensive compensation to individuals, local communities or even the research communities. This policy of upholding IPR by offering and actually giving adequate compensation will facilitate the establishment of collaboration between several parties and scientific and technological base laboratories engaged in natural product-driven drug discovery as well as build trust[19].

Policy formulation

Policies and strategies must be developed and continuously amended to meet upcoming future scientific and technological challenges. This policy will definitely set the goal for phytomedicine and at large traditional medicine. The policy will not only develop and facilitate the use of phytomedicine but also regulate phytomedicine practice by protecting the populace from quackery, fraud and incompetence.

Development of new product

There is the need in the future to be desirous of rolling out new herbal products from completed scientific studies. The studies should be rich enough to file an Investigational New Drug (IND) for a new pharmaceutical product or a plant base dietary supplement.

Promotion of scientific research on phytomedicine and collaboration work

It is important that research be conducted with the right scientific and technological tools to ascertain the safety, efficacy and quality of phytomedicine. Research therefore should be conducted to validate claims made on quality, safety, and efficacy of phytomedicine and traditional medicines used for the management of priority disease like malaria, HIV/AIDS, sickle-cell anaemia, diabetes and hypertension. Collaboration of traditional medicinal practitioners with others in the scientific community is very crucial for the supply of initial information on the plants to the scientist. This can be achieved through staff exchange and training programmes, sharing of expensive equipment and joint publications.

Conclusion

Phytomedicine has over the years sustained good health and had served as sources of many modern drugs. Despite the challenges befalling it today, however it is not impossible with the right application of science and technology to overcome the pitfalls. This golden field of Phytomedicine must be seriously explored and investigated to the brim to increase the frontiers of the mainstream medical field. But I would like to recommend a strong research capacity that will allow us deal with a large variety of future challenges, whether medical or public health emergencies, environmental problems, security threats or crises that we cannot yet predict. However, it is my utmost believes that solutions to pressing problems will continue to emerge in unexpected ways from new scientific and technological knowledge. Therefore we must work hard in the centuries to come by increasing our capacity to solve problems and creative discoveries if we must be relevant intellectually and economically. So let us be the change we desire.

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