

ASIAN BIOTECHNOLOGY AND DEVELOPMENT REVIEW



Special Issue on Women and Biotechnology

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Krishna Ravi Srinivas, Lucy Hoareau, and Magalie Lebreton-Traoré

PAPERS

Challenges and Opportunities in Bioscience for Women in China

Nancy Y. IP

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Banu Subramaniam

A Feminist Perspective on Biotechnology and Technoscience

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A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia

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Medical Agricultural Biotechnology and Public Health: The Interface between TRIPS and Cartagena Protocol on Biosafety

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Women and Biotechnology Editorial Introduction

Krishna Ravi Srinivas*
Lucy Hoareau**
Magalie Lebreton-Traoré***

When we thought of the theme for this special issue we discussed many themes but zeroed in on “Women and Biotechnology” because it fitted well with - UNESCO’s interest and activities on women and S&T and also with the broad objectives of the ABDR. It is easy to bring out a special issue on topics and issues that are hotly debated or are well addressed in the literature. But to bring out one on an issue that should have been given more attention than it has been given is a challenging task. For us, it was an experience in learning. Women are often invisible in the discourses on biotechnology and socio-economic development. At times, they are partly visible in some contexts, in studies that address gender dimension or issues like employment, labour cost and public perception. But this is not unusual as often the value neutrality and gender neutrality of S&T is taken as an axiom.

At the risk of over simplification, we may categorise the approaches to women and science and technology into three categories. The first approach of women in S&T is conflated with or is considered as a sub-component of increasing women’s participation in S&T at all levels, from students to reaching higher echelons. Under this approach, the issue is discussed more in terms of constraints and opportunities, institutional culture, sensitisation

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and opening up more spaces for women in S&T. The solutions which are often suggested include incentives, special schemes, promoting women friendly milieu in institutions and institutionalising structures and norms that address the gender bias and related issues. By now we have much literature on efforts to increase participation of women in S&T.¹

The second approach drawing insights, *inter alia*, from sociology of S&T, science and technology studies and social constructivism looks at the problem of participation of women in S&T and impact of S&T on women differently. It takes into account the structure and norms of S&T bodies and looks at various other dimensions such as construction of scientific knowledge, the role of gender relations in shaping technology and gender in the history of S&T.²

The third approach is informed by the feminist perspectives on S&T, including feminist analysis of the philosophy of science, feminist critiques of techno-science and women's experiences with S&T as users, participants and patients/targets. While there is an overlap between the second and third approaches, a distinct strand of feminist approach informed by the critical feminist perspectives is discernable in the literature.³ Parthasarathy points out breast cancer activists influenced policy making by effectively using feminist perspectives (Parthasarathy 2010).

In our view, although each of the approaches has merits and demerits to get a better understanding of women and S&T, we need these three approaches and they should not be conflated. This means that we should approach women and S&T issues with an open mind instead of assuming that we know both the problems and the solutions. This facilitates use of insights from different approaches and makes us aware of the limitations of our assumptions and solutions. For example, if the objective is to increase women's participation in S&T traditional approaches like incentives, and women friendly milieu are necessary but not sufficient as there could be barriers and constraints that could not be resolved by these solutions. In fact those favouring the second and third approaches may even question some of the goals and can caution against quick fix solutions that fail to address deeper issues like gender relations in society, gender roles and segregation of jobs on the basis of gender.

In this special issue of the ABDR, we have four papers, a book review and an executive summary of a report from UNESCO. The three papers espouse different view points on women in S&T and the executive summary highlights the findings from a study. The diversity in the views is important to understand the questions that have to be addressed when we discuss women and biotechnology.

Often the important narrative that drives the biotechnology and development discourse is that biotechnology has immense potential and is very important for developing countries. Although critical voices have countered this, it is important to know that feminist critiques of biotechnology have their roots in the feminist critiques of techno-science, particularly the reproductive technologies. These critiques since the late 1970s have highlighted how women have encountered and experienced these technologies. It is not that there is only one perspective on feminist analysis of techno-science or biotechnology but what matters is that they foreground the link between gender and technology and try to question the claims on gender neutrality of the technologies and the gender-blind views on technology and socio-economic development.

The paper by Banu Subramaniam provides a critical feminist perspective and it is neither pro-technology, nor anti-technology. Instead it takes a position that examines the potential of technology and cautions against claims that technology will bring only benefits. But the larger question is: what should be done to ensure that women really benefit from biotechnology or more specifically what sort of biotechnology should be promoted if women are to benefit most from biotechnology? The paper by Nasrin Moazami addresses the gender gap in S&T and suggests some solutions to address this. The paper by Nancy Y. IP looks at the recent developments in women and biosciences in China and there are some interesting lessons from China in addressing the gender gap in biosciences. Though the focus of the executive summary of the UNESCO Report is on Asia, it is still relevant for other regions also as it covers many inter-related topics.

An important concept in science and technology studies is known as 'social construction of science and technology'. Although there has been much discussion on the very idea of 'social construction of science and technology', this concept is useful in both understanding the S&T and

society dynamics and to chalk out alternative utopias/futures based on S&T. Eschewing technology determinism and techno-utopianism social construction of technology perspective argues that we should look at the link between S&T and society more carefully than to assume that S&T will determine the society or vice versa. Applying social constructivist perspective on women and biotechnology is important but not much has been done on this in case of agricultural biotechnology and women while there are many studies on women and reproductive technologies. But as there have been many studies on women/gender and agriculture, we hope that in future there will be more research on women and agricultural biotechnology. But that should go beyond 'add gender and stir' approach.

UN agencies like UNCTAD have examined women and S&T policy, but have not looked into women and S&T in the context of different technologies in depth and there is an urgent need to do that as there are specific issues to be addressed in the context of each technology. Moreover, there is a need to take a comprehensive look at the various initiatives in different countries for mainstreaming women in S&T and do a comparative analysis of what works well and in what context. In 2004 a report from UNCTAD stated:

“It is clear from the discussions that gender dimensions to biotechnology development and application do exist. Many exist in terms of the effects of technological development on women and men in general; however, there are gender dimensions which are uniquely relevant to biotechnology. Three issues stand out. In many areas the gendered impact of biotechnology on the lives of women and men is not known apart from a few anecdotal cases. Much more research is needed before we can identify the full range of gendered impacts. Secondly, regarding agriculture, it is well documented that in much of Africa and Asia men are responsible for growing certain crops and women are responsible for growing quite different crops. Current evidence suggests that the application of biotechnology has mainly been directed to the crops grown by men rather than those grown by women. This hypothesis needs to be tested and appropriate implications drawn and understood. Thirdly, in the health domain, biotechnology has a different impact on the lives of men and women mainly because of biological and sex differences. There are also gender differences, but the biological differences seem to be more important both in terms of benefits, as in the case of microbicides which are potentially empowering for women; and

risks, as in the potential for exploitation and trafficking of women's genetic material" (UNCTAD 2004).

But not much research has been done on the suggested lines. Although there are references in the literature on gender and biotechnology development, we have not come across extensive and systematic studies that address the gender dimensions in biotechnology.⁴ Women should not be seen as mere beneficiaries or users of biotechnology but considered as stakeholders whose interests go beyond that of users. Ezezika *et al.* (2012) identify five areas that deserve attention in this regard. The five areas identified by them are: (1) inclusion of women, especially women farmers in trait selection and decision making in GM/biotech crops; (2) equal representation for women in agricultural education and in agri-biotech R&D; (3) greater involvement of women in farmers' associations and extension services; (4) equal access to women in resources for biotech/GM crop cultivation; and (5) more control by women farmers over crop management and income generation.

Although their research was done in the context of gender and agricultural biotechnology in Sub-Saharan Africa, the findings can be important for other regions also.

We hope that this Special Issue of the ABDR will kindle more interest and research on women and biotechnology among academics, government agencies, funding agencies, feminist groups and policy makers. With this we present the outcome of our modest effort before you. Your comments and suggestions are welcomed.

Endnotes

- ¹ For example, *Feminist Approach to Technology* (2014), Thege *et al.* (2014), Pearson *et al.* (2015), and Sujatha (2015).
- ² For example, Wirtén (2015) and Jardins (2011).
- ³ For example, Ernst and Horwath (2014), Takeshita (2011), and Morgall (1993). For example, for applying 'gender lens' in S&T see UNCTAD (2011).
- ⁴ Molfino and Zucco (2008). It is one of the few volumes that provide a gender perspective on biotechnology, covering many areas in biotechnology. See also Wagner (2008) and Subramanian *et al.* (2010).

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Challenges and Opportunities in Bioscience for Women in China

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Abstract: Asian biotechnology has undergone rapid development within the past two decades. China, like many other countries in Asia, has made huge strides in biosciences and invested in the core elements to help transform it into a leading biotechnology hub in the region: state-of-the-art infrastructure, advanced technologies, pioneering research programmes, as well as rigorous science education and training. The rapid growth of the industry has translated in increased career opportunities for budding scientists. However, global statistics indicates that like most of the world, gender inequality in the biosciences persist in China due to traditional mindsets of women's role in society. However, in recognition of the valuable contributions women have made and are making in bioscience development, initiatives aimed at closing the gender gap are being implemented from the level of government to policies in universities. Thus, there are considerable opportunities and avenues for young women in China with the passion and persistence to pursue a career in biosciences.

Keywords: Gender, China, Biosciences, Biotechnology, Innovation

Introduction

Growing Opportunities in Bioscience in China/Hong Kong

Rapid growth in the science and technology sector in China is driving research innovation, capabilities and output, and the resulting push towards a knowledge-based society is enhancing career prospects in the biosciences. In recent years, the central government has made huge investments to boost research and development. For example, in 2010, having identified

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science and technology as one of the major goals of its national development strategy, the government implemented the 12th Five-Year Plan with the aim to increase R&D funding from 1.8 per cent of the GDP in 2010 to 2.2 per cent in 2015.¹ In 2012, the government invested 228.5 billion yuan (US\$ 36.1 billion), a 12.4 per cent increase from 2011. Of this, 32.5 billion yuan was earmarked for basic research, a 10.1 per cent increase from 2011 (Qiu 2012). Additionally, the budget of the National Natural Science Foundation of China (NSFC), the main funding agency for basic research, increased to 17 billion yuan in 2012, 8 times greater than in 2003 with an average annual growth rate of 28.5 per cent.² Furthermore, to foster a culture of basic research, the NSFC supports young scientists to help them establish themselves as researchers. For example, in 2013, NSFC supported 15,367 young researchers with 3.7 billion yuan of the Young Scientists Fund, granted 399 projects with 399 million yuan of the Excellent Young Scientists Fund, and sponsored 198 projects with 388 million yuan of the National Science Fund for Distinguished Young Scholars.³ Meanwhile, although bioscience development is on a smaller scale in Hong Kong, compared to activities on the mainland, there is a thriving research community engaged in innovative basic and applied bioscience research. Local government commitment to support development is through the Innovation and Technology Commission, with additional support from the Hong Kong Science and Technology Parks Corporation, Hong Kong-based public and private charity trusts, and the local biopharmaceutical industry. Overall, in both Hong Kong and China, new initiatives are opening up educational, training, and career opportunities in areas such as basic and translational research, drug discovery, clinical research and development, regulatory affairs, biopharmaceutical manufacturing, and marketing and sales. Thus, the future for bioscience development looks bright and will continue to progress and bring in new opportunities for young graduates.

Challenges

There has been much discussion about the lack of women representation in science, and global statistics and reports indicate that women are still marginalised in science fields including the biosciences. According to the UNESCO's Institute of Statistics, globally women make up only 30 per

cent of the world's researchers; in Asia, this number drops to 18.9 per cent.⁴ Cultural and social factors are the major factors of gender disparity. In many patriarchal societies, women are constrained by social pressure and persistence of traditional mindsets that a woman's role is in the home. In these instances, they may not have equal access to education and have fewer opportunities to develop professional careers (Castle 2014).

In China, inequality in educational opportunities is less of an issue compared to other Asian countries. Chinese parents, in general, are as supportive of a daughter's education as they would be of a son's. Society is also more supportive of women's participation in the workforce. Greater shared responsibility within the family unit – and, in Hong Kong, the availability of domestic helpers – takes off some of the burdens of childcare, thus enabling more women to join the workforce. In fact, Chinese women play prominent roles in many facets of society and contribute significantly in many professions. However, gender disparity is observed in the biosciences in China as in other parts of the world. And in line with global trends, while the number of women may equal (or even exceed) the number of men in bachelor programmes, their numbers quickly diminish as they move up the education ladder with marginal representation at higher echelons of academia and industry. For example, in the Chinese Academy of Sciences (CAS), the prestigious and leading academic institution in China, a huge disparity is seen between the number of male and female academicians; presently only 6 per cent are female.⁵

Many reasons have been cited for this phenomenon, also termed as the 'leaky pipeline'. Women may be subjected to discriminatory hiring practices, since they may take time off to have children and hence be considered less productive. In some cases, women may put their careers on hold or opt out completely to start a family, based on the notion that it is not possible to balance work and family commitments. Undertaking a demanding science career while being solely responsible for childcare and family duties can be a challenging endeavour. They may also discontinue their careers due to lack of family support. Young women may switch fields due to lack of mentors and role models in the field. Furthermore, low female representation at high levels in bioscience fields could be perceived as a barrier to senior positions, which could compel some women to seek out alternate career paths.

Overcoming Challenges and Seizing Opportunities

While studies confirm that challenges exist for young female scientists building careers in biosciences, it is critical that young women do not intentionally hold themselves back from a potentially rewarding career based solely on these findings. In fact, in recognition of the gender disparity, there has been a push for policy changes at high-levels of academia and industry to address the challenges women may face. Some new initiatives include family-friendly policies to ensure gender parity in recruitment, promotion, and awards. For example, some universities have begun providing support to women faculty affected by pregnancy and childbirth by reducing teaching load, extending the tenure clock, and providing maternity pay and child care facilities. Recognising the achievements of women scientists through award programmes is another major global initiative. The purpose of these awards is to celebrate and promote notable accomplishments and successes of women scientists, encourage more women scientists to engage in natural science research, as well as provide female role models for younger generations. An example is of the China Young Female Scientists Award, an extension of the prestigious UNESCO For Women in Science Award, jointly established by the All-China Women's Federation, the China Association for Science and Technology, the Chinese National Commission for UNESCO, and L'Oreal (China) Ltd. Presented annually to 10 candidates from mainland China, Hong Kong and Macau, the award honours young women who have made important and notable achievements in their field of work.⁶

Specific government policies have also been established to tackle the issue. One example is the 'Outline for the Development of Chinese Women 2011-2020', established by the China's State Council in 2011 to increase the proportion of women in science and technology to 35 per cent (SciDev. Net 2011). The CAS has also identified increasing women representation in science as an important priority. The organisation hosted the Third World Organisation for Women in Science (TWOWS) 4th General Assembly and International Conference in Beijing in 2010, a forum to address gender disparity in the developing world and develop initiatives to support and encourage the full participation of women in science and technology.⁷ Additional progress towards overall gender equality in the country can be seen by the announcement by the Chinese Ministry of Human Resources and Social Security on its review of the retirement age of women in China.

Under the current regulations, regular female workers retire at the age of 50 and female public servants retire at 55, while the retirement age for men is 60. There is a growing push by women scientists for the same rights to retirement age as men.⁸

In addition to these top-level changes, there are also a number of things young women can do themselves to overcome gender-related challenges and succeed in their chosen professions. First, they should not be disillusioned by the issue of gender disparity. Instead, they should be aware of its existence and identify the various support mechanisms that are available to them to support their upward career mobility. Second, young women should proactively seek out mentors, especially during the early stages of their careers. Mentors provide support and encouragement, as well as invaluable guidance on research and career paths. They can also help dissipate unfounded fears. Joining professional women's organisations in science and technology is another avenue of support, as these organisations provide invaluable support as well as host forums on essential career-related topics. Third, they must have the right attitude, be persistent, and be prepared to pursue their dreams with focused enthusiasm and drive.

Perspective of a Woman Scientist in Biosciences

My own journey in pursuing a career in the biosciences has been exhilarating and inspiring; a road compounded by challenges, setbacks, successes, and a great sense of satisfaction. As I progressed from an aspiring student to an independent scientific researcher, I faced a number of challenges not dissimilar to what young women face today. First, there were few female role-models to emulate. Thus, as I pursued my undergraduate and graduate degrees and underwent the rigorous training, that is part of becoming a scientist, I sought out mentors and role models; scientists who inspired and challenged me and provided encouragement, guidance, and a supportive environment for me to learn and build my career. I also identified opportunities to get hands-on experience in cutting-edge research, and worked with distinguished researchers to develop and hone crucial skills and come into my own as a scientific researcher. Second, as discussed previously, many women opt out of science as they feel they need to choose between starting a family and pursuing a bioscience career. I chose to embrace both. I firmly believe that with a certain degree of prioritising, sacrifices, and

family support, women can have successful research careers as well as raise families. Thus, I underwent post-doctoral training at Harvard Medical School, after which I worked in the biopharmaceutical industry in the United States, and at the same time, endeavoured to maintain a balance between my family life and my bioscience career. Thus, passion and perseverance are important ingredients for success in science.

In 1993, I returned to Hong Kong with my family to join the then newly established Hong Kong University of Science and Technology (HKUST). Returning to Hong Kong to embark on an academic career at a newly-established university brought with it a different set of challenges. During this early period of life science development in Hong Kong, there were few commercial ventures and the local biopharmaceutical industry was very much in its infancy. However, my colleagues and I were motivated by the opportunity to promote bioscience development in Hong Kong, and we enthusiastically embraced the challenge to help shape the life science programmes at the university and lay the foundations for advanced neuroscience research. Since those early years, there has been tremendous progress, most evident by the increased funding support for innovative projects, greater training opportunities, and the emergence of a dynamic research culture. HKUST is now recognised for leading-edge neuroscience research, and many of the projects that I have overseen have resulted in success stories and opened new avenues of research. It has been immensely gratifying to be a part of the pioneering team of researchers involved in establishing Hong Kong as a world class hub for molecular neuroscience research, and in developing the local biotechnology industry.

Conclusion

China's former paramount leader once famously proclaimed that "women hold up half the sky". This could not be truer for bioscience development in China today. This sector is undergoing an exciting period of scientific development which requires tremendous input from talented and motivated individuals to drive creativity and innovation. As the government increases investment in basic and applied science, there is a critical need for a highly skilled work force. Thus, academia and industry must nurture their best home-grown talent and cannot afford to discriminate based on gender. Meanwhile, young women in China must not shy away from seizing

opportunities. With the right attitude, dedication, and persistence to pursue their dreams with focused enthusiasm and drive, they can excel in this rapidly developing sector.

Endnotes

- ¹ The State Council, People's Republic of China (2011).
- ² China Ministry of Science and Technology (2014).
- ³ *ibid.*
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Colonial Legacies, Postcolonial Biologies: Gender and the Promises of Biotechnology

Banu Subramaniam*

Abstract: Three decades of work in the feminist studies of science and technology have shaped our evolving understandings of the relationships between sex, gender, and biotechnology. Sex, and gender are most often reduced to binary categories, severely limiting our conceptions not only of human diversity, but those of science and technology. Using two case study set in India, transnational surrogacy and the Indian Genome Variation Project, this paper explores how popular positions around biotechnology are reduced to binary positions promoting and opposing biotechnology as the solution for the economic and social development of India. By locating surrogacy and genomics within the larger geopolitical, historical, economic and cultural transformations of postcolonial India, the paper argues that both technologies are far more complex in their impact on women and gender. Why does technology become the major site of hope for the future? Why does genomics become the site for the promises of good health? Why has India become a site for reproductive tourism, and transnational surrogacy in particular? Drawing on the social studies of science, the paper argues that technology and human bodies are never neutral but always prefigured with a gender, race, caste and sexuality. Surrogacy and genomics should be understood within these colonial and postcolonial histories of science and technology.

Keywords: Transnational Surrogacy, Genomics, Feminism, Gender, Women

Introduction

In her famous essay, “Why it is difficult for us to count past two,” Evelyn Fox Keller (1992) describes how when asked about her work, she tells people that she researches issues of *gender* and the sciences, yet, she is continually asked to discuss what she had learned about *women* in the sciences. Despite decades of feminist explication of the differences

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The views expressed in the paper are those of the author and they need not represent the views of RIS or UNESCO.

between sex and gender, she argues, most people constantly conflate the two. She laments about our incapacity to count past two. Two decades later, the binaries endure. The “binary” world we live in can be striking: we talk about men and women, masculine and feminine, upper class and lower class, upper caste and lower caste, black and white, homosexual and heterosexual, trans and cis, ability and disability, etc. In reality, none of these categories is binary, but rather represent a range of people in multiple categories if not a continuum. Yet the impulse to categorise this diversity into two categories, one superior and the other inferior, persists. The distinction between sex and gender is an important one, and while they are related, their relationship is far more complex than the linear correspondence that binary thinking implies, where the terms sex and gender are often used interchangeably. The idea of sex is most often grounded in the biological/material body, while gender has come to represent the profound consequences of the social meanings we have given to a binary sex system, i.e. gender represents the social rules of masculinity/femininity of inhabiting male/female bodies. Even this formulation shows binary thinking, where sex is biological, and gender is social, thus invoking yet another binary frame of a biology/social binary.¹ While human bodies may or may not be strictly binary in their phenotypic manifestations,² the idea of binary sex persists, as do claims of a vast apparatus of gender differences. We consistently see claims of gender differences in men and women, such as aggression, nurturing, logic, rationality, emotions, scientific and mathematical ability.

Decades of work in the social studies of science remind us that scientific claims of difference – be they about sex, gender, race, class, caste or sexuality – have been a persistent aspect of science. Claims of biological difference most often support the superiority of the political elite and the inferiority of those in the margins (Bleier 1984, Hubbard 1990, Birke 1999, and Fisher 2011). Science, it would seem, is ultimately a social institution that reproduces and replicates the power structures that it is located in. Science and society co-produce, indeed co-constitute each other (Reardon 2001). Scientific knowledge emerges from the circulation of knowledge, as knowledge continually travels between science and society, and back (Fausto Sterling 1987, 2003). Far from being removed from politics, or living up to its claims of value neutrality, science is deeply implicated in structures of power – and thus implicated in the histories of

sex, gender, race, and caste (Rose 1994). As it has grown to be a powerful institution, science has also been embraced and utilised by programmes and movements for social justice. Science is increasingly a contested zone, and has emerged as a tool for progressive movements and causes, and with its increasing democratisation it has also become a tool for liberatory movements (Campbell 2009 and Benjamin 2013). However, it should be no surprise that a history where women have been seen as inferior beings, would produce a science that is male dominated, and developed as a “world without women” (Noble 1992 and Schiebinger 1989). In the world with a “persistent patriarchy,” scientific knowledge continues to be shaped by the interests of the powerful and against science’s more democratic potential (Longino 1990 and Sur 2008). This history of science that developed as an all-male province has profoundly shaped scientific practices, its cultures and knowledge production (Subramaniam 2014). Furthermore, the development of science has shaped and been shaped by the politics of race, class, caste and sexuality, as well as by colonial expansion. Science and technology have been “the jewels in the crown of modernity” (Harding 2012:2), central to the expansion of empire and critical to the contemporary world. Sciences should, therefore, be understood as “sciences of empire” (Schiebinger 2004); indeed almost all modern science should be understood as “science in a colonial context” (Seth 2009).

While one can explore how science has shaped and been shaped by various structures of power such as sex, gender, race, caste, colonialism, heterosexuality, ableism, etc., I will focus on sex and gender in this paper. Ideologies of sex and gender are not neutral – those qualities that are deemed to be masculine have been historically overvalued and overrepresented in the hallways of power, compared to those deemed feminine (Schiebinger 1989, 1993). Social studies of science shows us that these gendered ideas and ideologies go deep, permeating most aspects of knowledge, including science and scientific knowledge production (Collins 1999). Ideas and ideologies of sex and gender permeate our thinking beyond the human body. Early feminist work has argued that western science has historically been imbued with masculinist ideals - to control nature, develop reductionist models of nature, extoll an impossible “objectivity” in our studies of the natural world (Harding 1991, 2006, 2012). Scientific temperament extols the objective, logical, rational, unemotional, removed from the social and political world.

In contrast, we see less attention to ideas deemed feminine, such as less exploitative models of living with nature, interdisciplinary models of knowledge production and subjective explorations of the world. Feminists have long argued that masculinity and femininity together represent an important resource for all humans, and have called to dismantle our binary system for a set of values that embraces feminist ideals, appreciating the strengths of both the masculine and the feminine.

This special issue is dedicated to the topic of “women and biotechnology.” Three decades of feminist scholarship have shown this to be a more complex topic than initially meets the eye. First, we can of course talk about women scientists who participate in biotechnology – we can ask about the demographics of women in biotechnology, and whether and in what proportion they are represented in different levels of research and administration. We can also ask if the presence of women shapes the kind of research that is undertaken. Second, we can explore the gendered dimensions of biotechnology, beyond the presence or absence of women. How have gendered ideas and ideologies shaped the innovations in biotechnology? What are the goals of biotechnology and whose interests do they serve? What questions have we asked, and what have we not? Finally, we can ask how biotechnology has shaped the lives of women at large. Has it empowered and improved the lives of women or has it continued to marginalise women and their interests? Each of these questions is related to the others.

According to Kiran Mazumdar Shaw, an Indian entrepreneur, and founder of biotech company Biocon Limited, “Today anything can be done – we the techniques.” Whereas Vandana Shiva, Scientist and Environmental Activist said, “You are not carrying the world on your shoulder. It is good to remember that the planet is carrying you.” The two statements show that the binary positions permeate our discussions around women/gender and biotechnology - is it good or bad? Is it progressive or reactionary? Is it good for women or harmful? Is it life affirming or life-killing? Should feminists support it or oppose it? Kiran Mazumdar Shaw sees the promises of technology, and believes it is a tool for the social progress of India. As a pioneer in the field, and as a woman, she sees technology as a site of social justice and believes in its promises for women in India (Weidmann 2014). As she says, technology can have wide impact and be a boon to India and that we should use it, and because with technologies’ wide reach and its innovative

potential, “anything can be done.” In contrast, Vandana Shiva, an Indian environmental and anti-globalisation activist and author has largely staked positions against biotechnology, which she sees as macho and masculinist and as a destructive system of people and the planet (Shiva 1988, 2005). Instead, she advocates that we return to traditional systems of farming in India, that are more woman-focused and that draw on the feminine *prakriti* to return to a more human and natural “nature.” Both figures are beloved in their respective communities of pro-technology and anti-technology.

Rather than stake a pro- or anti-technology position, I ally with the emerging consensus in science and technology studies that technology is best understood not as always either good or evil, or as a neutral tool that is subsequently appropriated by political actors for either good or evil, but rather as a site that is intricately interconnected with power and society. We, thus, need to trace and understand how *technology* becomes a site of knowledge and social action and how it is connected to other forces and structures in society (Wajcman and MacKenzie 1985 and Takeshita 2011).

Women, Gender and Science

Representations of scientists are strongly correlated with the demographics of power in a nation. Studies have shown that members of socially more powerful groups are better represented in more prestigious fields. A history of women in the sciences, both historically and in contemporary times, shows the continued marginalisation of women and minority groups across the globe (Alic 1986, Rossiter 1982, Abir-Am and Outram 1987 and Gupta 2007). In India, we see the strong effects of the politics of gender and caste in shaping science and the practitioners of science in India (Sur 2011). While the numbers of women in undergraduate and graduate education have risen, representation in the scientific workforce remains low (Huyer and Halfkin 2013). Furthermore, there are patterns to women’s under-representation across the disciplines in the sciences. Like in several other countries, in India, women tend to be more highly represented in the life sciences than the physical sciences and engineering. Demographic patterns across the globe also suggest that women’s representation is correlated with the status of the sub-discipline in the country. Disciplines with higher status and economic importance show greater male dominance. For example, computer science as a field began with a much higher proportion of women, and despite

considerable efforts, the proportion of women has dropped as the field has become more important and prestigious (Stross 2008). Despite being a 'hot' field, and despite efforts to increase the numbers of women scientists, the proportion of women in computer science has declined, leaving it very much a "boy's club" (Banerjee 2014). Such a pattern is a strong reminder that women's under-representation is tied to socio-economic and political factors rather than biological unsuitability (Campion and Shrum 2004, Subramanian 2007, Varma 2010). Women and gender are also not universal categories, always mediated by the politics, race, religion, caste, class, and sexuality (Beoku-Betts 2004 and Sur 2011). While there is scant data on the demographics of women scientists in India, the data that is available shows a similar pattern to the rest of the world. Women scientists remain under-represented across the fields in science and engineering (Gupta and Sharma 2002 and Kumar 2009). Women scientists are represented in higher numbers in the biological sciences, but women scientists in India still form a small proportion of women, and a minor portion of working women in India (Bal 2004).

Why the under-representation? Competing theories have postulated different reasons: whether women are not interested in science, not good at science or whether they leave the sciences because of a hostile or unwelcoming environment (Valian 1999, Cech and Blair-Loy 2010 and Garforth and Kerr 2009). Studies over the last several decades have documented that both historically and in the present, women show great interest in science and perform well academically (Rosser 2008). Indeed, women have persisted in their love of science, often under arduous conditions (Rossiter 1982 and Alic 1986). Despite decades of programmes to support and nurture women scientists, women have not achieved parity, especially at more senior levels. Studies suggest that this is because of continued inequities within science, and persistent barriers and systematic discrimination of women in science and technology (Bystydzienski and Bird 2006). To describe the under-representation, a recurring metaphor in the field is the "pipeline" and the women in science literature has documented a very "leaky pipeline" as women leave the scientific workforce at all stages of their travel from elementary school to the top echelons of science (Handelsman 2005 and Subramaniam 2009). Efforts to increase women in the sciences are often premised on "plugging" the leaks in the pipeline.

Others have argued that rather than “fixing” women to inhabit the culture of science, we should “fix” science to be a more inclusive institution (Rosser 2004). After all, increasing the number of women in the sciences does not automatically produce a culture that is more progressive or supportive of women (Garforth and Kerr 2009). Data suggests that women in sciences are participants in the scientific enterprise and thus often driven by the same goals and objectives of mainstream science (Acker 2000 and Garforth and Kerr 2009). Scientific culture that developed as a “world without women” continues to betray these histories (Traweek 1992). We need to see structural change, where the priorities of science, its mechanisms of judging merit, its policies for promotion, and advancement, and its methodologies of knowledge production need to change to recognise different life histories, priorities and needs of a diverse workforce. As a result, recent proposals to increase the representation of women in the sciences have shifted from a focus of changing “women,” to a focus of making science a more hospitable space for all scientists. Ultimately, strategies to “decolonise,” “degender,” and “regender” science are necessary to imagine a more progressive and democratic science.

While women remain under-represented in the higher echelons in biological sciences, and while the women in the field have not transformed biotechnology in significant ways, the impact of the sciences on women goes beyond the number of women who are in biotechnological fields. The 20th century was labelled the “century of the gene” (Keller 2002), and the biological sciences, and biotechnology, in particular, represent the site of great investment and focus in contemporary times. The field has infiltrated nearly all walks of life – from manipulating DNA to large-scale biological warfare, from bio-nano-particles to industrial replicators. What has biotechnology delivered, for whom does it work, and what impact has it had on the lives of women?

Biotechnological Body

Biotechnologies involve technologies of biological organisms, but their relationships to gender are best explicated by looking at biotechnologies of human bodies. Our imaginations around the body and its workings have been thoroughly biologised in the 21st century. In a wonderful exploration of biotechnology in India, Shiv Viswanathan and Chandrika Parmar (2002)

conclude that the biotechnology controversy around genetically modified organisms (and I would argue other biotechnology debates) has all the makings of a great “moral debate.” The two epigraphs that began this essay show us the contours of that great moral debate. Is biotechnology a tool we should embrace in our visions of a progressive and democratic society? Or is it a technology that ushers in a dystopic future for humanity? Viswanathan and Parmar (2002) argue that “biotechnology as a scientific venture in the populist and technocratic imagination is alive and well but biotechnology as a part of the new democratic imagination committed to the rule of law and regulation, and governance sensitive to the ideas of risks, is fragile. One needs to build concrete set of institutions around the practice of biotechnology and locate it within the wider debates on innovation, property and the commons.” They remind us that biotechnology is best understood not just as a set of methods that can be deployed to varied means and ends, but as an institution that has been developed in the aid of particular political and ideological visions (Bliss 2012). The research questions asked and the innovations that are developed in biotechnology are tied to funding agencies, corporations or governments and their priorities. We can certainly imagine technologies that are in the service of women, and even feminist technologies of the body. However, biotechnology as a field and like much of contemporary science and technology, has often served the interests of the powerful. The interests of women, feminist and democratic ideals have often been marginalised in the founding and governing visions of the field. I use two very different examples, transnational surrogacy and genomic medicine to illustrate this point. Transnational surrogacy is a burgeoning privatised industry in India that commodifies the body of “individual” women, and relies on a local and regional infrastructure to foster economic transactions transnationally. In contrast, recent investments in an Indian Genome Variation Initiative Consortium (IGV) work at the molecular level, are imagined as a national database, and rely on a national infrastructure and imagination. India is not alone, as many such projects have been undertaken by other countries in Asia. These projects have strong backing from the state, creating new linkages between genetic identities and national sovereignty. The emerging biotechnology industry in Asia can be seen as a rising “bionationalism” that is reshaping the global development of genomics, as Asian and other developing countries are asserting their

“genomic sovereignty” (Benjamin 2009, Kelly and Nichter 2012 and Ong and Chen 2013). Exploring these two very different cases, will illustrate how contemporary biotechnology is imagined and how in both cases, women and gender are impacted unequally in the goals, objectives and imaginations of biotechnology.

Bodies of Biotechnology: The Case of Transnational Surrogacy

Transnational gestational surrogacy is a commercial industry that has grown into a multi-billion dollar industry in India. Gestational surrogacy involves implanting an embryo created through *in-vitro* fertilisation (IVF) into a surrogate mother who carries the foetus to term. The child is then given to the commissioning parents. In contrast to genetic surrogacy, a gestational surrogate mother according to the law and medical understandings does not ostensibly contribute any “genetic” material and is, therefore, unrelated to the foetus. The exponential rise in this practice is evidenced by the sharp rise in estimates – from US\$ 445 million in 2008 to over US\$ 20 billion in 2011 (Nayak 2014:2). The term “surrogate” is derived from the Latin *subrogare*, which means “appointed to act in the place of” (Sama 2012). While commercial surrogacy is illegal in many parts of the world, it is a growing industry in India, largely unregulated since inception and only recently beginning to be regulated (Menon 2012). Technoscientific surrogacy employs high tech reproductive technologies utilising a low tech and economically marginalised workforce (Goodman 2008).

Over the last decade, India has emerged as a site of “reproductive tourism,” where infertile couples from India, the Indian diaspora and non-Indians abroad have come to India to what has come to be termed as “rent a womb” for their potential embryos from a gestational surrogate (Carney 2010 and Voigt *et al.* 2013). This is a global industry with complex and multiple circuits of travel where intended parents enter into “reproductive exile” (Inhorn 2012) to go to another country for conceiving a child. The circuits are so complex and transnational that some Indian couples are priced out of India, and have to travel to foreign countries like Dubai for various forms of reproductive technologies (Inhorn 2012).

A growing number of academic and journalistic accounts have chronicled complex and fascinating narratives of the surrogacy and the experiences of surrogates (Pande 2014, and Vora 2015). These narratives on the business

of commercial surrogacy are striking, and in examining stories about media reports and research accounts of surrogacy, a consistent narrative has emerged. The framing of the debates as Susan Markens (2012) argues, have revolved around the questions of whether the globalisation of reproductive labour is an exploitation of the surrogate mother or an opportunity for her and in a related vein whether the surrogacy narratives are best understood as one of gendered altruism or one of gendered empowerment – the literature, thus, presents this as an ethical issue of reproductive liberalism versus exploitation (Banerjee 2010).

First, surrogacy is presented both to the surrogates and the world as a de-sexualised model of reproduction – this is a technologised mode of reproduction ostensibly without the relational or ethical messiness of sex or sexuality. Second, the bodies of women are commodified as a “rent a womb” enterprise. Depending on the region, caste, class, skin colour, and educational background of the woman, the value of the womb varies (Sama 2012). Third, the pregnancy is entirely scripted as a medical process rather than an affective model of mothers or mothering. Surrogate mothers carry the foetus to term through a medically regulated pregnancy. Indeed, various towns in India like Anand, called the surrogacy outsourcing capital of the world (Nayak 2014), have become famous for their surrogacy centers where surrogate mothers live in hostels for the length of their pregnancy, closely surveilled and monitored for optimum foetal development (Pande 2009, 2014 and Voigt *et al.* 2013). While there is variation across India, a dominant narrative of gestational surrogacy has emerged.

Those arguing for the positive impact of surrogacy, point to the opportunity that gestational surrogacy has opened up as a site of labour. While there is much criticism about the exploitative and coercive nature of gestational surrogacy, it is important to understand and contextualise surrogate bio-labour within other forms of labour. While surrogacy is a very intimate and physical form of biolabour, other forms of labour have their own exploitative regimes. As Sharmila Rudrappa (2015) shows in her excellent ethnography, for some women, surrogacy presents a less exploitative model of labour than others, like the garment industry. Rudrappa describes the long hours, the physically arduous work, the lack of control, the sexual harassment, and at times violence that surround women’s experiences of labour in the garment industry. Is this really an improvement on surrogacy,

she asks? Surrogacy affords food, rest and relaxation (for some) during the duration of the pregnancy, and health care to a population that has little access to it – even though these benefits end with the birth. Surrogacy also gives women access to money (although there is considerable regional variation). Making money in nine months that would usually take her four to ten years to make is significant for the lives of women, and their role and power within the family and community. The technology of surrogacy has also revolutionised our conceptions of the family. It has allowed us to imagine and expand our notions of kinship and family (Thompson 2002). It has considerably expanded who can have babies and allowed the formations of new and more extended transnational family networks. For the affluent, surrogacy has opened up new options to deal with the stigma of infertility. Given that children and families remain the social net for old age in India, technologies of surrogacy have opened up new modes to build families that ensure individuals' future financial and bodily health.

However, critics of surrogacy have also raised important issues. Surrogacy has been presented into a medicalised and desexualised model, converting traditional ideas of pregnancy to be re-imagined as medicalised labour and clinical labour (Cooper and Waldby 2014). In this model, the woman's body becomes a receptacle of commerce (Sama 2012). The process of medicalisation is entirely regimented with clear steps and protocols that need to be faithfully followed. A prescribed meal, which is ostensibly based on western ideas of balanced nutrition, is consumed along with regimes of exercise, rest, and relaxation. The language of medicine frames so-called medical protocols into the legal contract of gestational surrogacy. Thus sexual abstinence, battery of tests and heavy medication (rarely explained to the surrogates), c-sections, lack of breast feeding, and regimented protocols of hygiene, nutrition and exercise are codified into the legal contract ostensibly based on the health of the foetus. Payment for the surrogacy (a large portion of which is only available after delivery) is dependent on following the medical protocols. The boundaries between private and contractual are very blurry leaving very little that remains in the private sphere of surrogate mothers, and thus giving them little control and agency in the process (Pande 2009, and Sama 2012).

Campbell (1992) argues that “contemporary medicine has transformed the human body into a source of instrumental value, a resource of value

to others: patients, physicians, and researchers...Such practices seem to presuppose a basic feature of property, that is, the capacity and power of alienation or transfer.” Indeed, gestational surrogacy disaggregates women’s bodies as resources rendering the womb as a disembodied, “empty” and “not being used” resource that is available to make money. Like sperm, ova, and organs, wombs have also been isolated as an individual commodity (Cohen 2009 and Nayak 2014). The body is entirely abstracted and commodified and transformed into a “manufacturing mode” of (re)production (Darling 2014).

No doubt that we can imagine the technology of surrogacy in an equitable, non-coercive or altruistic model. However, the inequalities in the world transform such a vision into one riddled with inequities and exploitation. Today, techno-scientific surrogacy has reframed the role of women in reproduction, one that renders pregnancy and the postcolonial female body invisible. In desexualising, medicalising and commodifying reproduction in gestational surrogacy, the language of mothers and mothering is discarded for a new language of bio-labour, commodified organs, and disposable bodies. The affective politics of love, of mothers and motherhood is only available to the commissioning parents and their future families. Thus, techno-scientific surrogacy allows the erasure of some women as women and mothers, while enabling the womanhood and motherhood of others. This is particular ironic given that infertility rates among the poor and marginalised are often higher than richer communities (Roberts 1997). Like other innovations around reproduction, such “stratified reproduction” organised around hierarchies of race, gender class, ultimately replicate and reinforce underlying inequalities rather than erase them (Colen 1995). In the practices of contemporary surrogacy, surrogate mothers have little bargaining power in the process. This is precisely what some feminists have been pushing for – not an end to surrogacy, but in developing regulation that protect the rights of surrogate mothers (Sama 2012). Biotechnology and its imaginations it would seem replicate the interests of power within the larger political economy. It enables the desires of the elite through the bodies of the poor. Whether it is good for women or not, depends on *which* women we care about, whose interests are the basis of the laws and regulations that govern surrogacy. An attention to the power and inequities that shape the system of surrogacy can allow us to imagine the more progressive possibilities of bio-technology. Realising them is possible only when the

nexus between power, gender and technology is understood and forms the basis for regulation of technology.

The Biotechnology of Bodies: The Indian Genome Variation Project

From women's bodies and their pregnancies, let us move to the molecular level. Over the last few decades, we have seen the "molecularisation" of life (Rabinow and Rose 2006, Rose 2006, and Egorova 2013). The biology of organisms, rather than being considered in their entirety, and in the context of their environments, are increasingly reduced to their molecular selves. The Human Genome Project, the HapMap Project, the Genographic projects are all projects about the molecularisation of life. India has embarked on its own indigenous genomic database. As critics have pointed out, the molecularisation of life has shifted our conceptions of ill health and disease from a focus on the social contexts of poverty and access to nutrition and care, to a presence of a genetic propensity to ill health or disease (Kahn 2009, Dumit 2012, and Chambers *et al.* 2014). Like transnational surrogacy, we can imagine the progressive possibilities of molecular biology – enabling drug production, histo-compatible tissue, interventions in the genetics of some modes of cancer, the possibilities of stem cells and other forms of regenerative medicine. However, ignoring the social contexts of disease and illness (as we have seen in the recent pandemic of Ebola) can be severely limiting to global health and welfare.

In keeping with global trends in biotechnology, India has launched its own biotechnology revolution. The Indian Genome Variation Initiative was initiated in 2003 involving six constituent laboratories of the Council for Scientific and Industrial Research (CSIR), and with funding from the Indian government. They include: Institute of Genomics and Integrative Biology (IGIB), Delhi; Centre for Cellular and Molecular Biology (CCMB), Hyderabad.; Indian Institute of Chemical Biology (IICB), Kolkata; Central Drug Research Institute (CDRI), Lucknow; Industrial Toxicological Research Centre (ITRC), Lucknow; and the Institute of Microbial technology (IMTECH), Chandigarh.

This is an ambitious project, conceived as the "first large-scale comprehensive study of the structure of the Indian population" (Narang *et al.* 2010) with wide-reaching implications. As the project organisers argue, India is a large, populous and diverse country on many levels. It

comprises “more than a billion people, consists of 4693 communities with several thousands of endogamous groups, 325 functioning languages and 25 scripts.” The project argues that to “address the questions related to ethnic diversity, migrations, founder populations, predisposition to complex disorders or pharmacogenomics, one needs to understand the diversity and relatedness at the genetic level in such a diverse population” (Indian Genome Variation Consortium 2005). The project has been touted as one of disease gene exploration (Indian Genome Variation Consortium 2008). They have identified over a thousand genes to study. These genes have been “selected on the basis of their relevance as functional and positional candidates in many common diseases including genes relevant to pharmacogenomics.” (Indian Genome Variation Consortium 2005).

The Indian project joins a global shift in turning human health into a biotechnological project, with a specific end goal, a pharmaceutical solution, ushering in the “pharmaceuticalisation” of life. International genomic efforts, such as the HapMap projects are interested in the global distribution of genomic variation. To be sure, the development of biotechnology – infrastructure, methods, instruments, scientists, methods, data – can be important and revealing. With the onset of such investments India has arrived as an international player and an emerging power in biopolitical governance. In particular with the geneticisation of biomedicine, such projects attempt to ascertain both the global distribution of genetic diseases, as well as the distribution of disease susceptibilities, arguing that such distributions will powerfully shape future health care globally. These aspirations are very much linked to the pharmaceuticalisation of medicine (Pollock 2014), and the development of pharmacogenomics whereby genetic susceptibilities spawn new classes of drugs. Countries such as India and Mexico are seen as “Pharma’s Promised Lands” (Benjamin 2009).

While one can no doubt argue that it is important for a nation like India to assert their bio-political independence, nurture local talent and build a strong infrastructure, and pursuing a purely genomic solution to health is also severely limiting and short sighted. We must ask why millions of dollars of public funding is invested into sequencing the Indian genome. Why would a country still reeling from extreme poverty, where preventable and communicable diseases consume most of its citizen deaths invest so much in DNA technology? India’s health statistics still looks so abysmal

even after decades of strong economic growth; less than one per cent of its GDP is spent on public health care and has only nine hospital beds per 10,000 people, compared to an equivalent rate of 41 per 10,000 in China (New York Times, Editorial, 2014).

The “Indian Genome Project” argues that DNA technology will aid the health and wellbeing of its citizens through sequencing genomes and uncovering disease vulnerabilities. In one of their publications they suggest that the genetic landscapes of India provide us with “a canvas for disease gene exploration.” Yet the vast majority of deaths in India are due to causes that are well recognised, and preventable with current technology. Transforming ill-health into a genetic problem with a pharmaceutical solution supports a particular ideological and economic agenda. If ill-health is a problem due to individual’s genetic propensity to be ill rather than the inequities of an every day life of poverty, polluted environments, and the lack of access to good health care, then the problem and the solutions shift from the state and public policy to the individuals and their faults. Similarly, a solution that is about pharmaceutical drugs rather than access to good air, water, and nutrition similarly benefits certain economic players; the solutions support the development of (most often) a privatised drug industry rather than public infrastructure that is accessible for all. Strong political, economic, and ideological assumptions undergird these biotechnological assumptions and priorities. In the United States, we have seen similar moves as the category of “race,” once argued to be a social and not biological category, has been re-biologised in recent times (Stepan 1982, Gannett 2001, Kahn 2005, Reardon 2005, and Hammonds and Herzig 2009).

Surely, improved health in India can be imagined to be both social and technological? Studies on the ill health of the Indian population point to the need for important social and political interventions.

In a country where women feed themselves last, the health statistics of women are particularly horrendous. More than 90 per cent of adolescent girls in India are anaemic, and 40 per cent of Indian mothers are underweight (Harris 2015). Global public health presents the poor in India as one of the most abject populations in the world. Despite evidence that genetics play little role in much of this ill health (Harris 2015), the funding of a mega genomic project rather than one of public health infrastructure is striking.

In response to the ill health within India, we need to include the proven strategies and knowledge that science and technology has already produced. India needs more investment in meeting basic health and nutritional needs, and should address the disparities and inequities in health. A pharmacogenetic solution cannot be our only option. These shifts in biomedicine have led to what Donna Dickenson calls 'Me Medicine,' a set of practices that aims to focus on an individual's needs and interests have resulted in mixed results. Her analysis shows that the scientific plausibility is not the key determining factor in availability of new treatments and options such as umbilical cord banks. Rather what has driven recent biomedicine is the development of new markets, products and services catering to individual needs, perceived threats and risks drive the diffusion and availability of products and services. Instead, she calls for a return to a 'We Medicine' approach that emphasises investment in public health infrastructure that has already extended our life spans radically. 'We Medicine,' that emphasises technology used for the common good coupled with better regulation of biotechnology industry, she argues should be our path forward to restoring the idea of the commons in modern biotechnology. It is important to critically examine what goes in the name of common good from gender perspective and who matters in the 'We Medicine' (Dickenson 2013).

The Possibilities of Postcolonial Biologies

What both case studies show, I hope, is the failure to consider women in our biotechnological imaginations. Biotechnology gets heralded as the economic engine of a nation, even while its imaginations continue to marginalise a large proportion of the population. What is often missing in the discussions is a contextual understanding of biotechnology, locating it within its economic, political, cultural, and national contexts. It is not that biotechnology cannot be used towards more liberatory goals, but rather that the dominant face of biotechnology are ones that moved us to more corporatised, commodified, and privatised ventures. By locating biotechnology within these larger forces, we can see the broad and myriad issues that shape the relationship of women and biotechnology.

How should we study the world? A specialised academia has vivisected an inextricably interconnected world into myopic disciplines that have divided the world into binary categories of nature/culture, and human/non-

human. One of the central methodological insights of the feminist studies of science and technology has been refuting the binary worlds of nature and culture. Defining the object of the biological sciences as non-human life creates the illusion of a human-free world, a world removed from ideology, politics, and culture. Conversely, human culture remains in the purview of the social sciences and humanities, a world removed from the natural. But what if we refuse this nature/culture binary? In coining the term *naturecultures*, Donna Haraway challenges us to reject the binaries of nature and culture and attend to the constant traffic of discourses, information, and theories between the worlds of natures and cultures (Haraway 1999). There is no nature or culture, only naturecultures. Similarly, many feminists who are critical of the impact of the sciences and technology on women's lives have refused to support an anti- science/technology/ globalisation, arguing instead that we need to reimagine science and technology and their relationship with society (Haraway 1997). In this paper, I have explored two very different case studies of biotechnology in India to show how our politics of gender - shapes and is shaped by biotechnology and through it, the lives of women. I use these two very different case studies because they work across different scales and levels, demonstrating how gender gets deployed in very similar ways across macro- and micro-scales of analysis. In each, we see how objective sciences and the knowledge they produce are deeply entangled in the politics of gender in a post-colonial nation. Post-colonial biologies thus get shaped by the gendered scripts of the colonial legacies that it inherited (Verran 2002), and subsequently by the complex political shifts in independent India. Ultimately, biotechnology is an exciting site of innovation, and has the potential to enable democratic and progressive visions of society, but in practice has instead gotten imbricated in the old colonial and gendered scripts of the nation. But contestations over technology open up new spaces for innovation and the possibilities for developing a biotechnology as if women really mattered.

Endnotes

- ¹ This is a very simple rendition of the history of sex and gender. Both terms are today seen as much more complex. See Fausto Sterling (2012).
- ² Considerable work on intersex has shown that human bodies appear as a sexual continuum rather than in only two categories of male and female. See Dreger (1998).

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A Feminist Perspective on Biotechnology and Technoscience

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Abstract: Biotechnology has much potential to meet the challenges of the global society in diverse sectors. Hence, it can certainly contribute to improving the health conditions of women and contribute to their well-being. But this is not happening as expected on account of various factors. Although women have made much progress in getting access to science and technology education, they are still underrepresented in science and technology. Hence, there is an urgent need to enhance women's participation in science and technology, particularly biotechnology. Women's needs should be given importance in biotechnology research and development. For society to derive significant benefits from science and technology, particularly biotechnology, women's needs for technology should be taken into account and women's participation in science and technology should be enhanced. This should not be limited to laboratories but also to enterprises, whether they are small, medium or large.

Keywords: Biotechnology, Gender, Innovation, Participation, Sustainable Development

Throughout human history, agriculture has also been used for non-food purposes, including energy, clothing, shelter, medicines, and other everyday human needs.

In many parts of the developing world, women play a key role in food production and household nutrition, working in agriculture-related and food preparation activities. They are often the holders of traditional knowledge, for instance on seeds, production techniques, climate, soil conditions, and seasonal plant cycles. Women, however, do not only rely on using ancient methods and materials, they are also technology producers and users. They

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experiment and develop new techniques, for example, to improve seeds, better manage pests, and conserve food. Their role in this context is often not formally recognised.

Over the ages, women have made important contributions to society. Their influence grew as they began entering the workforce in greater numbers and won access to academic institutions at all levels. While major advances have been made around the world in recent decades, gender disparities persist in the world of work and parity with men on socio-economic measures ranging from pay and access to capital to representation on the boards of major corporations, has not been achieved. Closing these gaps, while working to stimulate job creation more broadly, is a prerequisite for ending extreme poverty and boosting shared prosperity. Today women make up approximately 40 per cent of the world's labour force. The employment rate for men is nearly 30 per cent higher (Aguirre *et al.* 2012). Tremendous progress has been made in education and in the workplace during the past 50 years. Even in historically male fields such as business, law, and medicine, women have made impressive gains. In scientific areas, however, women's educational gains have been less dramatic, and their progress in the workplace is still slower. In an era when women are increasingly prominent in medicine, law, and business, few women are becoming scientists and engineers.

Globally, women control about US\$ 20 trillion in annual consumer spending and earn about US\$ 18 trillion in total yearly earnings (Silverstein and Sayre 2009). A large and growing body of evidence demonstrates both the business and the development case. Booz and Company estimates that raising female employment to male levels could have a direct impact on GDP, increasing it by 34 per cent in Egypt, 12 per cent in the United Arab Emirates, 10 per cent in South Africa, and 9 per cent in Japan, taking into account losses in economy-wide labour productivity that could occur as new workers entered the labour force (Silverstein and Sayre 2009). Yet almost half of women's productive potential globally is unutilised, compared to 22 per cent of men's, according to the International Labour Organisation. A growing body of evidence suggests that there is not only a moral argument for investing in women, but a business case as well. Women remain seriously under-represented in some specific disciplines of science, engineering and technology (SET), and, furthermore, are not well-represented at the most

senior levels in all disciplines. There needs to be a greater recognition of the value of the different perspectives, priorities and operating styles that women can bring to SET (Redden 2012). The presence of women in the fields of science, technology and innovation remains significantly lower than men, even in some of the world's wealthiest regions. In some cases, the socio-cultural environment may discourage women's progression in S&T careers. Gender pay gaps persist in S&T, including in countries where women are as well- or better-qualified than their male colleagues. While the number of women in science and engineering is steadily growing, men continue to outnumber them especially at the upper levels of these professions. The striking disparity between the numbers of men and women in science and technology has often been considered as evidence of biologically driven gender differences in abilities and interests.

Gender issues in biotechnology policy and trade are rapidly emerging as some of the most interesting and challenging within these fields. Yet important differences also exist among countries. Technology is influenced by cultural, economic and social factors, therefore, it is not gender-neutral. The international evidence suggests that underrepresentation is mainly a culture phenomenon, rather than due to innate differences and that policies can affect workforce diversity.

There are many reasons for concern at the lack of proportional representation of women in senior positions in all facets of our society, including politics, law, medicine, the arts, business, and academia. Women are 51 per cent of the nation's population. Using their talents to the full at all levels of scientific and technological education, training and employment is an economic necessity, and an investment in future development. Men and women may have different needs and aspirations; in most cultures and regions, women play a central role in food production and provision of healthcare. It is clear that gender dimensions of biotechnology development and application do exist in terms of the effects of technological development on women and men in general; however, there are gender dimensions which are uniquely relevant to biotechnology. The cultural issue raised with respect to the role of biotechnology in the industry concerns the acceptance of women working in industries where they were previously not present for various reasons. In fact, women have often been displaced and marginalised by technology development, with many of their activities becoming sidelined

or taken over by men. We live in a fossil-based economy where we depend on oil for our energy, transport, materials and chemicals production. At the same time, it is becoming apparent that our economies are unsustainable. The transition to the post-petroleum, bio-based economy, therefore, goes hand in hand with the transition to more sustainable agriculture, renewable energy and sustainable transport.

Biotechnology can be at the forefront of this battle, to improve the lives of millions of women and men throughout the world. The bioscience industry has demonstrated that it is a generally strong and steady job generator, is creating jobs over the past decades, can boost green employment and green growth, and above all, a world bio-based economy can lead to lower CO₂ emissions, less use of fossil resources and less economic dependency on these resources. Biotechnology is not an end itself but, similar to other technologies, it is a tool to achieve certain goals. As such it affects and is affected by the socio-economic, political, cultural and environmental systems in which it is placed.

As the global bio-business sector undergoes rapid transformation, there are growing opportunities to tap into female talent, and greater success for men and women working together. This aspect should be further developed so as to harness fully the abilities and efforts of more than half of humanity. It is possible to identify a number of local and global trends today which point towards forthcoming changes in business and society. Technological developments are slowly dissolving the boundaries between sectors and are changing traditional modes of working. These rapid and complex shifts are affecting labour markets around the world, constantly challenging the balance of supply and demand, and labour market and education policies, growing diversity, and increasing representation of gender and ethnic groups in the labour force. Achieving equality of status in research and higher education is a management responsibility at all levels. The initiatives in support of equality will improve mankind's overall research potential and the technological capacity of women (MDG-F 2007).

Women may have a long way to go, but the future looks bright. Both large companies as well as start-ups are employing more women. Industrial biotechnologies are also expected to have a critical role in political and economic stability in the 21st century, both in developing and developed countries, and to provide some of the more smart ways to combat man's

impact on the planet. Debate on sustainability of the planet has increased and is a key strategic component of national and international elections to governing bodies.

The world today is faced with rapidly expanding research agenda in science and technology. Women have the potential to play a leading role in determining the direction and scope of these developments. Through education, networking, outreach, and activism, women can direct their own future careers.

In 21st Century, the world will be characterised by increasing globalisation, greater global complexity and technological advancement. Future problems will include international crises and serious risks of environmental pollution affecting virtually every country in the world. These developments show how vulnerable the world is and will lead to a greater awareness of global responsibility.

At least three developments highlight a company's need and opportunity to attract qualified female employees. Many developed countries will face a shrinking population over the next two decades; the percentage of highly educated women is rising; and the knowledge society is growing.

Biotechnology is being promoted in many countries in view of its enormous potential to improve agriculture, food, health, environment and energy requirements of the population, to create opportunities for employment generation and to add to the economic progress of the nation through environmentally sustainable industrial development.

Arguments for fully including women in research career range from addressing skills shortages and increasing innovation potential by accessing wider talent pools, to greater market development, stronger financial performance, better returns on human resource investments, and developing a better point from which to compete in the intensifying global talent race. The wider the pool is from which to draw, the more perspectives, experiences, and ideas will be brought to the creative process. Women spend a large amount of time performing labour-intensive tasks.

The failure to recognise women's technology needs and to support women's role in development hinders poverty reduction and national sustainable development. It is true to say that gender bias limits excellence in S&T and, therefore, reduces the benefits that research and development

bring to society. In addition, it is important to factor in intellectual property issues. Women traditionally hold much local and indigenous knowledge, but may not own it or derive financial benefits from it. In particular, local women are likely to lack knowledge of the patenting process and resources to support a patent application.

Women's needs and preferences are not necessarily taken into account in research and development, which traditionally has been mainly carried out by men. This can be attributed to a number of factors, including the lack of gender balance in product design teams and the lack of consideration of gender differences in determining end-user preferences.

As we move towards 2030, more and more women will have higher-qualified jobs, but will still lag behind men in both developed and developing countries if nothing is done to address the main challenges. These are to translate the female representation in higher education into corresponding representation in the labour market with adapted wage structures and access to management and decision-making positions for women. Further, women's participation in entrepreneurship and innovation are key to job-creation, wealth-generation and national economic growth. The participation of women in the establishment, management and leadership of medium and large-scale enterprises, including technology-related companies, should be an important objective in strengthening and reducing inequalities in national innovation.

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A Complex Formula: Girls and Women in Science, Technology, Engineering and Mathematics in Asia*

Abstract: What factors might be causing the low participation of women in Science, Technology, Engineering and Mathematics (STEM) fields? What can be done to attract more girls and women into STEM in Asia and beyond? A regional study published by UNESCO Bangkok in early 2015 explores a wide range of issues from gender differences in learning achievement in mathematics and science, participation in higher education as well as educational, psychosocial and labour market factors, all of which can influence girls' and women's attitudes towards STEM fields as a choice for further study and as a career. The report focuses on findings based on a regional desk study with research conducted in seven countries under review: Cambodia, Indonesia, Malaysia, Mongolia, Nepal, Republic of Korea and Vietnam. It is the second of two research studies as part of a three-year research project conducted by the UNESCO Asia and Pacific Regional Bureau for Education (UNESCO Bangkok) in collaboration with the Korean Women's Development Institute (KWDI), which aims to explore issues of gender, learning achievement and transition to the labour market.

Keywords: Gender, STEM, Asia-Pacific, Higher Education, Labour Market

Executive Summary

Our world today faces a multitude of increasingly interlinked challenges. Climate change, global health epidemics, demographic changes, pressures from rapid technological advances and unprecedented inequality are but some of our most pressing concerns. In this context, the technical knowhow and capability to uncover new solutions to overcome these challenges requires advanced skills in Science, Technology, Engineering

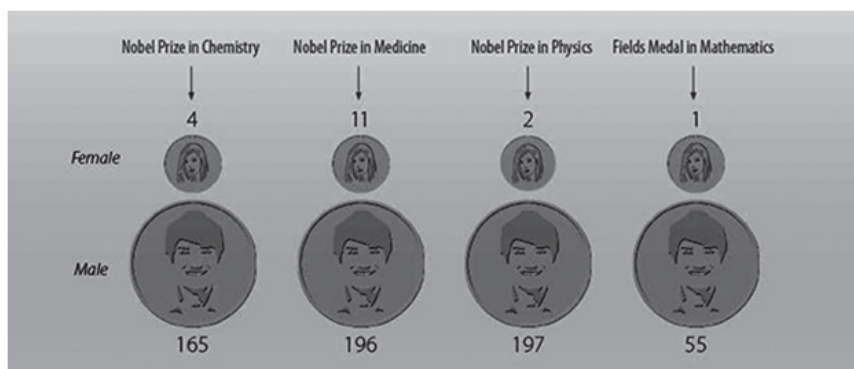
* This paper presents the Executive Summary of the UNESCO report. The full report can be accessed at: <http://unesdoc.unesco.org/images/0023/002315/231519e.pdf>. It has been formatted so that it is compatible with ABRD guidelines for research papers.

and Mathematics (STEM).

Despite this, there exists a serious labour shortage in STEM fields, particularly among women. Indeed, in the Asia-Pacific, a global survey indicates that as of 2014, the region faces ‘talent shortage’ of 45 per cent, with the most in-demand categories mainly comprising STEM-related occupations (ManpowerGroup 2014). It is also estimated that globally, women represent less than 30 per cent of researchers in science, technology and innovation (UIS 2014a).

This is reflected in the most prestigious awards in STEM fields – including the Nobel Prize in Chemistry, Medicine and Physics, as well as the Fields Medal in Mathematics – where awards to women are few and far between (see Figure 1). With a global labour shortage in STEM fields, and with women representing approximately half the world population, one may consider the magnitude of untapped potential and talent at a time in which STEM fields are all the more important.

Figure 1: Number of Female and Male Nobel Laureates and Fields Medallists in STEM-related Fields



Sources: Nobelprize.org (2014) and IMU (2104).

As we arrive at the target date for achievement of the Education for All (EFA) Goals and the Millennium Development Goals (MDGs) in 2015, it is important that the post-2015 development agenda reflects a number of areas related to the context of this study, such as learning achievement and more broadly the quality of education, as well as the importance of STEM

sectors in their contribution to economic and social development. While there has been remarkable progress in achieving gender equality both in terms of access to and achievement in education (IIEP 2012), a lack of gender parity from the secondary level onwards persists in many countries of the world (UNESCO 2014).

These are no easy questions given the diversity of Asia and the differing obstacles to attracting more girls and women to STEM fields across different countries. Nonetheless, the dearth of research and understanding and the significant need for increasing numbers of women in STEM, justifies a thorough investigation into this area. This report thus aims to address the lack of information in the area of gender, learning achievement and progression to study and work in STEM fields in Asia, as well as enhance knowledge and inform policy among education stakeholders and policymakers. Combining existing data with the views and perspectives of young people in the region, this report focuses on seven countries in Asia – Cambodia, Indonesia, Malaysia, Mongolia, Nepal, the Republic of Korea and Vietnam, while drawing upon relevant examples from other countries of the region.

Ultimately, this report reveals that gender differences in STEM fields do not start in the labour market, nor even in higher education – they begin in student performance as young as 15 years old. In countries where the gender gap in student performance at the secondary education level is at the expense of girls, women tend to be under-represented in STEM fields of study in higher education and in the labour market. Girls also tend to do relatively better in science as opposed to mathematics at the secondary level, which may explain why females prefer to choose science-related fields of study in higher education and occupations, such as biology, chemistry and medicine as opposed to more mathematics-oriented fields such as physics and engineering. Although these differences are impacted by wider socio-cultural and labour market preconceptions, education has a significant role to play to address this problem: 1) by stimulating interest among female students in STEM-related subjects, 2) by ensuring that educators are equipped to take more gender-responsive approaches and encourage female students to pursue STEM fields, and 3) by taking policy measures that are conducive to increasing the number of women in these fields. Stimulating, encouraging and supporting fair and equal opportunities for girls and boys to perform in STEM-related subjects at school, therefore, would equate to

more girls and women in STEM fields of study in higher education and the world of work.

In reaching this conclusion, this regional synthesis report asks three fundamental questions with regard to girls and women in STEM – (i) Where do we stand? (ii) What led us here? and (iii) Where to from here?

Where Do We Stand?

While differences across country contexts are undeniable, a number of major challenges can be identified when it comes to the participation of girls and women in STEM fields across Asia. In some countries, access to higher education for young women remains a challenge in itself. This was especially true for Cambodia, for instance. In others, a higher proportion of females may be enrolled, yet remain the minority in specific disciplines within STEM such as physics, mathematics and engineering such as in Malaysia, Mongolia and the Republic of Korea. Despite increasing access to higher education for girls, this does not always translate to participation in STEM fields of study. Globally, data shows that despite increased parity in enrolment at the Bachelor's² level (or equivalent) in higher education, in STEM disciplines male students outnumber female students in 91 per cent of countries with available data (UNESCO 2010, p. 5). Findings from the OECD also argue that young women are far less likely to opt for STEM fields of study at the Bachelor's level, and this only declines further from the Master's level and above (OECD 2011, p. 2).

This also raises important questions as to the possible linkages between participation in higher education and student performance at the upper secondary level with regard to STEM-related subjects such as mathematics and science. Looking at this age range, the gender gap in student performance in the results of both international and national assessments also shows variances by country, while among the highest performing students, such as those participating in International Olympiads for instance, very few females were identified across all countries.

Turning to the seven country case studies, three major findings were identified with regard to female participation in higher education and gender differences in learning achievement in mathematics and science:

Female Participation in STEM Fields in Higher Education

First looking at the proportion of female graduates in science programmes in tertiary education in Asia, data shows that as of 2011, this stood at 59 per cent in Malaysia as opposed to just 11 per cent in Cambodia as of 2008 (UIS 2014b). Looking more closely at the national data within STEM disciplines among the seven countries, a higher proportion of females are found in certain disciplines such as pharmacy, medicine and biology yet remain underrepresented in others such as computer science, physics and engineering. For instance, in Malaysia, which among the seven countries showed the highest proportion of female graduates in science programmes, 72 per cent of students enrolled in pharmacy were female, as opposed to just 36 per cent of students in engineering as of 2012 (MoHE 2013). As of 2013 in Mongolia, 73 per cent of students enrolled in biology were female as opposed to 30 per cent in computer science and just 24 per cent in engineering (MEDS 2013). With a similar situation identified among other countries, this indicates that further analysis may be required to better understand the low participation of women in specific STEM disciplines such as computer science, physics and engineering. Among those women, who are enrolled in STEM fields, however, data shows that the proportion of female students tends to fall as the level of education increases beyond Bachelor's level or equivalent within and beyond STEM fields of study. As of 2011 in the Republic of Korea for instance, while the proportion of females enrolled at Bachelor's level stood at 52 per cent in science and 19.5 per cent in engineering, at doctoral level female enrolment was 38 per cent in science and just 12 per cent in engineering (WISET 2014).

Learning Achievement among Females and Males in Mathematics and Science

In international assessments such as the Programme for International Student Assessment (PISA) for instance, results show that overall females appear to be increasingly catching up with males in STEM-related subjects, particularly in science. At the same time, a more noticeable difference in achievement is observed in mathematics – either in favour of boys or in favour of girls – showing very different patterns with regard to the gender gap in achievement both among the highest and lowest performing countries. According to PISA 2012 results, for instance, boys outscored girls in

mathematics by 18 points in both Japan and the Republic of Korea – two countries that rank among the highest performing, whereas girls outscored boys by 8 points in Malaysia and by 14 points in Thailand – two countries which perform below the OECD average (OECD, 2014).

According to a study analyzing PISA results over ten years, it appears that the most prominent gender gaps occur at the highest levels of performance with boys outperforming girls markedly (Stoet and Geary, 2013). When it comes to student participation in prestigious competitions in STEM-related fields such as the International Olympiads, for instance, data shows that in the year 2014, female medallists, and more generally female contestants, were significantly underrepresented. For instance, the percentage of female contestants stood at just 4 per cent for informatics, 5 per cent for mathematics and 6 per cent for physics, yet it reached an average of 28 per cent in biology among countries in the region, the latter reflecting the findings on female enrolment within STEM disciplines in higher education (IBO, 2014; IOI, 2014; IMO, 2014; IPhO, 2014). Even among delegations from countries, where learning achievement in mathematics and science is largely in favour of female students, this was not reflected. In delegations from Malaysia and Thailand, for instance, there were no female contestants in the International Olympiads in informatics or physics (IOI 2014; IPhO 2014).

Linkages between Gender Differences in Learning Achievement and Female Participation in STEM Fields

Based on the analysis in this report, linkages can be identified between gender differences in learning achievement in mathematics and science and the proportion of females entering STEM fields of study in higher education. For instance, in countries where the gender gap in achievement is in favour of boys, it appears that a comparatively lower proportion of females are enrolling or graduating in STEM fields of study as opposed to countries where the gender gap in achievement is in favour of girls. At the same time, data on female participation in STEM fields in higher education, even among countries that show a higher degree of participation, shows that they tend to be concentrated in specific disciplines within STEM. This implies that a number of wider influences may be at play beyond learning achievement and enrolment issues.

What Led Us Here?

Educational Impacts

At the policy level, specific gender-sensitive or STEM-related policy frameworks on education are difficult to identify, and where they exist, it is difficult to see how far these have been implemented. Looking more broadly at how educational aspects may influence interest in STEM among female students, the following findings have been identified.

Fewer Female Teachers in STEM-related Subjects and at Higher Levels of Education

At the school level, there are a limited number of female teachers in mathematics and science subjects, which limits the number of role models for female students in learning these subjects. Out of 20 classes observed in Nepal as part of this research, eight out of ten teachers were male in science classes, and nine out of ten teachers were male in mathematics. Even in countries that have seen the increased feminisation of the teaching profession, the proportion of female teachers tends to drop, across all fields of study, as the level of education increases. In the Republic of Korea, for instance, data from 2013 shows that while the proportion of female teachers stood at 99.2 per cent at the pre-primary level and 78.2 per cent at the primary level, they made up 46.7 per cent of teachers at the upper secondary level and just 34.1 per cent in higher education, and we may only assume that these rates would be lower in STEM-related subjects (MoE, 2014).

Lack of Gender-responsive Teacher Training in STEM-related Subjects

The findings also indicate that there is a lack of teacher training policies to properly prepare teachers in STEM-related subjects through gender-responsive teaching strategies. This was reflected in the findings based on the data collected from classroom observations for the purpose of this study. While broadly there appeared to be equal treatment of both female and male students by teachers in mathematics and science classes, different patterns were identified in some cases. For instance, in Indonesia, female students were shown to be more engaged and to participate more actively

in asking questions than their male peers. In Cambodia, however, it was found that while female students tended to give more correct answers, they demonstrated higher levels of reluctance, shakiness and anxiety in answering questions, with some female students even waiting until the class was over to ask specific questions to their teachers. In Vietnam, while male students seemed less confident in presenting in front of the classroom, the number of interactions between teachers and male students were far higher than with female students, averaging at 65 per cent for mathematics and 61 per cent for science. This indicates that gender-responsive teacher training in these subjects could help address the different needs and behaviours of female and male students.

Stimulating Interest among Girls in Learning STEM-related Subjects

Looking more closely at teaching strategies, there is a need for gender-responsive teacher training with regard to STEM. In addition, availability of resources and equipment for the teaching of STEM-related subjects cannot be underestimated in enhancing students' ability to access practical 'hands-on' and creative activities. According to findings from a study in Cambodia, the provision and use of science labs can not only have a positive impact on student participation and interest, but could also help overcome preconceived notions of girls' inability to perform well in science (Kelley *et al.* 2013). Arguably, the increased resources for experiments, which offer the opportunity for students to apply their knowledge in practice, could help stimulate interest among female students to potentially pursue these disciplines in further study.

Teaching and Learning Materials Still Permeate Gender Stereotypes

The content of teaching and learning materials, particularly textbooks, continues to permeate gender stereotypes in the ways in which they portray the roles of females and males with regard to STEM-related subjects. In Indonesia, while the content of the 2013 curriculum in mathematics and science is considered gender-sensitive, the learning materials used in its implementation could be considered quite the opposite (Sani 2014). An extract from a Grade 7 science textbook, for instance, shows students learning science, all of them being male. In another example from a

Cambodian Grade 9 science textbook, an illustration on the central nervous system and the different functions of the brain depicts males as thinking and exercising as opposed to females who are depicted as smelling flowers and tasting food. Indirectly, it could be inferred that this illustration communicates subtle messages regarding the most basic human functions (Szmodies and Eng 2014).

More Girls Receiving Private Tutoring

The gender dimension of private tutoring in mathematics and science also provides some interesting insights into the relationship with learning achievement in a region with persisting competition in education, a phenomenon partially driven by examinations at school and systems levels (Bray and Kwo 2014). According to the questionnaire results in the seven countries, a higher proportion of female students are receiving private tutoring across all subjects in all of the seven countries, with the exception of Cambodia and Vietnam where female and male students appear to receive private tutoring in near-equal numbers. A similar pattern is observed when looking specifically at STEM-related subjects and in some cases shows an even higher proportion of female students. Of all students surveyed in the Republic of Korea, for instance, only female students reported receiving private tutoring in physics. The overall higher number of female students receiving private tutoring could perhaps indicate that girls need more support, or that girls feel greater anxiety with regard to their performance in these subjects.

Limited Opportunities for Gender-responsive Career Counselling, Scholarship and Mentoring

Turning to career counselling, scholarship and mentoring opportunities, it appears that there are limited gender-responsive initiatives to attract more female students into STEM fields in most countries. In countries where scholarships to pursue STEM fields of study do exist, they may not always take female students into consideration. For instance, in Indonesia, the proportion of students who received scholarships for further study in STEM fields was slightly higher for male students at 8.65 per cent as opposed to 7.76 per cent for female students (Statistics Indonesia 2013). In the Republic of Korea, however, some scholarships for students to pursue STEM disciplines

include quotas in order to increase opportunities for female students (MSIP 2014). Greater opportunities for gender-sensitive career counselling in schools, scholarships as well as mentoring opportunities for young female professionals would arguably help not only attract but also retain more females in STEM fields.

Psycho-social Influences

Psycho-social aspects can significantly impact upon female participation in STEM fields. The importance of these influences in shaping student attitudes, achievement and eventually participation in STEM fields has been increasingly recognised through a growing body of research. In particular, studies point to the need to recognise the vulnerability of female students to the threat of negative stereotypes and the importance of students developing a ‘growth mindset’ where capability or talent is developed over time – it is not predetermined at birth (Hill, Corbett and St Rose 2013). Related to the wider issue of negative stereotype threat, the gender dimension of student interest and attitudes towards mathematics and science may not only affect learning achievement in these subjects but also choices for further study and careers. According to a 2011 OECD report on gender equality in education, employment and entrepreneurship, it appears that gender differences in these choices could be more influenced by psychosocial aspects such as motivation, confidence and perseverance than by one’s ability or performance (OECD 2011, p. 2). This study considered these influences, particularly through the collection of primary data in the seven countries, which brought about a number of key findings:

Gender Differences in Subject Preferences and Perceived Performance

Based on the results from the student questionnaire conducted as part of this study, it appears that while female and male students often choose mathematics and science among their most enjoyed subjects, mathematics is more likely to appear among the most enjoyed for males, and science subjects are more likely to appear among the most enjoyed subjects for females. At the same time, mathematics is also more likely to appear among the lowest perceived performance and science among the highest perceived performance subjects for female students. This indicates that male students

appear to prefer mathematics whereas females appear to prefer science, which to a certain extent may be consistent with the patterns observed in the gender differences in achievement in international assessments.

Higher Rates of Anxiety around Mathematics and Science Subjects in Females

Looking at student attitudes towards mathematics and science subjects in terms of interest, perceived importance, confidence, anxiety, as well as motivation and perseverance, different findings arose among the seven countries. The questionnaire results showed that females may experience higher rates of anxiety around mathematics and science subjects. This appeared to be consistent across all countries where the gender gap in participation and learning achievement was either in favour of girls or boys in mathematics and science. This suggests that even when females perform better in mathematics and science, they may experience higher anxiety towards these subjects than their male counterparts.

Importance of Parental and Teacher Encouragement

Parental and teacher encouragement with regard to mathematics and science can impact student attitudes towards these subjects, and could provide an important area for further investigation. Based on the questionnaire results, female and male students equally perceived encouragement from their parents and teachers as important. Analysis from Cambodia also shows that based on the results of the questionnaire, correlations exist between the perceived importance of parental encouragement towards mathematics and science and the student's perceived importance of those subjects. Parental and teacher encouragement, therefore, could be fundamental for all students in addressing environmental and psychosocial influences which have so far limited the participation of women in STEM fields.

Labour Market Effects

Women's participation in STEM fields within the labour market, and more broadly the status of women in the workplace also play a significant role. A number of factors, however, continue to limit women's participation in these fields. With this in mind, the major findings from this study include:

Fewer Female Role Models for Girls

The lower participation of women in STEM fields means that there is a lack of female role models in STEM, which can further affect young women's choices for further study and their future careers in STEM fields. An OECD study argues that this is one of the greatest barriers to attracting women and girls into occupations that may traditionally be viewed as predominantly male (OECD 2011, p. 28). Increased exposure to female role models could potentially help alleviate the negative stereotypes faced by female students with regard to these fields (Hill, Corbett, and St Rose 2013, p. 41). Estimates show that women make up just 30 per cent of science researchers globally (UIS 2014a), and the OECD argues that the lack of professional role models for young women in STEM professions could be a factor influencing lower levels of participation (OECD 2011, p. 28). There also appears to be a mismatch within STEM fields that females are choosing to pursue as opposed to those for which there is demand. For instance, in Mongolia, female STEM professionals may find themselves unemployed due to lack of demand in certain STEM fields, while at the same time the country is facing a high demand for engineers due to its booming mining sector (Khishigbuyan 2014). In other countries, such as the Republic of Korea, data shows that female graduates in STEM fields are also less likely to be employed than their male counterparts.

Unequal Female Participation in the Labour Market and Unequal Wages

Economic and development indicators across the seven countries under review, including female participation in the labour market and wage differences between women and men are still unequal across all fields of work. Even in cases where the female labour participation rate is high, unequal wages persist. For instance, in the case of Nepal, where the female labour participation rate stands at 80 per cent, wage differences are calculated at 0.62 on a scale from zero to one, with one representing equality (World Bank 2013; World Economic Forum 2014). By contrast, in Malaysia where the labour participation rate is the lowest at 44 per cent, the equality in wages is the highest among the seven countries at 0.80 (Ibid).

Concentration of Women in Specific Occupations within STEM

Looking at participation within STEM fields, women appear to be concentrated in specific occupations – a similar pattern to enrolment of female students in STEM by field of study in higher education. Here, a higher proportion of women work in professions related to medicine or biology, as opposed to a low proportion of women working in physics or engineering, which relates to the proportion of female students enrolled in these respective fields of study in higher education. In Malaysia, for instance, 72.9 per cent of pharmacists are female as opposed to just 10.6 per cent of professional engineers (DoHE 2014). In Indonesia, the Gender Parity Index (GPI)³ among senior STEM researchers receiving grants in the year 2013 was 1.8 in biology and just 0.1 in physics (Directorate of Research and Community Services 2014).

Concentration of Women at Lower Levels and Ranks within STEM Occupations

Women are also concentrated at lower levels and ranks within STEM occupations, where they are less likely to reach higher level positions. In the case of the Republic of Korea, for instance, women are more likely to be in non-regular or temporary work, which can greatly affect their prospects for promotion to higher level positions. At the same time, it appears that limited support offered to women working in STEM fields may affect retention as well as progression in these fields due to the difficulties faced in maintaining a balance between family responsibilities and professional life – a balance which could also be shared by male scientists.

Link Between Gender differences in Learning Achievement and the Number of Female Researchers in STEM Fields

When looking at women's participation in STEM fields, it appears that there may be a link between learning achievement in mathematics and science and the proportion of female researchers in science, technology and innovation. Countries which have a higher proportion of female researchers, for instance in Malaysia (49 per cent) and Thailand (51 per cent), girls tend to outscore boys in these subjects in international assessments (UIS, 2014c). In countries where a lower proportion of researchers are female such as

the Republic of Korea (17 per cent) and Japan (14 per cent), boys tend to outscore girls in mathematics and science (Ibid).

Whereto From Here?

As these findings illustrate, women are poorly represented in STEM fields of study and occupations in most, if not all countries under analysis. This trend is not surprising, given the dearth of female representation in STEM worldwide and the concerning statistics regarding female ‘talent shortage’ in STEM related fields of occupations. Findings here have also demonstrated the multivariate factors and influences contributing to the lack of engagement of women in STEM: educational, psychosocial and economic, and their compounding nature; these factors undoubtedly intersect to inform and shape attitudes as part of an ongoing feedback loop.

Figure 2: How can we get more girls and women into STEM?



This is not to suggest that these factors are irreversible and the greater engagement of women in STEM study and occupation is somehow out of reach. On the contrary, the identification of these multivariate factors allows one to critically assess how their impacts may be carefully unwound. The following provides a summary of the key recommendations governments and policymakers of Asia may consider in addressing this important shortage:

- **Further data disaggregated by sex is needed** to conduct in-depth analysis at country level and help provide a clearer picture of women and girls' participation within STEM, which will inform policies and programmes for increased participation of women in STEM-related education and employment sectors such as engineering and physics.
- **Gender-responsive action from governments**, through education and labour market policies, enforcement of gender-related laws, as well as specific initiatives for advocacy and awareness raising, is needed to attract more women and girls into STEM fields.
- In order to ensure the effective implementation of policies related to education, gender and/or STEM, **coordination between ministries** should be strengthened. This may involve joint programmes across various government sectors such as ministries of education, women's affairs or gender equality, science, technology and innovation, as well as labour.
- **Curricula and learning materials** should undergo further rigorous review from a gender perspective to ensure that they do not perpetuate gender stereotypes. This would ideally involve a representative group of stakeholders with male and female experts in order to ensure different perspectives.
- **Teacher education and policies on recruitment** must ensure a fair representation of both male and female teachers in all subjects, including mathematics and science, at all levels of education and especially in higher levels of education where students look to their teachers as role models as they begin to shape career perspectives and choices.
- Teacher education, be they pre- and in-service programmes, should be transformed to ensure that teachers are trained in **gender-responsive teaching strategies** so that female and male students can develop their full potential in STEM-related subjects.
- Appropriate funding for **equipment and resources** should be allocated in order to stimulate student interest in mathematics and science, particularly among female students. Allowing students to practically apply their learning in real-life situations as well as creative and hands-on experiments will not only contribute to

enhancing the quality of learning but also increasing student interest in learning these subjects.

- Structured and formalised **gender-responsive career counselling** programmes should be considered in order for both female and male students to have support and objective guidance as they begin to shape their career choices.
- **Scholarship programmes** targeted at women and girls in STEM would also contribute to increased opportunities for young women to pursue further study and eventually careers in STEM fields.
- Promoting more **female role models in STEM** fields, whether female teachers in mathematics and science at the secondary level, female students and faculty members in higher education, and more broadly more women working in STEM fields, is an important strategy to attract women and girls into STEM fields.
- Finally, adequate **support programmes and initiatives for female STEM professionals** would help to address some of the factors which can cause them to discontinue their careers, including family responsibilities. This will also help them be equipped with the most up-to-date knowledge and skills in fields which experience fast-paced change and innovation.

Conclusion

This study has looked to address the significant gap in literature on girls and women in STEM in Asia by analyzing a number of factors with regard to their participation and achievement in STEM fields through case studies in seven Asian countries. While the findings demonstrate a serious gender gap with far too few women engaged in STEM fields of study and occupations, this report also points the way for greater action to help address these gaps and ensure women are not sidelined from further study and pursuing a career in fields, in which they could contribute with equal talent, enjoyment and passion. Indeed, if women are to stand alongside men as equal contributors in the building of just, peaceful and prosperous societies, they must be ensured the equal opportunity to learn in all areas, including STEM fields. Addressing the fundamental educational, psychosocial and economic influences that have traditionally inhibited their participation in

these fields requires careful analysis, policy action and advocacy to help ensure greater gender equality in STEM, and for young women to have the equal opportunity to pursue further study and careers in any field they wish to pursue in Asia and beyond.

Endnotes

- ¹ 2014 UNESCO-L'Oréal International Fellowship Winner, Singapore.
- ² The levels of higher education cited in this publication reflect the 2011 International Standard Classification of Education (ISCED) as developed by the UNESCO Institute of Statistics.
- ³ The gender parity index (GPI) is the most common measure of gender parity in access to education for female and male students where the figure 1 would constitute perfect gender parity, whereas a figure below 1 would show access in favour of male students and above one in favour of female students.

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Book Review

Ghost Stories for Darwin: The Science of Variation and the Politics of Diversity

Author: Banu Subramaniam

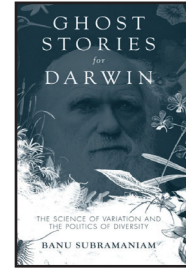
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Stock Hollywood imagery features ghost stories, hushed and roared, to children around crackling campfires. Stories about spirits with unresolved earthly affairs are meant to terrify and scintillate. While delightful in its horror, ghost stories can summon communal attention and insist all listeners bear witness to long neglected cruelties. Ghost stories are like forlorn biographies; their unearthing can bring about a type of justice. In *Ghost Stories for Darwin: The Science of Variation and the Politics of Diversity* (2014), Banu Subramaniam builds upon Avery Gordon's *Ghostly Matters* and asks, "How do you learn to see ghosts" (21)?

Subramaniam tells unlikely ghost stories about experimental biology and women's studies, about marginality and disciplinary hierarchies, and about entangled matters rendered singularly "natural" or "cultural." She translates Donna Haraway's feminist destabilisation of nature/culture into a *naturecultural* practice that values experiential knowledge and communal storytelling as epistemic sources. She seeks a methodology that harnesses ghostly sightings and haunting. She is haunted by apparitions of evolutionary biology's eugenic past. In terms of method (or meta-method as *Ghost Stories* functions as a meta-story about told and untold stories of sameness and difference), this monograph's style will most likely astonish readers new to Subramaniam's signature, lyrical approach to mediating disciplinary trench warfare. Through inventive genre and style remixes, she deftly interweaves forgotten social and political histories about morning glory flowers, autobiographical testimonies, parables and "fictional sciences," media and narrative analyses, focus group findings, and experimental field biology results.

“Variation” is a central organising concept in evolutionary biology, and “diversity” is a core object of study in certain social sciences and humanities fields. Subramaniam asks “[Do] theories about plant diversity have anything to do with theories of human diversity” (29)? In that variation and diversity are both riffs on “sameness” and “difference”—both are boundary-drawing projects—naturecultural practices can support collaborative, interdisciplinary, and reconstructive projects. Trained in ecology and evolutionary biology at Duke University and currently an associate professor in women, gender, and sexuality studies at University of Massachusetts-Amherst, she urges her academic audiences, particularly in the biological sciences and women’s studies, to pay heed to the eugenic hauntings of “variation” and its related politicisation of “difference” and “diversity.” What is at stake if scholars remain ignorant of the stories behind hauntings? Must we continue to silence genealogies of forgotten cruelties? Are we willing to sustain this academic enterprise—one that continues to erect disciplinary silos and willfully produce one-sided tales — at the expense of human and non-human populations which universities supposedly serve? Organised into three major stories of variation — that is, genealogies, geographies, and biographies—*Ghost Stories for Darwin* convincingly argues for the necessity of natureculture as scholarly practice. Beautifully written and textured in composition, it is also a remarkable touchstone for knowing, doing, and imagining the world differently.

In *Part I. Genealogies of Variation: The Case of Morning Glory Flowers*, Subramaniam accomplishes three main tasks. First, she recounts her doctoral research on morning glory flower colour variation, then overlays a critique of its disciplinary constraints. She provides a primer on genetics that should prove useful to readers who are years removed from their high school biology courses. She asks whether the flower’s social history, such as its localised history in North Carolina’s tobacco industry, is of relevance (41). Her “carefully constructed and contrived” experiments (e.g. planting plants equidistant from other in ways that would not happen in “nature”) were designed to frame morning glories as a model system for understanding evolutionary forces; however, in reflection, they ultimately failed to “capture the complexities of environmental contexts outside the experimental cycle” (42-3). Second, she demonstrates how a naturecultural approach to *seeing ghosts* in her morning glory work requires unearthing evolutionary biology’s historical entrenchment in eugenics debates and

social policies. This genealogy of variation starts with Charles Darwin's theory of natural selection and proceeds to trace his thoughts through and around key figures—such as Thomas Malthus and Francis Galton—and fields such as statistics, biometrics, population genetics and reproductive technologies. The history of evolutionary biology cannot be told without its social context; just as the social prompted biological work, scientists also promoted social policies. In all, this genealogy of variation is a convincing argument. As a note, it behooves the reader to make a concerted effort to keep track of names, debates, and historical moments in this richly traced genealogy. Third, in what is the most adventurous and whimsical of *Ghost Stories*, Subramaniam dreams up a new genre of “fictional science” or alternative science. She spins a tale, must like a parable, about three young heroines, a series of researchers, and a field of morning glory flowers in India. This fictional science is a vehicle through which the author successfully illustrates how academic disciplining constrains what can be known and erects barriers to collaboration. This parable is Subramaniam's vision of a reconstructive, naturecultural project which embraces collaboration and communal storytelling, all for the betterment of people's wellbeing and lives.

In *Part 2. Geographies of Variation: The Case of Invasion Biology*, Subramaniam analyses popular representations of invasion biology. She organises this media analysis into four acts. Each act exemplifies an instance of naturecultural migration, sensationalised as foreign threat to the U.S. homeland. In Act 1, she details discursive parallels between foreign plants and foreign peoples (106). Act 2 demonstrates how post 9/11's “war on terrorism” rhetoric incited representationally violent campaigns to eradicate the Chinese snakehead fish. Act 3 develops the concept of “obligation of reluctance”; ends should never justify the means, and scholars have an obligation to research the political, ecological, historical, and economic roots of positions and attendant consequences. In other words, there is an obligation to locate and listen to the ghosts of present day organisations or positions before aligning oneself with them. Obligation of reluctance is a provocative concept, yet seems relatively underexplored compared to the other acts. In the final act, she further problematises “native/invasive” as ontological states for plants, insects, and animals. She argues for an alternative approach to classifying organisms that relies less on geographies of origin and more on their functions in an ecosystem (119). Doing so does

not eschew concern for habitat conservation, but it does call for an end to xenophobic rhetoric. The parallels between discourses on native/invasive species and terrorism are not coincidental; they evince larger economic, political, social and cultural anxieties about immigration, foreigners, and belonging (121). She cautions, if we do not take a naturecultural approach that pays heed to ghostly hauntings — that excavates variation, diversity, and difference as foundationally integral to nativist discourses — then we are bound to be forever haunted (124).

Part 2 also demonstrates how to practice experimental science using a feminist science studies approach. More specifically, a naturecultural methodology recasts the “native/alien” dichotomy as “native and naturalised/introduced.” Working collaboratively with two biologists, she investigates the ecological context of plants, particularly the role of mycorrhizal fungi in soil communities (129). Readers can contrast this naturecultural project with her doctoral research on morning glory colour variation. While at times thick with ecological terms, especially for unacquainted readers, it showcases a rigorous reconstruction of invasive biology research. Chapter 5, “My Experiments with Truth: Studying the Biology of Invasions,” is a radical and rare intervention into conventional scientific epistemology and methodology and, because of this, it may generate the most amount of friction from scientific audiences. Experimental scientists ought to consider this an excellent model for feminist science studies possibilities in the lab and/or field.

In this part’s last chapter, “Aliens of the World Unite! A Meditation on Belonging in a Multispecies World,” she notes a kinship affinity to reviled invasive flora and fauna; they are both “First the alien, the exotic, the foreign species, then the long-term resident, the exotic, and the naturalised species” (144). She explores how multi-species alliances could generate new naturecultural ways of knowing which would center economic, political, and cultural entanglements. This chapter helpfully includes a number of clear examples, such as the Chinese origin of the famed Georgia peach (147-8).

Finally, Part 3 addresses *Biographies of Variation: The Case of Women in the Sciences*. This includes excerpts from the author’s graduate school journal in which readers learn more about the author’s life history. As a child and throughout college in India, she was a confident, curious student who easily found community. However, after starting graduate studies in

North Carolina, she immediately encountered her own marginality. Being minoritised in almost every conceivable way led to experiences of insecurity, marginalisation, and invisibility (160). She thoughtfully speaks to both her women's studies and biology audiences. She utilises a source of knowledge, as well as theories and methods of knowledge production, that resonate with social science and humanities audiences. At the same time, the topic of her personal narrative—that of enculturation into “Western science”—will resonate with those in the biological sciences who are attentive to dimensions of difference, including gender, sexuality, race, and nation. What is remarkable and unexpected in Chapter 7, “Through the Prism of Objectivity: Dispersions of Identity, Culture, Science,” is how feminist consciousness brought about a reaffirmation of Subramaniam's love for science. Through women's studies classes and feminist conversations, her political consciousness about the culture and politics of science developed her interests in biology into a “more complicated and nuanced” love (178-9). This is a pleurably readable and emotionally poignant chapter. It will resonate with readers who have traversed boundaries of difference that divide disciplinary cultures. Also filled with incredible vignettes of masculinist scientific posturing, this chapter provides colourful insight, particularly to women's studies audiences who may not have deep experiences in scientific culture.

Part 3 continues with an overview of Subramaniam's co-led National Science Foundation (NSF) funded research project. This study examined how faculty could better mentor women graduate students. They facilitated conversations between focus groups of faculty and students, and what emerged was a compendium of tacit rules for assimilating into masculinist culture. She poses a more feminist mentorship framework: instead of training women students to excel according to sexist standards, why not re-imagine a scientific culture in which diversity, differences, and variation among practitioners are valued? The final chapter, “The Emperor's New Clothes: Revisiting the Question of Women in the Sciences,” in Part 3 addresses dominant discourses around women-in-science initiatives and details five key weaknesses in such initiatives.

Ghost Stories for Darwin calls for both the sciences and women's studies to change: “...a feminist project must include exploring and transforming scientific culture to include not only different bodies but also different

visions and cultures, as well as different epistemologies, methodologies, and methods” (221-2). A naturecultural epistemology approaches non-human fauna and flora as co-inhabitants of the world. It values a multi-species kinship that recognises each other’s entangled formations through purity and assimilation discourses. A multi-species kinship subjectivity tells different stories and asks different questions. For example, a conceptualisation of “Asian American” that allies the author with “invasive” Asian carp, dismantles disciplinary silos and allows the grains of knowledge production to mix (109). A naturecultural methodology harnesses multi-species kinship subjectivities as vital sources of knowledge, directs scholars to question seriously the hauntings of unspoken pasts, and to do so through collaborations. Concepts of variation, difference, and diversity bridge and contextualise “nature” and “culture” as constructed binaries.

In conclusion, Subramaniam’s elegantly woven genealogies, geographies, and biographies operate at a meta-level. Parts 1, 2, and 3 tell naturecultural stories about variation, and the stories as a whole provide an illustration of naturecultural practice in action. Each part is thoroughly grounded in the epistemologies, methods, and methodologies called for by its particularities. This text is like a precise timepiece—elegant and nuanced in its assemblage and superlatively intricate. It insists the reader concentrate closely on details, structures, and meta-structures. Rereading passages with an open mind and diligent pen—especially for biologists reading feminist theory-centered chapters or for feminist scholars engaging biology-focused parts—should be anticipated as a part of a worthy interdisciplinary pursuit. Throughout, there are many moments of revelatory friction, enough potentially to start a fiery revolution. *Ghost Stories for Darwin* proposes scientists and women’s studies scholars work together to transform their localised practices. While such collaborative, reconstructive projects may not materialise until far into the future, let us hope Subramaniam’s story about ghost stories haunts us until then.

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Medical Agricultural Biotechnology and Public Health: The Interface between TRIPS and Cartagena Protocol on Biosafety

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Abstract: This paper presents convergent normative and governance arrangements on the road to vulnerable population feeding and immunising and endemic epidemic diseases treatment with medical modern biotechnology materials. After a succinct review of main current applications of medical agricultural modern biotechnology in public health, this research considers normative avenues towards a medical agricultural modern biotechnology option in the implementation of the WTO-WHO Declaration on TRIPS and Public Health throughout post-Rio+20 decades. Matters related to the biological safety of medical agricultural modern biotechnology products are guaranteed by the United Nations Cartagena Protocol on biosafety provisions. Finally, this contribution shows that the Africa Rice Center offers a suitable regional academic institutional environment to conduct R&D activities on medical agricultural modern biotechnology to feed, immune and heal vulnerable populations exposed to endemic epidemic diseases and poverty in the post Rio+20 decades.

Keywords: Agricultural Medical GMOs, Population immunising, Nutrition, Epidemic diseases, Poverty eradication

Introduction

Agricultural modern biotechnology innovative activities in public health can contribute in making poverty eradication a reality. This paper shows current positive R&D trends to develop New Rice for Africa (NERICAs) varieties in the regional context of West Africa. These trends are presented as positive prerogatives leading developing countries to consider the option of adopting medical agricultural modern biotechnology to support poverty eradication efforts in the future. The UN GA/RES/66/288 Resolution¹ has provisions carrying out a potential of creating favorable conditions

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for medical agricultural modern biotechnology products to support immunisation and epidemic diseases treatment policies in the developing world. This contribution highlights UN A/RES/66/288 Resolution provisions related to public health, green economy, poverty eradication, sustainable development and others which can be implemented by the development and consumption of medical NERICAs to feed and immune vulnerable populations. This research will focus mainly on developing countries and on endemic epidemic diseases treatment such as those in West Africa. This research will also be built on the normative context of the Doha Declaration on TRIPS and Public Health which has been revived by the Heads of State and Government at Rio+20 Summit to be implemented. However, the Doha Declaration will be backed up by the Cartagena Protocol on Biosafety to guarantee full biological safety in medical agricultural Genetically Modified Organisms (GMOs) development and dissemination. This paper will be concluded with the growing goodwill among Nations on matters related to R&D and regional cooperation. These two mechanisms are apprehended as essential to any normative activity and policy making on the development and the consumption of medical NERICAs to feed, immune and relieve vulnerable populations exposed to endemic epidemic diseases.

Medical Agricultural Biotechnology Public Health and Diseases

Research activities on immunisation and diseases treatment with agricultural GMOs are more and more common. Immunising population with food is indeed a win-win poverty eradication public health policy. Medical agricultural GMOs were presented even fifteen years ago by the International Food Policy Research Institute (IFPRI) as agricultural GMOs of the next generation.² A number of developing countries such as Senegal and India are already seeing in modern biotechnology applications a potential way out from pandemic circumstances. In these two countries research activities are being conducted. Korea has already reached the commercial stage of medical agricultural GMOs. The case of Senegal and correlatively the Indian experience will be considered in the sub-section below while the example of Korea will be taken up in the second sub-section. We will consider the sector of nutrition in large in a third sub-section.

Senegalese national daily newspaper, *Le Soleil*, in its edition of 27 April 2004 mentioned the existence of research activities on medical agricultural GMOs at University Cheikh Anta Diop of Dakar.³ Such activities are being conducted in the Plant Biology Department of the Faculty of Science and Techniques according to Professor Amadou-Tidiane BÂ, director of the department who also has been Minister of scientific research in the country.⁴ Dr. BÂ affirmed that several contagious diseases were being covered by the research programme. AIDS was mentioned among those diseases.⁵ The source made the precision that Professor Souleymane Mboup was conducting the AIDS research programme at the biomolecular level.⁶ Banana and other fruits varieties are being developed to host vaccines to immune the population against contagious diseases.⁷ Professor BÂ also mentioned that gene products such as enzymes and proteins are being developed by biotechnology techniques and methods and kits to detect diseases at their early stage.⁸ Moreover, in 2005, *Le Soleil* reviled the information on a collaborative work between Senegal and India in medical agricultural modern biotechnology. In its edition of 15 July, the national daily newspaper wrote that Professor Yage Kène Gassama-Dia at her appointment as Senegalese new Minister of scientific research took an advanced training course on medical agricultural GMOs at the Indian Institute of Science.⁹ The communication presented Dr. Gassama-Dia as a scientist dedicated and committed to food vaccines development by plants genetic modification.¹⁰

Population immunisation is one of the medical sectors with a big potential on which medical agricultural GMOs are expected to strengthen public health policies and programmes. Diseases treatment is one of those promising sectors. The Korean experience will catch our attention in the following sub-section.

On 6 October 2008, the Republic of Korea announced through the Secretariat of the United Nations Convention on Biological Diversity (CBD) the development of two genetically modified rice isoflavone plants.¹¹ Both have cancer fighting properties among other proprieties.¹² The Government of Korea mentioned in its communication to the Secretariat to the Convention on Biological Diversity (SCBD) that the Korean Rural Development Administration developed two rice varieties that contain isoflavone genistein for the first time in the world.¹³ Bringing more context, the communication reminded that isoflavone genistein is not found in

existing rice varieties but twelve types of isoflavones are found in soybean and are major functional ingredients and genistein acting as a cancer-fighter and an anti-oxidant in inhibiting prostate and breast cancer cell growth, according to a variety of study results.¹⁴ The synthetic isoflavone gene used to develop the anti-cancer rice variety in Korea belongs to the cytochrome P450 genes with unstable gene expression.¹⁵ The communication added that no rice variety infused with the gene had been successfully created but the Korean Environmental Bioengineering Division of the Rural Development Administration has successfully separated the two isoflavone-forming genes from soybean and inserted the genes into both general and colored rice.¹⁶ The Government of Korea noted that the Korean anti-cancer rice can help people consume the amount of isoflavones equivalent to 40 per cent of the daily recommended intake and will greatly improve public health.¹⁷

Population immunisation and diseases treatment with medical agricultural GMOs are public health strategies with a potential to support the nutritional sector where medical agricultural GMOs are already making an important contribution.

Therapeutic nutrition is the field whereby medical agricultural engineering has contributed the most in public health over the last decades. This sector has been playing an efficient role against malnutrition and vitamin deficiencies. According to Fitzpatrick and others, “the term vitamin describes a small group of organic compounds that are absolutely required in the human diet. Although for the most part, dependency criteria are met in developed countries through balanced diets, this is not the case for the five billion people in developing countries who depend predominantly on a single staple crop for survival. Thus, providing a more balanced vitamin intake from high-quality food remains one of the biggest challenges for the global human nutrition in the coming decades.”¹⁸ In a study on transgenic multivitamin corn production through bio-fortification of endosperm, Shaista Naqvia, Changfu Zhua, Gemma Farrea and their collaborators stated that vitamin deficiency affects more than 50 per cent of the population in the world.¹⁹ Most of that population is living in developing countries.²⁰ This research identified more than 700 carotenoids with antioxidant functions that are synthesized by plants and seaweeds.²¹ Carotenoids provide vitamins as micro-nutrients contained in our food. These contribute greatly to human nutrition balance.²² Animals can't be used to synthesize directly

carotenoids vitamins but indirectly by feeding them with plants.²³ Plants and by extension vegetables, fruits and seeds are therefore excellent sources of carotenoid vitamins.²⁴ When genetically modified for the purpose transgenic plants can help bringing in more vitamin materials to meet the needs of population exposed to nutritional deficiency.²⁵ Current research on medical agricultural GMOs aims to increase plants capacities in carotenoid vitamins production.²⁶ rDNA techniques have been used to produce, calibrate and increase b-carotene levels in Arabidopsis seed. Since b-carotene proceeds from vitamin A, the potential of such a discovery is huge.²⁷ According to the World Health Organisation (WHO), an important part of the population in developing countries faces vitamin A deficiency among which two hundreds millions are under school age.²⁸ WHO statistics are confirmed by Maneesha Aluru *et al.* of Iowa State University who also came to the conclusion that vitamin A deficiency touches more than 250 million of people in the world. Dr. Aluru and his collaborators stated that such statistics shows that vitamin A deficiency is one of the most common nutritional deficiencies in the developing world. These facts have negative impacts on socio-economic development. Such tendencies can, however, be reversed since several methods have been developed to increase vitamin A quantities by genetic modification in tomatoes, potatoes and rice. The best example is transgenic golden rice 2 which contains enough vitamin A to meet the needs of consumers.²⁹ Medical agricultural plants have been compared to therapeutic products and health engineered genetic materials fabrics.³⁰ Progress on medical agricultural transgenic plants science has greatly benefited from the increasing knowledge on the endosperm development and function.³¹ The endosperm is a nutritive tissue produced and stored by the seeds of flowering plants.³² It is the source of human food calories and proteins.³³ Transgenic methods can help engineer the endosperm to produce and stock in cereal crops important quantities of engineered genetic material such as starch and other proteins.³⁴ Rice endosperm appears to be an ideal method to produce recombinant proteins and vitamins by genetic engineering.³⁵ The best results are obtained with multigene transformation techniques involving several genetic materials at the same time to make genetic modifications occur.³⁶ Vitamin A deficiency is related to eye-sight problems. Such problems can in some cases lead to blindness.³⁷ In South-Est Asia, near a quarter of a million of children become blind every year because of vitamin A deficiency.

Moreover, vitamin A deficiency can lead to diarrhea, respiratory illnesses and to measles in children.³⁸ Chronic diseases such as heart diseases, some types of cancer, both diabetes types and obesity find their source partly in vitamin A deficiency.³⁹ Multidisciplinary initiatives of plant breeders, plant metabolic engineers, chemists, nutritionists, experimental medics, clinicians and epidemiologists are much needed to produce the needed vitamin A in order to face public health challenges.⁴⁰

Medical agricultural GMOs in their multiple functions as vaccines, medicines and vitamins can contribute facing public health challenges under existing normative frameworks related to international public health law. The second part of this contribution will give us the opportunity to lay out a suitable normative arrangement under the UN A/RES/66/288 Resolution for the use of medical agricultural GMOs in poverty eradication.⁴¹

Public Health Imperatives and UN A/RES/66/288 Resolution

Public health was addressed at Rio+20 Summit as one of the thematic areas and cross-sectorial issues whereby the framework for action and follow-up of the future we want are planned to be implemented. Health and population have been targeted by the international Community as one of the major challenges on the road to green economy in the context of sustainable development and poverty eradication. At Paragraph 138 of UN A/RES/66/288 Resolution head of States recognised indeed that health is a precondition for, an outcome of, and an indicator of all three dimensions of sustainable development.⁴² Rulers of the world said having understood that the goals of sustainable development can only be achieved in the absence of a high prevalence of debilitating communicable and non-communicable diseases, and where populations can reach a state of physical, mental and social well-being.⁴³ There added being convinced that action on the social and environmental determinants of health, both for the poor and the vulnerable and the entire population, is important to create inclusive, equitable, economically productive and healthy societies.⁴⁴ Countries called at paragraph 139 for the involvement of all relevant actors for coordinated multi-sectoral action to address urgently the health needs of the world's population.⁴⁵ They emphasised at paragraph 140 that HIV and AIDS, malaria, tuberculosis, influenza, polio and other communicable diseases remain serious global concerns compelling the international community

redoubling efforts to achieve universal access to HIV prevention, treatment, care and support, and to eliminate mother to child transmission of HIV as well as to renewing and strengthening the fight against malaria, tuberculosis, and neglected tropical diseases.⁴⁶ The global burden and threat of non-communicable diseases (NCDs) has been acknowledged at paragraph 141 as constituting one of the major challenges for sustainable development in the twenty first century and therefore requesting a commitment to strengthen health systems toward the provision of equitable, universal coverage and promote affordable access to prevention, treatment, care and support related to NCDs, especially cancers, cardiovascular diseases, chronic respiratory diseases and diabetes.⁴⁷ Likewise, rulers took the commitment at paragraph 146 to reduce maternal and child mortality, and to improve the health of women, men, youth and children.⁴⁸

In this paper dedicated to public health normative arrangements on the road to combat pandemics by medical agricultural GMOs under UN A/RES/66/288 Resolution normative framework, we will consider mainly the Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health and the United Nations Cartagena Protocol on Biosafety. The first instrument will cover the medical functions of medical agricultural GMOs and the second will be used to address biosafety challenges related to medical agricultural modern biotechnology products.

The Doha Declaration and Public Health

In this section of our contribution we are aiming to lay out how the Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health is a suitable framework to the contribution of medical agricultural GMOs in public health and poverty eradication. The Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health commonly called Declaration on TRIPS and Public Health, is the outcome of a long process of negotiations between the World Trade Organisation (WTO) Members and Parties to the World Health Organisation. The first normative elements of the Declaration were confided in the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights more known as the WTO TRIPS Agreement. The main objective of the Agreement is presented at its Article 7. Here, Members agree

that the protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations.⁴⁹ Thus, brought forth, the main objective of the TRIPS Agreement provided normative avenues towards needed arrangements between WTO Members and Parties to the WHO on public health challenges specially in developing countries facing epidemic diseases. This is in fact the normative environment on which WTO Members and Parties to the WHO built the motives of the Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health. Countries recognise, at paragraph 1 of the Declaration, the gravity of the public health problems afflicting many developing and least-developed countries, especially those resulting from HIV/AIDS, tuberculosis, malaria and other epidemics.⁵⁰ Such a normative environment is presented below.

Paragraph 1 of Article 8 of the TRIPS Agreement specifies that Members may, in formulating or amending their laws and regulations, adopt measures necessary to protect public health and nutrition, and to promote the public interest in sectors of vital importance to their socio-economic and technological development, provided that such measures are consistent with the provisions of this Agreement.⁵¹ As we can see, such a normative provision offers a suitable context for the use of medical agricultural GMOs to find solutions in time of public health hardships along with other pharmaceutical products. Medical agricultural GMOS used also as pharmaceutical products in a pandemic context in developing fall also under patent exceptions dressed out in section five (5) of the Agreement. In fact, even though owners of patents have been given full guaranties for a full benefit from their discoveries⁵², the international Community fixed a number of exceptions which would allow countries to lift any burden from patents to face public health and nutritional challenges in certain circumstances.⁵³ For example, paragraph 2 of Article 27 brings forth the exception that Members may exclude from patentability inventions, the prevention within their territory of the commercial exploitation of which is necessary to protect *ordre public* or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment, provided that

such exclusion is not made merely because the exploitation is prohibited by their law.⁵⁴ Likewise paragraph 3b of the same Article 7 is another exclusion from patentability stating that Members may also exclude from patentability plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes.⁵⁵ This latter patentability exception was even targeted at the eve of the WHO Doha inter-ministerial Conference when the industry requested suppression of patentability exception adopted at WTO TRIPS Article 27 (3b).⁵⁶ This normative provision has a potential of reducing any patent burden on developing medical agricultural modern biotechnology products and other pharmaceutical materials to face pandemic crises. This very visional goal of the international Community is in fact the main foundation on which the Doha Declaration on TRIPS and Public Health was negotiated.

The Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health was adopted at the Doha Conference held in November 2001 from the 9th to the 14th. This achievement brought comfort among Nations. The previous Conference held in Seattle did not led to a final text and the failure was much heavily felt by an international community recognising the gravity of the public health problems afflicting many developing and least-developed countries, especially those resulting from HIV/AIDS, tuberculosis, malaria and other epidemics.⁵⁷ Therefore, in order to allow developing countries to act optimally in pandemic circumstances, Members agreed at paragraph 4 of the Declaration that the TRIPS Agreement does not and should not prevent members from taking measures to protect public health.⁵⁸ Nations affirmed that while reiterating their commitment to the TRIPS Agreement, the Agreement can and should be interpreted and implemented in a manner supportive of WTO Members' right to protect public health and, in particular, to promote access to medicines for all.⁵⁹ They reaffirm in this connection the right of WTO Members to use, to the full, the provisions in the TRIPS Agreement, which provide flexibility for this purpose.⁶⁰ Paragraph 5 of the Declaration stressed out that flexibility include that each provision of the TRIPS Agreement shall be read in the light of the object and purpose of the Agreement as expressed, while applying the customary rules of interpretation of public international law.⁶¹ Also, each member has the right to grant compulsory licenses and the freedom to determine the grounds

upon which such licenses are granted.⁶² Another kind of flexibility was granted to each member is the right to determine what consists of national emergency or other circumstances of extreme urgency.⁶³ Public health crises, including those relating to HIV/AIDS, tuberculosis, malaria and other epidemics, are national emergencies or other circumstances of extreme urgency.⁶⁴ In conclusion to the concept of flexibility, Members agreed to leave each Member free to establish its own regime for such exhaustion without challenge.⁶⁵ In addition to such flexibilities, Members recognised at paragraph 6 of the Declaration that WTO members with insufficient or no manufacturing capacities in the pharmaceutical sector could face difficulties in making effective use of compulsory licensing under the TRIPS Agreement⁶⁶ and instruct, therefore, the Council for TRIPS to find an expeditious solution to this problem.⁶⁷ To better support developing countries under pandemic hardships Members reaffirmed in paragraph 7 of the Declaration the commitment of developed-country members to provide incentives to their enterprises and institutions to promote and encourage technology transfer to the least-developed country members⁶⁸ in full consistency to paragraph 2 of Article 66 of the TRIPS Agreement.⁶⁹ In such perspective, medical agricultural GMOs can be involved in the implementation of the Doha Declaration on TRIPS and public health as any other pharmaceutical material.

The Declaration on TRIPS and Public Health is a normative framework which shows full adequacy regulating the pharmaceutical component of medical agricultural GMOs. The international Community will, however, need the Cartagena Protocol on Biosafety to assure safety in any contribution of this category of agricultural GMOs in public health. Together, these two normative frameworks will allow medical agricultural GMOs contributing to poverty eradication along with other pharmaceutical products. In fact, it's only apprehended as a pharmaceutical product that medical agricultural GMOs would be considered when we are reminded of the exclusion of pharmaceutical GMOs products from the scope of the Protocol.⁷⁰

Cartagena Protocol on Biosafety and Safe Use of Medical Biotechnology

Cartagena Protocol's provisions organise with adequacy trans-boundary movements of agricultural GMOs. This treaty is one of the most restrictive

instruments in the current age of international law. Because of this very fact, one can be assured of the safe use of medical agricultural GMOs as vaccines to immune population against pandemic diseases and as medicines to heal people from epidemic diseases in implementing process of the Doha Declaration on TRIPS and public health. Biosafety in trans-boundary movements of agricultural living modified organisms (LMOs) has been a big debate among nations over the last decades. Human health is one of the different aspects of such a debate. The implementation of the Doha Declaration on TRIPS and public health in the current post Rio+20 decades offers, therefore, an ideal opportunity to consolidate biological safety in international trade law of agricultural GMOs products. Such a normative environment suits the precautionary approach which governs trans-boundary movements of agricultural GMOs as stated in Article 1 on the objective of the Protocol.⁷¹ Biological safety of medical agricultural GMOs will be assured through the main mechanisms chosen by the international Community to carry out the precautionary approach⁷² in the international trade of agricultural products consisting of GMOs.

In the next sub-section we will present the Cartagena Protocol key provisions adopted by the Parties to apply the precautionary approach: the advance informed agreement procedure (AIA), decision procedure, review of decisions and risk assessment.

An Advance Informed Agreement Procedure (AIA) to carry out the Precautionary Approach

The AIA is the foundation of the precautionary approach in agricultural GMOs international trade law. It is applied through different mechanisms namely: notification, acknowledgment of notification, decision procedure and review of decisions. Paragraph 1 of Article 8 on notification starts the AIA process by stating that the Party of export shall notify, or require the exporter to ensure notification, in writing, the competent national authority of the Party of import prior to the intentional trans-boundary movement of a living modified organism, the notification shall contain a minimum of information.⁷³ Article 9 takes up the process with the acknowledgement of receipt of notification and specifies at its paragraph 1 that the Party of import shall acknowledge receipt of the notification, in writing, to the notifier within 90 days of its receipt. At its paragraph 4, Article 9 brings in more constraint

by stating that a failure by the Party of import to acknowledge receipt of a notification shall not imply its consent to an intentional trans-boundary movement.⁷⁴ The decision should follow within two hundred and seventy days of the date of receipt of notification. The Party of import shall then communicate, in writing, to the notifier the decision⁷⁵ which can even consist of prohibiting⁷⁶ the import. Also, to carry out the precautionary approach, Parties to the Cartagena Protocol agreed on a mechanism of reviewing decisions at Article 12 of the treaty which states specifically that a Party of import may, at any time, in light of new scientific information on potential adverse effects on the conservation and sustainable use of biological diversity, taking also into account the risks to human health, review and change a decision regarding an intentional trans-boundary movement.⁷⁷ In addition to all these constraints, Parties have also agreed at Article 15, on provisions related to a risk assessment procedure carried out in a scientifically sound manner taking into account recognised risk assessment techniques and other available scientific evidence in order to identify and evaluate the possible adverse effects of living modified organisms on the conservation and sustainable use of biological diversity, taking also into account risks to human health.⁷⁸ Paragraph 2 mentions that it may require the exporter to carry out the risk assessment⁷⁹ and the cost this shall be borne by the notifier if the Party of import so requires⁸⁰ according to paragraph 3 of the same Article.

Cartagena Protocol and Medical Biotechnology GMOs

The Cartagena Protocol's provisions mentioned in the previous section carry out a strong weight of constraint. The possibility for importing Parties to refuse the trans-boundary movement of agricultural GMOs shows such a constraint. However, there are ways out to use medical agricultural GMOs in the implementation process of the Declaration on TRIPS and Public Health. Medical agricultural modern biotechnology materials fall into the scope of the Protocol because of their agro-food component and are adequately regulated by the treaty along with all other agricultural GMOs.⁸¹ Such a provision can be backed up by paragraph 1 of Article 13 which states that a Party of import may be exempted from the advance informed agreement procedure⁸², provided that adequate measures are applied to ensure the

safe intentional trans-boundary movement of living modified organisms in accordance with the objective of the Protocol.⁸³ Parties in such circumstances must, however, specify in advance to the Biosafety Clearing-House imports of living modified organisms.⁸⁴ These provisions are ways out and can help in applying biosafety measures while using medical agricultural GMOs in the context of the Declaration on TRIPS and public health. Obviously and from a normative perspective, there are indeed ways out for medical agricultural GMOs to take part in poverty eradication throughout the post-Rio+20 decades.

In conclusion to this we may point out that since the adoption in 2001 of the Declaration on TRIPS and public health, its implementation has been but a slow process. As for the Cartagena Protocol on Biosafety adopted in year 2000, progress of implementation has been noted with normative activities. An additional protocol to it on liability has been adopted. Also, there have been many National Biosafety Frameworks (NBFs) and many National Biosafety Laws (NBLs) developed and adopted by almost all developing Parties. However, a few agricultural GMOs have been released in general. Nevertheless, there should be hope especially concerning medical agricultural GMOs when we consider the case of the Korean republic where a medical agricultural has been released to contribute facing public health challenges.⁸⁵ Moreover, the international Community has shown political goodwill to revive the Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health in the *Future We Want*. In fact, at paragraph 142 of UN A/RES/66/288 Resolution, Nations reaffirm the right to use, to the full, the provisions contained in the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), the Doha Declaration on the Agreement on Trade-Related Aspects of Intellectual Property Rights and Public Health.⁸⁶ In this same provision, a reminder has been made about the decision of the World Trade Organisation General Council of 30 August 2003 on the implementation of paragraph 6 of the Doha Declaration on the TRIPS agreement and public health.⁸⁷ The call to flexibilities for the protection of public health, and, in particular, to promote access to medicines for all, and exhortations to developed countries to encourage the provision of assistance to developing countries in this regard⁸⁸ have been the main goals of such a reviving call to action.

Public Health and Medical Agricultural Biotechnology in Africa

UN A/RES/66/288 Resolution is reviving the goodwill of the international Community to eradicate poverty by finding perennial solutions to public health issues. The academic milieu of R&D has a key role in response to the call for further collaboration and cooperation at national and international levels to strengthen health systems through increased health financing, recruitment, development, training and retention of the health work force, improved distribution and access to safe, affordable, effective and quality medicines, vaccines and medical technologies, and through improving health infrastructure.⁸⁹ No doubt, R&D has a huge responsibility in the implementation process of paragraph 143 of the *Future We Want*. The academic world should be a key partner to the World Health Organisation established by the Nations as the directing and coordinating authority on international health work.⁹⁰

In this last section of the paper, we aim to consider the Africa Rice Center and its NERICAs as a suitable institutional framework whereby UN A/RES/66/288 Resolution provisions on green economy in the context of sustainable development and poverty eradication can be implemented with medical agricultural GMOs.

Green Economy and R&D in the Context of Sustainable Development and Poverty Eradication

The international Community commitment expressed in UN A/RES/66/288 Resolution to reach the goals of a green economy in the context of sustainable development and poverty eradication sets forth a political goodwill foundation favourable to the use of medical agricultural GMOs as any other pharmaceutical products under the implementing process of the Declaration on TRIPS and public health. Heads of State and Government at Rio+20 affirm indeed in paragraph 2 of UN A/RES/66/288 Resolution that eradicating poverty is the greatest global challenge facing the world today and an indispensable requirement for sustainable development.⁹¹ They went further with the full participation of civil society to renew their commitment to sustainable development and to ensure the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations.⁹² They added that they are in this

regard committed to freeing humanity from poverty and hunger as a matter of urgency.⁹³ In order to fulfill such a commitment, a suitable framework built up with strong collaborative and cooperative tides at the national and international levels is needed within the R&D academic sector. Such a framework should also be backed up by a political goodwill motivated by common challenges among countries involved. In the example of West-Africa, the current Ebola endemic epidemic fever which is hitting many countries of West Africa at the same time is a common challenge such as many other endemic pandemic disasters in that continent and in the world.⁹⁴ Also, there is region a common commitment to self-sufficiency in rice in that. These two main regional challenges have a huge potential bringing in regional common strategies implementing UN A/RES/66/288 Resolution and WHO-WTO Declaration on TRIPS and public health provisions with medical agricultural modern biotechnology. In such a perspective, the Africa Rice Center and its vast experience in developing New Rice for Africa varieties (NERICAs) is being suggested to hit two birds with one stone namely the choice of a regional research center and the choice of rice which is the basis of food for many population of West Africa.

Self-sufficiency in Rice: A Socio-economic and Strategic Regional Goal in Africa

Rice is a strategic foodstuff in most of the West African countries. It is the main food component for the majority of the urban population living in this region of the world. However, the production of rice is far from meeting the needs. Ivory-Coast import a million of tonnes of rice every year and Senegal imports the same quantity in worst years.⁹⁵ Nigeria imports two million tonnes of rice a year.⁹⁶ These countries are conscious of the negative impact of such circumstances on developmental efforts and aim to reach self-sufficiency in rice by 2016 for Ivory-Coast, 2015 for Nigeria, 2017 for Senegal.⁹⁷ Rice has not always been the main foodstuff in Ivory-Cost.⁹⁸ It has become such over the years with the increasing urbanisation of the population.⁹⁹ In order to reach its objective of self-sufficiency in rice, by 2016 Ivory-Coast aims to produce 1.9 million tonnes.¹⁰⁰ Gambia is aiming to ban rice import by 2016 and to feed the population with rice produced locally.¹⁰¹ The country imports 176,000 tonnes of rice every year which represents 70 per cent of the domestic rice consumption.¹⁰²

Africa Rice Center is an international African research association conducting activities to produce a high-yielding rice variety adapted to the conditions of African regions south of the Sahara.¹⁰³ It was created in 1971 as the West Africa Rice Development Association (WARDA).¹⁰⁴ In 2009, its Council of Ministers took a historic decision at its 27th Ordinary Session in Lomé (Togo) to officially change the Center's name to Africa Rice Center.¹⁰⁵ Rice varieties developed by the Africa Rice Center are called New Rice for Africa (NERICAs).¹⁰⁶ NERICAs are interspecific rice varieties from crossing between the high-yielding Asian rice known as *Oryza sativa spp. Japonica* with locally adapted African rice known as *Oryza glaberrima*.¹⁰⁷ Some of these NERICAs are quite close to each other with almost an absence of genetic distance.¹⁰⁸ There can be noted, however, a wide range of genetic differences among some of them.¹⁰⁹ NERICAs have shown a stable and high yield and tolerance to major biophysical production constraints in a range of upland environments.¹¹⁰ NERICAs have been easily disseminated in West Africa mainly by small rice farmers.¹¹¹ These farmers play an important role through participatory vegetal selection and would in some cases select and evaluate varieties on their own farms.¹¹² In this regard, it has been noted a particular progress made in Guinea where from 1997 to 2000 the number of farmers participating in participatory vegetal selection rose from 116 to 20,000, the area sown with NERICAs from 50 to 8,000 hectares.¹¹³ An informal seed system has been developed and implemented in this regard.¹¹⁴ A survey has shown in year 2002 that 37 per cent of 2,289 farmers have already grown a rice participatory selected variety and had obtained seed via informal mechanisms from other farmers through gift, exchange or purchase.¹¹⁵ A more recent participatory varietal selection consists of enabling crucial issues to be identified and accommodated among which issues are utilising existing seed spread mechanisms, facilitating formal release of acceptable varieties, assessing post-harvest traits.¹¹⁶ There is also the need of sustainability throughout the participatory varietal selection process.¹¹⁷ No doubt, the recent full dedication of the International Community to green economy at the Rio+20 Summit, the current regional call to self-sufficiency in rice, the suitability of the Africa Rice Center and its New Rice for Africa development policy open together a door for medical agricultural GMOs to contribute finding solution to developmental issues in public health and poverty eradication. The desire expressed by the

Heads of state and government to revive the Doha Declaration on TRIPS and Public Health at the Rio+20 Summit will benefit from these favorable conditions to poverty eradication.

We will highlight in the following section normative elements of UN A/RES/66/288 Resolution with a potential to lead towards a political goodwill in favor of the implementation of the Doha Declaration on TRIPS and Public Health with medical agricultural GMOs to eradicate poverty.

Previous section shows that in the West African context, all conditions seem to be gathered to have, among many other options, medical agricultural modern biotechnology used to help governments facing public health and nutritional challenges. Moreover, a number of UN A/RES/66/288 Resolution provisions can allow laying forth a foundation for a growing political goodwill especially in the areas of environmental governance for R&D and international cooperation to eradicate poverty. The political goodwill of the Nations is essential in implementing process of the Resolution in general and in particular in the option of implementing the Doha Declaration on TRIPS and Public Health with medical agricultural GMOs. Such a political goodwill among the Nations should start with coherent institutional governance carried out at paragraph 77 of UN A/RES/66/288 Resolution where Heads of States and governments acknowledge the vital importance of an inclusive, transparent, reformed, strengthened and effective multilateral system in order to better address the urgent global challenges of sustainable development today.¹¹⁸ Leaders of the world also underscore at paragraph 78 the need to strengthen United Nations system-wide coherence and coordination, while ensuring appropriate accountability to Member States, by enhancing coherence in reporting and reinforcing cooperative efforts under existing inter-agency mechanisms and strategies to advance the integration of the three dimensions of sustainable development within the United Nations system.¹¹⁹ They promote synergies and coherence between agencies and programs at paragraph 79.¹²⁰ Such exhortation to synergy will help in building accountability and coherence between United Nations organisations that may be involved in the implementation of the Doha Declaration on TRIPS and Public Health with medical agricultural GMOs namely WHO, WTO, the Cartagena Protocol on Biosafety, etc. Considering also the reality that the Doha Declaration on TRIPS and Public Health implementation with medical agricultural GMOs can consist of a local and regional scale

specially as suggested by the context of endemic pandemic crises, UN A/RES/66/288 Resolution provisions on local and regional arrangements are more than relevant. In this regard, section E of the Resolution is dedicated to regional, national, sub-national and local levels of implementation. The importance of the regional dimension of sustainable development was acknowledged and highlighted at paragraph 97 of the Resolution.¹²¹ Rulers of the world agreed on the reality that regional frameworks can complement and facilitate effective translation of sustainable development policies into concrete action at the national level.¹²² They encourage regional, national, sub-national and local authorities as appropriate to develop and utilise sustainable development strategies as key instruments for guiding decision-making and implementation of sustainable development at all levels.¹²³ Also they agree to have a special recognition integrating social, economic and environmental data and information. Effective analysis and assessment of implementation are held as important matters and steps in decision-making processes.¹²⁴ It is in such a collaborative environment that we better understand paragraph 143 of the Resolution carrying forth the provisions on collaboration and cooperation at the national and international levels to strengthen health systems through increased health financing, recruitment, development and training.¹²⁵ Retention of the health workforce, through improved distribution and access to safe, affordable, effective and quality medicines, vaccines and medical technologies are also apprehended.¹²⁶ In this same paragraph Heads of States and Governments along with the civil society at Rio+20 support the leadership role of the World Health Organisation as the directing and coordinating authority on international health work.¹²⁷ This leading organisation is the main United Nations agency entrusted to the implementation of the Doha Declaration on public health. There can be no better choice institution to host the option of implementing the Declaration with medical agricultural modern biotechnology products which is the object of the current contribution of poverty eradication.

In this last section of the paper, we did consider the Africa Rice Center and its NERICAs development as a suitable institutional R&D framework whereby UN A/RES/66/288 Resolution provisions on green economy in the context of sustainable development and poverty eradication can be implemented with medical agricultural modern biotechnology products. Development and dissemination of such products is a public health option

which can become a reality when we consider the growing political goodwill among West African countries to find perennial solutions to endemic pandemic crises such as the current Ebola fever and the growing common commitment to self-sufficiency in rice.

Conclusion

In this paper we endeavoured to underline that the UN A/RES/66/288 Resolution is giving an opportunity to the International Community to revive the implementing process of the WHO-WTO Declaration on TRIPS and Public Health. National initiatives in Korea and Senegal in developing and using medical agricultural GMOs to face public health challenges led us in this paper to encourage regional initiatives to cover larger scales of endemic pandemic crises such as the current Ebola fever. The growing common commitment to self-sufficiency in rice among West African Nations and the R&D experience of the African Rice Center have been presented as two key combined factors to generate activities of development and use of medical agricultural modern biotechnology genetic materials to assist governments finding perennial solutions to public health crises and poverty eradication. Africa can indeed contribute eradicating poverty in providing food and in guarantying at the same time physical health to its population with medical agricultural modern biotechnology innovation. This paper brings us to consider the necessity of international cooperation and investment in bio-industrial innovation to assist developing countries facing crucial challenges in food safety, food security and public health towards the Future we want.

Endnotes

- ¹ See the full text at http://www.icriforum.org/sites/default/files/UNGA_the_future_we_want.pdf
- ² The next generation of crops with improved output traits could confer nutritional benefits to millions who suffer from malnutrition and deficiency disorders. A gene encoding for beta-carotene/vitamin A has been incorporated into rice and can enhance the diets of the 180 million children who suffer from the vitamin A deficiency that leads to 2 million deaths annually. Similarly, a gene that increases iron deficiency that affects more than 2 billion people and causes anemia in about half that number (James and Krattiger, 1999).
- ³ In response to the question of how many contagious diseases were covered by the research project on medical agricultural GMOs Dr. Ba answer is quoted in the French original language as follow: Il y en a beaucoup. Nous avons l'exemple du sida sur lequel travaille

le Pr Mboup au niveau moléculaire. Ensuite, il y a l'équipe de détection (trousses mises au point par des techniques de biotechnologies qui permettent de détecter rapidement un certain nombre de maladies sur l'homme et sur l'animal). On est en train de mettre au point des vaccins que l'on va introduire dans la banane ou d'autres fruits (There are many. We have the example of AIDS Dr. Mboup is working on the molecular level. Then there is the detection team (kits developed by biotechnology techniques that can quickly detect a number of diseases in humans and animals). We are currently developing vaccines that we will introduce in the banana or other fruit) See, BA (2004).

4 *Ibid*

5 *Ibid*

6 *Ibid*

7 *Ibid*

8 *Ibid*

9 Main original quotation by the Ministry of Scientific Research of Senegal is: Après s'être perfectionnée à travers de nombreux stages de formation dont le dernier effectué à l'Indian Institute of Sciences sur la production des vaccins alimentaires par le procédé de la transformation génétique des plantes, elle est devenue un des plus grands spécialistes sénégalais et même africains sur les Biotechnologies, notamment les Organismes génétiques modifiés (Ogm)... (Having perfected through many training courses which were last performed at the Indian Institute of Sciences on the production of vaccines food by the process of genetic transformation of plants, she has become one of the largest Senegalese specialists in Biotechnology, including in genetic modified organisms (GMO)). See: <http://fr.allafrica.com/stories/200507150595.html>

10 *Ibid.*

11 Secretariat to the Convention on Biological Diversity (SCBD), Montreal, Canada ; <http://bch.cbd.int/about/news-post/?postid=49428>

12 *Ibid.*

13 *Ibid.*

14 *Ibid.*

15 *Ibid.*

16 *Ibid.*

17 *Ibid.*

18 Fitzpatrick *et al.* (2012).

19 Naqvi *et al.* (2009).

20 *Ibid.*

21 *Ibid.*

22 *Ibid.*

23 *Ibid.*

24 *Ibid.*

25 *Ibid.*

26 Gonzalez-Jorge, *et al.* (2013).

27 *Ibid.*

- 28 <http://www.who.int/vmnis/database/vitamina/x/en/index.html>
- 29 Aluru, *et al.* (2008)
- 30 Newell-McGloughlin (2008).
- 31 Bajaj and Mohanty (2005).
- 32 *Ibid.*
- 33 *Ibid.*
- 34 *Ibid.*
- 35 Paine, *et al.* (2005). See also Takaiwa, Kikuchi and Oono (1987).
- 36 Qu, *et al.* (2008).
- 37 Ye, *et al.* (2000).
- 38 *Ibid.*
- 39 Martin, *et al.* (2011).
- 40 *Ibid.*, pp. 1687-1695
- 41 The report of the 2012 World Environment Summit known also as Rio+20 has been adopted indeed by the United Nations General Assembly on its Sixty-Sixth Session in Agenda 19 under the title of “The future we want” as an annex to Resolution 66 adopted by the General Assembly on July 2012. [quoted there after as: UN A/RES/66/288 Resolution]; https://rio20.un.org/sites/rio20.un.org/files/a-conf.216l-1_english.pdf
- 42 UN A/RES/66/288 Resolution, par. 138, *Ibid.*, p.27. The three dimensions of sustainable development are economic, social and environmental and stated at paragraph 1 of UN A/RES/66/288 Resolution on our common the vision of the future we want : We, the Heads of State and Government and high-level representatives, having met at Rio de Janeiro, Brazil, from 20 to 22 June 2012, with the full participation of civil society, renew our commitment to sustainable development and to ensuring the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations.
- 43 *Ibid.*
- 44 *Ibid.*
- 45 UN A/RES/66/288 Resolution, par. 139, *Ibid.* p.27
- 46 UN A/RES/66/288 Resolution, par. 140, *Ibid.* p.27
- 47 UN A/RES/66/288 Resolution, par. 141, *Ibid.* p.27
- 48 UN A/RES/66/288 Resolution, par. 146, *Ibid.* p.28
- 49 World Trade Organization (WTO), Annex 1C, TRIPS Agreement on Trade-Related Aspects of Intellectual Propriety Rights – Part I. General Provisions and Basic Principles- Article 7; p. 323; http://www.wto.org/english/docs_e/legal_e/27-trips.pdf; See also: http://www.wto.org/english/tratop_e/trips_e/t_agm2_e.htm
- 50 Doha WTO Ministerial 2001: TRIPS – Declaration on TRIPS Agreement and Public Health adopted on 14 November 2001, WT/Min(01)/Dec/2, 20 November 2001; http://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_trips_e.htm
- 51 Supra note 48, Article 8; p. 323.
- 52 Article 27 on Patentable subject matter, Article 28 on Rights conferred to patent owners and Article 29 on Conditions on patent applicants; *Ibid.*, pp. P. 331-332.

- ⁵³ Article 30 on exceptions to rights conferred to patents owners states that members may provide limited exceptions to the exclusive rights conferred by a patent, provided that such exceptions do not unreasonably conflict with a normal exploitation of the patent and do not unreasonably prejudice the legitimate interests of the patent owner, taking account of the legitimate interests of third parties, *Ibid*.
- ⁵⁴ *Ibid*, Article 27, p. 331.
- ⁵⁵ *Ibid*, Article 28, p. 331.
- ⁵⁶ International Federation of Pharmaceutical Manufacturers Associations (IFPMA), The WTO Millennium Round: Position of the IFPMA, Geneva, <http://www.ifpma.org> [11 January 2002].
- ⁵⁷ See note 49.
- ⁵⁸ Declaration on TRIPS Agreement and Public Health adopted on 14 November 2001, WT/Min(01)/Dec/2, 20 November 2001; http://www.wto.org/english/thewto_e/minist_e/min01_e/mindecl_trips_e.htm
- ⁵⁹ *Ibid*.
- ⁶⁰ *Ibid*.
- ⁶¹ Declaration on TRIPS Agreement and Public Health, paragraph 5a.
- ⁶² Declaration on TRIPS Agreement and Public Health, paragraph 5b.
- ⁶³ Declaration on TRIPS Agreement and Public Health, paragraph 5c.
- ⁶⁴ *Ibid*.
- ⁶⁵ Declaration on TRIPS Agreement and Public Health, paragraph 5d.
- ⁶⁶ Declaration on TRIPS Agreement and Public Health, paragraph 6.
- ⁶⁷ *Ibid*.
- ⁶⁸ Declaration on TRIPS Agreement and Public Health, paragraph 7.
- ⁶⁹ Paragraph 2 of Article 66 of the TRIPS Agreement read as follow: Developed country Members shall provide incentives to enterprises and institutions in their territories for the purpose of promoting and encouraging technology transfer to least-developed country Members in order to enable them to create a sound and viable technological base.
- ⁷⁰ In fact, at Article 5 of the Protocol on pharmaceuticals, Parties agreed that “this Protocol shall not apply to the trans-boundary movement of living modified organisms which are pharmaceuticals for humans that are addressed by other relevant international agreements or organizations”. Secretariat of the Convention on biological diversity (SCBD)/Cartagena Protocol on Biosafety To the Convention on Biological Diversity; Text and Annexes, UNEP, ISBN: 92-807-1924-6, Montreal, 2000; p.5 <http://bch.cbd.int/protocol/text/>
- ⁷¹ In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration on Environment and Development, the objective of this Protocol is to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on trans-boundary movements. *Ibid*, p. 3
- ⁷² Both paragraph 6 of Article 10 (decision procedure) and paragraph 8 of Article 11 (procedure for LMOs intended for direct use as food or feed, or processing) confirm the precautionary principle as follow: Lack of scientific certainty due to insufficient relevant

scientific information and knowledge regarding the extent of the potential adverse effects of a living modified organism on the conservation and sustainable use of biological diversity in the Party of import, taking also into account risks to human health, shall not prevent that Party from taking a decision, as appropriate, with regard to the import of the living modified organism in question ... in order to avoid or minimise such potential adverse effects.

73 *Ibid*, Article 8, p. 6.

74 *Ibid*, Article 9, p. 7.

75 Article 10, paragraph 3, p. 7.

76 Article 10, paragraph 3b, p. 7.

77 Article 12, paragraph 3b, p. 10.

78 Article 15, paragraph 2, p. 12.

79 *Ibid*.

80 Article 15, paragraph 3, p. 12.

81 We may be reminded here that medical agricultural GMOs simply as vaccines, medications or vitamins can fall into Article 5 of the treaty which excludes from the scope of the Protocol, agricultural GMOs products consisting of pharmaceuticals, *Supra* note 69.

82 Article 13, paragraph 1b, p. 10.

83 *Ibid*.

84 *Ibid*.

85 *Supra* notes 10 to 16.

86 *Supra* note 40; Resolution A/66/288, paragraph 142, p. 27; https://rio20.un.org/sites/rio20.un.org/files/a-conf.2161-1_english.pdf.pdf

87 *Ibid*.

88 *Ibid*.

89 UN A/RES/66/288 Resolution, paragraph 143, pp. 27-28.

90 *Ibid*, p.28.

91 UN A/RES/66/288 Resolution, *Supra* note 40, par 2, p. 1.

92 UN A/RES/66/288 Resolution, par 1, p. 1.

93 *Supra* note 86.

94 This fact has been largely covered by the media and will not be taken up in this contribution.

95 Seck, Papa Abdoulaye (Minister), “Le marché international dicte les politiques de l’autosuffisance en riz en Afrique de l’Ouest.” (The international market dictates the rice self-sufficiency policies in West Africa.); http://www.senenews.com/2015/01/24/le-marche-international-dicte-les-politiques-d-autosuffisance-en-riz-de-l-afrique-de-louest-ministre_108104.html

96 *Ibid*.

97 *Ibid*.

98 Dembélé, Yacouba (Director), “Mot du Directeur Général,” République de la Côte d’Ivoire/Ministère de l’Agriculture/ Office National de développement de la riziculture, (“Word of the Director General”, Republic of Côte d’Ivoire / Ministry of Agriculture / National Office for Rice Development); <http://www.ondr.ci/editorial.php>; last assessed on 3 March 2015.

⁹⁹ *Ibid.*

¹⁰⁰ The Government of Côte d'Ivoire / Fraternité Matin, "Agriculture : La Côte d'Ivoire mise sur le riz pour juguler la sécurité alimentaire," ("Agriculture: The Ivory Coast placing on the rice to curb food security"), Government of Côte d'Ivoire/Ministry of Information, <http://fratmat.info/economie/item/11335-agriculture--la-c%C3%B4te-d%E2%80%99ivoire-mise-sur-le-riz-pour-juguler-l%E2%80%99ins%C3%A9curit%C3%A9-alimentaire>; last assessed on 3 March 2015.

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¹⁰⁴ Africa Rice Center, "Africa Rice Center is no longer WARDA", News release, Cotonou, Benin, 10 September 2009, <http://www.africarice.org/warda/newsrel-com-sep09.asp>; last accessed on 4 March 2015.

¹⁰⁵ *Ibid.*

¹⁰⁶ *Supra* note 94.

¹⁰⁷ Kishine *et al.* (2008).

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¹¹² *Ibid.*

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¹¹⁵ *Ibid.*

¹¹⁶ *Ibid.*

¹¹⁷ *Ibid.*

¹¹⁸ UN A/RES/66/288 Resolution, Paragraph 77, p. 14.

¹¹⁹ UN A/RES/66/288 Resolution, Paragraph 78, pp. 14-15.

¹²⁰ UN A/RES/66/288 Resolution, Paragraph 79, p. 15.

¹²¹ UN A/RES/66/288 Resolution, Paragraph 97, p. 19.

¹²² *Ibid.*

¹²³ UN A/RES/66/288 Resolution, Paragraph 98, p. 19.

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