Asia-Pacific Health 2020 and Genomics without Borders: Co-Production of Knowledge by Science and Society Partnership for Global Personalized Medicine

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Keywords

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*“For most complex problems, the pursuit of perfect knowledge is asymptotic.
Uncertainty, ignorance and indeterminacy are always present”*

-- Jasanoff 2007 [1]

1. ASIA-PACIFIC – A NEW FRONTIER FOR POSTGENOMICS MEDICINE

Is Asia-Pacific emerging as a leader in genome-based personalized medicine in 21st century? With news of senior “star” scientists from North America and Europe relocating to, or establishing satellite outpost laboratories in the Asia-Pacific region, this question has become topical among scientists, research funding agencies as well as investors in global health and knowledge-based innovations. In addition to attracting established scientists, the

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CONFLICT OF INTERESTS

None declared/applicable.

Asia-Pacific is actively investing in a young generation of skilled professionals. Based on the annual *Open Doors* report published by the Institute of International Education (IIE), the number of international students enrolled at colleges and universities in the United States (US) was 690,923 during the 2009/2010 academic year [2]. Of the top six sending countries, five were from the Asia-Pacific region - Mainland China and Taiwan, India, Japan and South Korea - representing more than half (52%) of the total international student population. A recent study on globalization of science using quantitative indicators found that the current growth rate for federal research funding in China greatly exceeds that in the US and the European Union (EU) [3].

Applications of genomics to enable personalized health interventions (a prime focus for the *CPPM*) have expanded in the Asia-Pacific to include not only targeted rational use of pharmaceuticals but also nutrition and nutritional genomics [4]. Bioinformatics community in the region has recently recognized the need to address the computational challenges of genomics/postgenomics high-throughput technologies, for example, at the annual conference of the Asia-Pacific Bioinformatics Network, held on September 7–11, 2009 at Biopolis, Singapore [5]. In Sri Lanka, personalized medicine research includes, for example, hepatitis C diagnostics and clinical management by measurement of patients' baseline viral load and genotype [6, 7]. Much of the fundamental research conducted within the Asia-Pacific research establishments - the Beijing Genomics Institute in China, the Eijkman Institute for Molecular Biology in Indonesia, the Institute of Molecular and Cell Biology in Singapore, the RIKEN Center for the Genomic Medicine in Japan, the Nutrigenomics New Zealand (the list is too extensive to do justice in this concise editorial) - now depends on genomics and other high-throughput technologies such as proteomics and metabolomics. Insofar as investment in clinical trials is concerned, the number of clinical trials in low- and middle-income countries (LMICs) has also increased markedly over the past decade [8].

Looking west across the Pacific to the US, science and technology are increasingly promoted as a key aspect of the policy agenda. As part of the recent American Recovery and Reinvestment Act of 2009, the US NIH Challenge Grants in Health and Science Research initiative provided substantial new support for research. To this end, one of the priority areas included *theragnostics* - combined delivery of diagnostic and therapeutic agents - a subject that has been intensively discussed as part of the *CPPM* editorial contents [see the past editorial overviews in 9, 10]. Further across the Atlantic in the EU, the Europe 2020 economic reform and growth agenda has been developing in full steam, initiated by José Manuel Barroso, the President of the European Commission. As in the US, this policy agenda is defined to a considerable extent by science and technology; one of the five EU-wide targets is R&D and innovation [11].

But could such investments in R&D and technology, alone, spur economic development and deliver on the promise(s) of sustainable, effective and equitable health systems and services in Asia-Pacific [12]? What about previously silent but important issues such as reversing the brain drain from LMICs [13, 14], or increasing the role of societal stakeholders in shaping (and democratizing) scientific expertise for “responsible innovation” [15, 16], or actually getting the innovations to those in greatest need?

2. ASIA-PACIFIC HEALTH 2020 DEVELOPMENT POLICY – THE TIME IS RIGHT

The new European Health 2020 policy, endorsed at the 60th session of the WHO Regional Committee for Europe, will set out an action framework to accelerate better health in the region, to be developed through participatory process with Member states, sectors and partners [17]. It would be timely and prudent to open a dialogue in other global regions, for example, in the context of “Asia-Pacific Health 2020”. This editorial article is intended to start this very discussion in the region in part because the *CPPM* aims to serve as a peer-reviewed multidisciplinary platform for advances in genomics/postgenomics personalized medicine applications in Asia-Pacific as well as internationally.

In the ensuing discussion, we provide a brief overview of the ways in which scientific innovations have been conceptualized in 20th century and how this understanding is now changing (though slowly) from technological determinism where science has been viewed as an autonomous activity, to one that relies on co-production of scientific knowledge by science and society partnership. This understanding is essential prior to further discussion on the Asia-Pacific Health 2020 takes place.

3. CO-PRODUCTION OF POSTGENOMICS KNOWLEDGE BY SCIENCE AND SOCIETY

3.1. Beyond Technological Determinism and Linear Model of Innovations

Innovation is a widely used term but often without due attention to its origins and conceptual underpinnings. Systematic approaches to understand the complex linkages between social change on the one hand, science and technology innovations on the other, predate to the time of The Great Depression in the US. In a reaction to the idea that radically creative thought is a result of “great genius”, the American sociologist William F. Ogburn emphasized the concept of “cultural lags” and that innovations are in essence a sequential process. According to Ogburn, as technological changes leaped forward, they created a cultural lag in society which then needed to adjust and adapt to the new realities introduced by inventions. The modern day idea of technological gaps or “time lags” between inventions and their commercialization can be traced, in part, to the concept of cultural lags [18].

The sequential nature of inventions postulated by Ogburn is metaphorically embedded in the frequently quoted “bench-to-bedside” model of biomedical research or the “linear model of innovation”. This model predicts that “innovation starts with basic research, is followed by applied research and development, and ends with production and diffusion” [19]. Despite frequent explicit or implicit references to the linear model in study of innovations, investments in basic science do not, however, invariably lead to applications in the clinic nor is the flow of knowledge always linear from laboratory to society [9, 20]. Oftentimes, consumer demands or end users of scientific knowledge (“user pull”) may decisively influence scientific practice.

Since Ogburn, social studies of science and technology over the past decades have led to three broad analytical frameworks. First is “technological determinism” - that it is the technology that shapes society [21], and that society typically displays a cultural lag before adopting a new scientific discovery [18]. This type of determinism views science as an autonomous activity that cannot be shaped by society; society has no choice but passively adopt a technology or innovation once it is introduced or available. Second is “social determinism” - the view that it is the society that shapes science and technology. This second view tends to be neglected among scientists involved in upstream discovery-oriented innovations even though the social factors such as end-user and stakeholder perceptions may decisively influence the downstream trajectory of a scientific discovery. Third is an “interactionist” framework whereby science and society shape each other [22–24]. Instead of technological determinism, this last framework also acknowledges the presence of multiple possible future(s) in regards to technology and innovation trajectories from lab-to-society.

Over the past two decades, governments and international organizations have increasingly moved away from the first “science-push” model above and the linear notions of technological progress more generally [15, 16, 25], in favor of greater participatory foresight and co-production of knowledge by science and society [26, 27]. For example, the involvement of patients by researchers assessing treatments for rheumatoid arthritis showed that, for most patients, fatigue was the dominant symptom of concern contrary to what researchers had assumed (pain) [28]. Such “upstream” public engagement can allow bi-directional exchange of expert knowledge and local evidence (e.g., patients’ personal experiences of illness) thereby shaping both scientific practice and uptake of scientific knowledge by end users [29]. Disconnects between other stakeholders are also noteworthy. Scientists and policy-makers often have very different views and perceptions on what constitutes evidence [30, 31]. Best articulated in the form of the “two-communities thesis”, scientists and policy-makers often work on a different time scale, under different priorities and may lack the ability to take into account the realities, priorities or perspectives of one another [30, 31]. This ultimately creates breeches in effective use of scientific data in policy-making and conversely, it may also result in creation of research that is redundant or evidence that cannot be utilized in policy-making in a meaningful manner. Lavis *et al.* in fact suggest that “researchers (and research funders) should create more opportunities for interactions with the potential users of their research. They should consider such activities as part of the ‘real’ world of research, not a superfluous add-on” [32].

4. GENOMICS WITHOUT BORDERS

In an era of rapid globalization of science, and in the face of both hype and resistance towards new biotechnologies, linking local knowledge with global action has appropriately received considerable attention in the literature [see, for example, 33]. On the other hand, despite growing cooperation in research implementation, research funding in Asia-Pacific have remained within national boundaries [34]. In contrast to the EU, support of research crosses relatively fewer national borders in Asia-Pacific [34]. There is a need for cross-border funding of research to foster knowledge-based innovations in the region.

Genomics and similar data intensive sciences rely on infrastructure science such as biobanks and large collections of datasets from different populations [35, 36]. To this end, it is noteworthy that science has historically been linked with the notion of discovery. In the postgenomics era, both infrastructure science (e.g., biobanks) and discovery science are inseparable components of knowledge-based innovations. To ensure further development of biobanks and other essential building blocks (e.g., bioinformatics) of the 21st century postgenomics personalized medicine, it is important to prevent the creation of a false hierarchy between discovery science and infrastructure science. The rapid emergence of large-scale databases and biobanks also raise issues at the intersection of law and policy, the need for new governance approaches at both national and international levels [37–39], and the ability to deal with ethical and moral issues which arise. The rise of emerging economies in Asia-Pacific and globally demands new models of collaboration within and across LMICs, including North-South, South-South and North-South-South partnerships [see 40, for a recent overview].

Despite cross-border funding, pan-European research faces significant ethical and legal challenges. While researchers now combine information from different national biobanks to create “virtual” mega European-cohorts - as illustrated by European projects such as ENGAGE [41] and BioSHaRE [42] - legal frameworks still differ from one jurisdiction to another. Since the hurdles encountered when developing pan-European infrastructures may potentially occur when developing research infrastructures in Asia-Pacific, the study of these past biobanking experiences may foster discussion on how best to develop genomics/postgenomics science infrastructure in a manner that takes into account both global and local contexts, and LMICs more generally.

CONCLUSIONS AND OUTLOOK

It has been noted that no more than 3% of the published genomics research has focused on the development of evidence-based guidelines for genomics applications and real life health outcomes [43]. Globalization of genomics research brings about further complexities and promises for personalized medicine and rational therapeutics in LMICs. While the Asia-Pacific, and many other countries globally, face new genomics applications, such evidentiary gaps might conceivably be more pronounced in LMICs. Although access to high throughput sequencing of the genomes indeed increased enormously, appropriately trained personnel who can *interpret* genomics data in a manner that is biologically and clinically meaningful are still scarce. Even more challenging is how best to evaluate emerging genomics data through the lens of global public health [44]. Pharmacogenomics and other postgenomics personalized health interventions (e.g., nutrigenomics) are fields where the data and interpretation of discoveries are particularly complex, demanding alignment across the Asia-Pacific and internationally [45–47].

Each of the emerging economies in the Asia-Pacific has different assumptions and different economic goals for prosperity through science and technology investments. On the other hand, if we are to adopt an interactionist participatory model of knowledge production by both science and society, we need to cultivate new capacities among scientists, policy-makers and universities to seek out what individual citizens and public(s) value, and why

they value it, in reference to genomics and personalized medicine. As noted by Jasanoff [1] “capacity-building in the face of uncertainty has to be a multidisciplinary exercise, engaging history, moral philosophy, political theory and social studies of science, in addition to the sciences themselves”. In order to develop a sustainable postgenomics science and development policy in the Asia-Pacific, it is also necessary to establish new governance mechanisms that take into account both supply and demand of knowledge and technology simultaneously across the national borders in the region [9, 15, 16].

As genomics crosses the national borders, there is a growing need for a code of practice on international recruitment of scientific personnel where not only senior scientists but also skilled young scientists are retained and encouraged for professional development.

Although science and technology might be a harbinger of socio-economic prosperity for Asia-Pacific, enabling international development through knowledge-based health innovations is fundamentally an interorganizational and cross-country activity that requires a knowledge system lens [33]. Few years ago, Choi *et al.* have proposed that there is a range of possible strategies for knowledge management to better bridge the interdisciplinary skills between researchers and policy-makers [31]. One concrete example provided in that paper [31], a chief knowledge management officer, might presumably be particularly relevant now for the LMICs in the Asia-Pacific to rapidly identify the genomics applications (i.e., the lowest hanging fruits) that are best suited from a public health genomics standpoint [44]. In the end, however, each country will need to identify the knowledge management and innovation policies that are best suited for their local realities while bearing in mind the global context. Broader models of societal and ethical review of emerging genomics and postgenomics health technologies will also have to be considered [for a discussion on these models, see 48].

As part of a Health 2020 agenda in the Asia-Pacific, the considerations raised in this editorial analysis, admittedly, only scratch the surface in regards to the needs of citizens in LMICs [see also 49–52]. We hope, however, that it opens an important dialogue and contributes to further reflection on the subject by both scientists and global society at large. Indeed, the concept of “genomics without borders” has been already put into practice successfully in a recent work by the HUGO Pan-Asian SNP Consortium, enabled by effective collaboration of a vast number of scientists and institutes among the Asia-Pacific countries [53]. We wish to underscore that societies that rely on (and invest in) knowledge-based innovations will be more sustainable by recognizing co-production – that scientific knowledge is a product of both what we know from technology as well as how and what we choose to know [1, 54]. The latter warrants the recognition of the ways in which human values contribute to construction of meanings from scientific discoveries, why publics want (or do not accept) an innovation, or might prefer a certain knowledge-based innovation over another. The progress in data intensive personalized medicine research also depends on sustained and coordinated investments in infrastructure science such as biobanks and databases in the Asia-Pacific [55].

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ABBREVIATIONS

EU	European Union
HUGO	The Human Genome Organisation
IIE	Institute of International Education
LMICs	Low and middle-income countries
US	United States

References

1. Jasanoff S. Technologies of humility. *Nature*. 2007; 450(7166):33. [PubMed: 17972866]
2. Institute of International Education (IIE). press release. Washington, DC: Nov 15. 2010 Available from: <http://www.iie.org/en/Research-and-Publications/Open-Doors> [Accessed February 5, 2011]
3. Hather GJ, Haynes W, Higdon R, et al. The United States of America and scientific research. *PLoS One*. 2010; 5(8):e12203. [PubMed: 20808949]
4. Barnett MP, Ferguson LR. Meeting report: fourth Asia-Pacific nutrigenomics conference: gene-diet interactions in gut health, Auckland, New Zealand, February 21–25, 2010. *Biotechnol J*. 2010; 5(9): 913–8. [PubMed: 20845383]
5. Ranganathan S, Eisenhaber F, Tong JC, et al. Extending Asia Pacific bioinformatics into new realms in the “-omics” era. *BMC Genomics*. 2009; 10 (Suppl 3):S1.
6. Manamperi A, Nugawela P, Gunawardene NS, et al. RNA positivity rates among anti-HCV reactive blood donors in Sri Lanka: a preliminary study. *Indian J Med Microbiol*. 2010; 28(3):264–5. [PubMed: 20644323]
7. Manamperi A. Current developments in genomics and personalized health care: impact on public health. *Asia Pac J Public Health*. 2008; 20(3):242–50. [PubMed: 19124318]
8. Normile D. The promise and pitfalls of clinical trials overseas. *Science*. 2008; 322:214–216. [PubMed: 18845744]
9. Ozdemir V, Husereau D, Hyland S, et al. Personalized medicine beyond genomics: New technologies, global health diplomacy and anticipatory governance. *Curr Pharmacogenomics Person Med*. 2009; 7(4):225–30. [PubMed: 20613883]
10. Ozdemir V, Someya T. A transdisciplinary forum for study of individual and population variability in response to health interventions and personalized medicine. *Curr Pharmacogenomics Person Med*. 2009; 7(3):146–8.
11. European Commission, Europe. 2020EU-Wide Targets. Accessed February 5, 2011 Available from: http://ec.europa.eu/europe2020/targets/eu-targets/index_en.htm
12. Pang T. Germs, genomics and global public health: How can advances in genomic sciences be integrated into public health in the developing world to deal with infectious diseases? *Hugo J*. 2009; 3(1–4):5–9. [PubMed: 21119758]
13. Serour GI. Healthcare workers and the brain drain. *Int J Gynaecol Obstet*. 2009; 106(2):175–8. [PubMed: 19535068]

14. Dodani S, LaPorte RE. Ways to strengthen research capacity in developing countries: effectiveness of a research training workshop in Pakistan. *Public Health*. 2008; 122(6):578–87. [PubMed: 18222502]
15. Roelofsen A, Boon WPC, Kloet RR, et al. Stakeholder interaction within research consortia on emerging technologies: Learning how and what? *Res Policy*. 2011; doi: 10.1016/j.respol.2010.10.015
16. Owen R, Goldberg N. Responsible innovation: a pilot study with the U.K. Engineering and Physical Sciences Research Council. *Risk Anal*. 2010; 30(11):1699–707. [PubMed: 21070299]
17. Jakab Z. Message from the WHO Regional Director for Europe: Embarking on Developing the New European Health Policy--Health 2020. *Eur J Public Health*. 2011; 21(1):131.
18. Ogburn, WF. *Social Change*. Dell; New York: 1922.
19. Godin B. The linear model of innovation. The historical construction of an analytical framework. *Science Technology and Human Values*. 2006; 31(6):639–67.
20. Guston DH. Innovation policy: not just a jumbo shrimp. *Nature*. 2008; 454(7207):940–1. [PubMed: 18719568]
21. Polanyi M. The Republic of Science: Its political and economic theory. *Minerva*. 1962; 1(1):54–74.
22. Fuglsang, L. Three perspectives in STS in the policy context. In: Cutcliffe, SH., Mitcham, C., editors. *Visions of STS: Counterpoints in Science, Technology, and Society Studies*. New York: State University of New York Press; 2001. p. 33–49.
23. Jorgensen MS, Jorgensen U, Clausen C. The social shaping approach to technology foresight. *Futures*. 2009; 41(2):80–86.
24. McGrail S. Nano dreams and nightmares: emerging technoscience and the framing and (re)interpreting of the future, present and past. *Journal of Futures Studies*. 2010; 14(4):23–48.
25. Tallacchini M. Before and beyond the precautionary principle: epistemology of uncertainty in science and law. *Toxicol Appl Pharmacol*. 2005; 207(2 Suppl):645–51. [PubMed: 16054183]
26. Ozdemir V, Armengaud J, Dubé L, Aziz RK, Knoppers BM. Nutriproteomics and proteogenomics: Cultivating two novel hybrid fields of personalized medicine with added societal value. *Curr Pharmacogenomics Person Med*. 2010; 8(4):240–43. [PubMed: 21399751]
27. Miles I. The development of technology foresight: A review. *Technological Forecasting & Social Change*. 2010; 77(9):1448–56.
28. Hewlett S, De Wit M, Richards P, et al. Patients and professionals as research partners: challenges, practicalities and benefits. *Arthritis Rheum*. 2006; 55:676–80. [PubMed: 16874772]
29. Kato K, Kano K, Shirai T. Science communication: significance for genome-based personalized medicine – a view from the Asia-Pacific. *Curr Pharmacogenomics Person Med*. 2010; 8(2):92–6.
30. Innvaer S, Vist G, Trommald M, et al. Health policy makers' perceptions of their use of evidence: a systematic review. *J Health Serv Res Policy*. 2002; 7:239–44. [PubMed: 12425783]
31. Choi BC, Pang T, Lin V, et al. Can scientists and policy makers work together? *J Epidemiol Community Health*. 2005; 59(8):632–7. [PubMed: 16020638]
32. Lavis J, Ross S, Hurley J, et al. Reflections on the Role of Health-Services Research in Public Policy-Making. Paper 01–06. Accessed February 5, 2011 Available from: <http://www.cihr-irsc.gc.ca/e/26574.html>
33. van Kerkhoff L, Szlezák N. Linking local knowledge with global action: examining the Global Fund to Fight AIDS, Tuberculosis and Malaria through a knowledge system lens. *Bull World Health Organ*. 2006; 84(8):629–35. [PubMed: 16917650]
34. Tan CY. Science star over Asia. *PLoS Biol*. 2005; 3(9):e322. [PubMed: 16149850]
35. Fortier I, Burton PR, Robson PJ, et al. Quality, quantity and harmony: the DataSHaPER approach to integrating data across bioclinical studies. *Int J Epidemiol*. 2010; 39(5):1383–93. [PubMed: 20813861]
36. Fortin S, Pathmasiri S, Grintuch R, Deschênes M. 'Access arrangements' for biobanks: A fine line between facilitating and hindering collaboration. *Public Health Genomics*. 2010 Jul 30. Epub ahead of print.
37. Tassé AM, Budin-Ljøsne I, Knoppers BM, et al. Retrospective access to data: the ENGAGE consent experience. *Eur J Hum Genet*. 2010; 18(7):741–5. [PubMed: 20332813]

38. Pang T, Daulaire N, Keusch G, et al. The new age of global health governance holds promise. *Nat Med*. 2010; 16 (11):1181. [PubMed: 21052062]
39. Genes without Borders? Towards Global Genomics Governance. Accessed February 5, 2011 Available from: <http://www.univie.ac.at/LSG/GwB/intro.htm>
40. Thorsteinsdóttir H, Ray M, Kapoor A, et al. Health biotechnology innovation on a global stage. *Nat Rev Microbiol*. 2011; 9(2):137–43. [PubMed: 21233851]
41. European Network for Genetic and Genomic Epidemiology (ENGAGE). Accessed February 5, 2011 Available from: <http://www.euengage.org/>
42. Biobank Standardisation and Harmonisation for Research Excellence in the European Union (BioSHaRE). Accessed February 5, 2011 Available from: <http://www.p3g.org/bioshare/?q=node>
43. Khoury MJ, Gwinn M, Yoon PW, et al. The continuum of translation research in genomic medicine: how can we accelerate the appropriate integration of human genome discoveries into health care and disease prevention? *Genet Med*. 2007; 9(10):665–74. [PubMed: 18073579]
44. Khoury MJ, Muin J. Khoury discusses the future of public health genomics and why it matters for personalized medicine and global health. *Curr Pharmacogenomics Person Med*. 2009; 7(3):158–63. [Accessed February 5, 2011] Available from: <http://www.benthamscience.com/cppm/openaccessarticles/cppm7-3/003AF.pdf>.
45. Ferguson LR, Hu R, Lam WJ, et al. Tailoring foods to match people's genes in New Zealand: opportunities for collaboration. *World Rev Nutr Diet*. 2010; 101:169–75. [PubMed: 20436263]
46. Wittwer J, Rubio-Aliaga I, Hoefl B, et al. Nutrigenomics in human intervention studies: Current status, lessons learned and future perspectives. *Mol Nutr Food Res*. 2011 Jan 31. [Epub ahead of print]. doi: 10.1002/mnfr.201000512
47. Kolker E. A vision for 21st century U.S. Policy to support sustainable advancement of scientific discovery and technological innovation. *OMICS*. 2010; 14(4):333–5. [PubMed: 20673064]
48. Yearley S. The ethical landscape: identifying the right way to think about the ethical and societal aspects of synthetic biology research and products. *Journal of the Royal Society Interface*. 2009; 6 (Supplement 4):S559–64.
49. Gemici G. The metrics of the physician brain drain. *N Engl J Med*. 2006; 354(5):528–30.
50. Pang T. Pharmacogenomics and Personalized medicine for the developing world - Too soon or just-in-time? A Personal view from the World Health Organization. *Curr Pharmacogenomics Person Med*. 2009; 7:149–57.
51. Thedja MD, Muljono DH, Nurainy N, et al. Ethnogeographical structure of hepatitis B virus genotype B distribution in Indonesia and discovery of a new subgenotype, B9. *Arch Virol*. 2011; doi: 10.1007/s00705-011-0926-y
52. Coloma J, Harris E. Molecular genomic approaches to infectious diseases in resource-limited settings. *PLoS Med*. 2009; 6(10):e1000142. [PubMed: 19855820]
53. Abdulla MA, Ahmed I, et al. HUGO Pan-Asian SNP Consortium. Mapping human genetic diversity in Asia. *Science*. 2009; 326(5959):1541–5. [PubMed: 20007900]
54. Law, J. After method. Mess in social science research. New York: Routledge; 2004.
55. Schofield PN, Eppig J, Huala E, et al. Sustaining the data and bioresource commons. *Science*. 2010; 330(6004):592–3. [PubMed: 21030633]