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SPECIAL ISSUE:
TEN YEARS AFTER: MAPPING THE SOCIETAL LANDSCAPE OF GENOMICS

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Editorial

In May 2010 the Centre for Society & Genomics, in collaboration with the ESRC Genomics Network and Valgen (Canada), held its biannual Conference on Society and Genomics in Amsterdam. The objective of the conference was to assess how the societal landscape of genomics had evolved since the sequencing of the human genome.

On June 26 2000 President Bill Clinton, together with Francis Collins and Craig Venter, solemnly announced, in no less a setting than the White House, that the effort to sequence the human genome was rapidly nearing completion. During this press conference, a whole series of metaphors was used to indicate what the human sequence means. Our genome was baptised as the "language of life", our "genetic code", "the working blueprint of mankind", the "book of life", our "instruction book", our "common inheritance", our "essence". Thus, a whole train of metaphors, each with its own history of rise and decline, was presented.

Yet, the dominant metaphor, introduced with remarkable emphasis right at the beginning of the ceremony, was the "map" metaphor. As President Clinton phrased it: "We are here to celebrate the completion of the first survey of the entire human genome. Without a doubt, this is the most important, most wondrous map ever produced by humankind."

The 2010 CSG conference was likewise designed as a collective mapping effort. How had the societal landscape evolved "Ten Years After"? Colleagues from humanities, social science, genomics research, policy, and the media were invited to join in a collective effort to determine how the genomics landscape had become populated, inhabited, organised and governed, and for this purpose, a number of "zones" were identified, such as the urban, the global, the industrial and the environmental.

CSG and the EGN are, of course, the publishers of *Genomics, Society and Politics.* The ideas explored in the conference are reflected in this special issue. The articles are devoted to analysing the societal impact of genomics across the agricultural, the environmental, the urban and the industrial zones.

Professor Hub Zwart, Scientific Director of CSG, is one of the editors-in-chief of *Genomics, Society and Policy* and he is also the editor of this special issue. We are grateful to him, and to our authors. The editors welcome proposals for future special issues.

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Beyond pessimism: The dialectic of promise and complexity in genomic research

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Abstract

How should we reflect upon the last 10 years since the completion of the human genome? One dominant response from within the humanities and the social sciences is to cast these events within a dialectic of promise and disappointment. Indeed, this contrast would seem to hold if we take Clinton's historic announcement as our point of departure. I choose an alternative departure: not in the rhetoric of press releases but from scientists' ambivalent accounts of complexity. Perhaps a dialectic of promise and complexity is a less pessimistic (but no less sceptical) way of reflecting on what has happened in the last 10 years. In this paper, I focus on two aspects of societal change within the 'urban zone': the rise of population-based biobanking and the marketisation of genetic susceptibility testing. Both developments are driven by the promise that genomic research will lead to new ways to 'prevent, diagnose, treat and cure disease'. However, genomic knowledge also reveals a level of complexity that has led to unprecedented scale in the production of granular information. In the last 10 years we have seen that traditional bioethics has struggled to cope with this scale. In the era of high-throughput sequencing and personal genomics, we have also seen that translating complexity into benefits for the health consumer is controversial. Arguably, ethical principles do not capture the subtle differences between predictive and susceptibility testing, and that more empirical research is needed to understand how people perceive and communicate complex risk information.

Introduction

When politicians are given the task of showcasing scientific achievements, optimism and hyperbole are often key ingredients of telling a good story. This was certainly the case when, on 25 June 2000, President Clinton announced "the completion of the first survey of the entire human genome".[2] Leaving aside the familiar tropes of blueprints, maps and codes, on that day a central promise was made: "Decoding the human genome will lead to new ways to prevent, diagnose, treat, and cure disease".[3] Ten years on, the task of this special issue is to reflect on the extent to which this promise has been realised and to consider how the 'societal landscape of genomics' has changed in this period. While holding politicians to their promises is prone to disappointment, I want to suggest that we look elsewhere to undertake this task of historical reflection. Rather than in the rhetoric of press releases or in the expectations of 'completion', I want to begin with scientists' ambivalent accounts of what that completed sequence contained: the *complexity* of DNA.

In February 2001, an article co-authored by Craig Venter and 275 other contributors appeared in *Science* entitled: 'The sequence of the human genome'.[4] This article offered a sobering description of the characteristics of the human genome sequence and a more circumspect account of promise. Actually, the 'major surprise' that the human genome contained far fewer genes than expected (23,000 - 26,000 rather than the predicted 50,000 - to 140,000) was not an indication of the reduced complexity of the human genome; quite the reverse. It meant that complexity was virtually *hidden* among the diversity of non-linear protein-protein interactions. The provisional map of the human sequence provided yet another blow to the 'gene for' paradigm: "This dynamic system … has many ways to modulate activity, which suggests that definition of complex systems by analysis of single genes is unlikely to be entirely successful," wrote Venter et al.[5] This cautious statement does not rule out the possibility that rare, highly penetrant, genes will be implicated in the pathogenesis of some diseases, but it does strengthen the hypothesis that many 'common' diseases are polygenic and multifactorial: "Thus, there are no 'good' genes or 'bad' genes, but only networks that exist at various levels and at different connectivities, and at different states of sensitivity to perturbation."[6] In contrast to the kind of *unqualified* promise made a year earlier, here we see that scientists' engage in highly moderated forms of promising based not on the imperative of translation (i.e. curing or preventing disease, etc.) but in overcoming a set of technical problems that have suddenly come into view: "The next steps are clear: We must define the complexity that ensues when this relatively modest set of about 30,000 genes is expressed."[7]

Since Clinton's historic announcement, we have seen an increasing pessimism towards the rhetoric of (genomic) promise. I want to suggest that rather than dwelling on a dialectic of promise and disappointment, we could look at the last decade less pessimistically (but no less sceptically) in terms of a dialectic of promise and complexity. By this I mean that we could examine the societal landscape of genomics in terms of various attempts to define, map and exploit genomic complexity; we could trace different and competing versions of complexity that engender their own forms of promise: future health and wellbeing, autonomy and security, solidarity and social justice; public trust and participation.

Complexity is, admittedly, an opaque term that can mean different things to different people. In the context of genomics, 'complexity' is the *probabilistic uncertainty* arising from multigenic and multifactorial models of disease risk. The uncertainty arising from genomic explanations is not simply a matter of identifying all the known or hidden factors that contribute to disease, but also recognising the non-linear and stochastic nature of gene-gene and gene-environment interactions. The uncomfortable (re)discovery of complexity is indeed related to the promise of broadening the scope of genomic research to investigate the underlying biology of 'common complex' diseases. The dialectic of promise and complexity proposed here is one that examines the ethical and social challenges arising from the enlargement of promise, especially when complexity is denied in the marketisation of risk prediction or when complexity increases demands for the collection of human DNA material.

This article examines the last decade of genomics in the context of the 'urban zone' – the application of genomics in the domain of contemporary healthcare, education and

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research. It is well beyond the scope of this article to offer a complete map of the urban zone. Instead, I will examine the interplay of promise and complexity in two main areas: i) *population-based biobanks* as data repositories for researching genomic complexity; and ii) *genetic susceptibility testing* as efforts to translate complexity into risk prediction.

The rise of population-based biobanking

The collection of genetic data on populations and families for medical research has existed for more than 30 years. These 'genetic databases' were at first relatively uncontroversial and small-scale. Since the Human Genome Project (HGP), however, the rise of *population-based biobanking* has become a controversial enterprise. The understanding that many common diseases such as cancer, heart disease and dementia are 'complex' means that research requires an ever-increasing volume of 'granular' (i.e. detailed) information. Genome-wide association studies (GWAS), for example, require much greater statistical power to identify both common and rare variants. This involves recruiting much larger samples of DNA – the bigger the better. In this sense, biobanks supply the essential capital to meet the increasing scale of population-based research.

The new generation of biobanks operates on a prospective basis, involving large-scale collections of DNA and personal medical information being held for long periods of time and for unspecified purposes. Despite the uncertainties of retaining this kind of sensitive information, they hold considerable promise for explaining the complex aetiology of common diseases, for improving future health for all, and for providing substantial economic benefits for their investors. Not surprisingly, in the last 10 years there has been considerable debate about the challenges that biobanks face in gaining consent, legitimacy and trust.[8]

It is not uncommon that when a practice becomes 'controversial' its meaning also becomes unstable. But controversies are also productive in that they provide an opportunity to respecify and stabilise ambiguous meanings. For instance, there have been disagreements in the literature about the definition of biobanks (e.g. whether it should be replaced by the term 'genetic database'); they have been connected to a whole range of activities (e.g. research in common complex diseases, pharmacogenetics, rare genetics diseases, oncology and stem cells, etc.); they are embedded in numerous institutions (hospitals, universities, pharmaceutical companies and charities); and their global development has been treated with suspicion (initiatives have appeared in the UK, EU, Quebec, USA, China, Singapore, Taiwan, Japan and Australia). The ambivalent relationship between public and private investment has also cast doubt on the legitimacy of biobanks: *potentially* they are a public good but they require commercial investment to actualise this good. To add further grounds for scepticism, recent historical events in the UK have eroded public trust in science (e.g. mad-cow disease, the GM debate, leaked climate change emails) triggering a 'crisis in trust'.[9]

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In the current climate of public scepticism towards science and governance, the developers and managers of biobanks face many challenges in establishing frameworks that can guarantee data security and win public trust. Such problems have thrown into relief the methods of consulting publics and communities and the various programmes designed to foster ‘active citizenship’ and ‘participation’ to remedy this situation. Some commentators have argued that public engagement projects may actually limit debate and be perceived by publics as mechanisms for manufacturing consent.[10] In the UK, there are particular concerns that public engagement has been treated as a kind of ‘risk management strategy’ rather than genuinely involving publics in issues of management.[11] Furthermore, the ethical and political aspects of biobanking have exposed the instability of the category ‘the public’, illustrating the degree to which the lingering belief in ‘knowledge deficits’ constitute ‘the public’ as ignorant, irrational, selfish and ambivalent.[12]

An issue that has attracted a great deal of attention in the literature is the process of securing informed consent from individuals who donate tissue samples and personal information. The events surrounding the Icelandic Health Sector Database in the late 1990s illustrated the problems arising from *presumed* consent: that the burden of responsibility was placed on individuals to opt out before a certain period to prevent their medical records from being included in the Database. In many ways, the controversy demonstrated how not to develop a biobank.[13] Over the last 10 years of biobank development there has been increasing involvement of bioethicists whose expertise in policy-relevant knowledge has provided additional layers of oversight. But rather than strengthening governance, there have been growing concerns that ethical frameworks produce bureaucratic overload, duplication of paperwork, and performative accountability.[14] Furthermore, traditional concepts of bioethics such as informed consent seem to impede research activity because the prospective nature of biobanking requires provision for multiple researchers over long periods of time; seeking re-consent can be time-consuming and expensive, while the possibility of refusals or non-responses can undermine the integrity of research. Some have even claimed that continual requests for consent might actually foster negative attitudes towards biomedical research.[15] Williams argues that in the UK experience of large-scale biobanking, the focus on informed consent is a distraction from political questions about the organisation of medical research or the accumulation of state power.[16] In the UK, ethical frameworks have opted for ‘open consent’ which affords greater flexibility between research and individual autonomy. However, Tutton et al. have warned that open consent restricts the rights of participants (and their relatives) to withdraw from future research.[17]

The debate on whether the concept of informed consent captures the relevant tensions between the micro and the macro is exacerbated by the enormous scale of genomic research. Knopper and Chadwick have argued that “the increase in population-based genetic research has led to calls for rethinking the paramount position of the individual in ethics”.[18] The complexity of the human genome warrants a new conceptualisation of ethics based on principles of reciprocity, mutuality, solidarity, citizenry and universality. According to this view, people have a duty to participate in

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biobanks as resources that will benefit future generations of society. The universality implied in such notions of public and future good outweighs autonomy as the ultimate arbiter. However, debates about whether new approaches to ethical reasoning are needed are further problematised by the pivotal role that biobanks play in the bioknowledge economy and the globalisation of bioinformation.[19] Biobanks can be seen as collection points for the harvesting of raw material in the production of biovalue.[20] The biological characteristics or 'potentials' of populations are treated as raw materials for economic exploitation. The precise nature of these raw materials is that they themselves are unstable or 'metastable' boundary objects – in different domains and to different actors they can be 'things', 'people' or segments of 'information'. Whether human tissue is the property of the donor (and of potential commercial value) or the property of those whose labour is invested (thereby creating commercial value) has been debated in case law and legal theory.[21] The key tension is that if commercial parties stand to profit from human tissue, should individuals from whom the tissue is taken be granted property rights to share in these profits? The argument that commercial investment in research on common disease is the necessary trade-off for significant future benefits is indicative of the way in which universal principles of the public good tend to surpass individual rights.

Biobanks have not only attracted ethical and political controversy, but they are also linked in complex ways to the politics of (collective) identity and race. Since the HGP, some commentators have expressed concerns about the biological reinscription of race.[22] Rose argues that "race now signifies an unstable space of ambivalence" between molecular biology and socio-political identification.[23] Despite the overwhelming genetic similarity shared across the spectrum of human difference, since the HGP it is the minor variations (e.g. single-nucleotide polymorphism - SNPs and haplolytes) that have been significantly correlated with disease susceptibility in different populations. Even notions of population have been constructed in terms of whether their purported genetic homogeneity or heterogeneity are sources of 'exchange value'.[24] The portrayal of Iceland as genetically isolated and homogenous formed part of the promissory value of the Health Sector Database.[25] However, a different identity politics has been played out in the USA and the UK, where issues of ethnic diversity are more prominent. In these countries, tensions between scientific methodology and social inclusion have emerged in relation to research on common complex diseases. Smart et al. cite evidence that a minority of researchers who worked in UK biobanks justified excluding ethnic and racial minority groups on methodological grounds (i.e. where race and ethnicity are potentially 'confounding factors' in homogenous populations).[26] In the US, similar concerns have led to initiatives to establish biobanks around the needs of specific racial/ethnic groups (e.g. African-Americans and Orthodox Jews). With the potential to identify different disease susceptibilities among different populations, the issue is not whether genomic research will reactivate further stigma and intolerance but how new rationalities and technologies of power over life will govern human differences.[27]

Genetic susceptibility testing

If prospective, large-scale collections of genetic and non-genetic information are one response to genomic complexity, then another is the translation of these raw materials into clinically relevant risk information. The HGP demonstrated both the means and the possibility of identifying many thousands of genes of small to moderate effect. It confirmed scientists' suspicions that many common diseases are in fact multifactorial, comprising gene-gene interactions as well as gene-environment interactions. This is very different from the kind of genetic risk commonly associated with presymptomatic predictive testing for Mendelian conditions such as Huntington's disease, cystic fibrosis and Fragile X syndrome. In the absence of a single dominant gene, genetic risk is essentially *probabilistic* and thus calculated on a delicate balance of uncertainties. And yet, in the last 10 years, there has been a massive increase in the marketisation of genetic susceptibility testing, the central promise of which is to predict and prevent disease. These developments are highly controversial for two reasons: the uncertainty of probabilistic risk information seriously undermines the *validity* of such tests, and the predictive or diagnostic inferences of such information may have an adverse *psychosocial* impact on individuals and families. The task is to consider the ethical and social differences between strongly and weakly predictive testing.

The social, ethical, legal and psychosocial aspects of genetic testing have been debated since the 1970s. A dominant style of professional ethical reasoning is the conceptualisation of ethical principles and disease exemplars. During the 1980s and 1990s, for example, the extreme scenario of Huntington's disease (HD) provided an ideal exemplar for the development of ethical policy. Boddington and Hogben have argued that using HD as an exemplar stresses "a difference in *degree* of seriousness" which "translates into a substantive difference of *kind* in justifying ethical argument".[28] They query whether the selection of other candidate conditions may have led to different policy conclusions. We could say that ethical policy for genetic testing has been influenced by the *mode of inheritance*; that is to say, HD was cast as an extreme case that exemplified the 'geneticisation' of ethical reasoning and the privileging of genetic factors over other aspects of a disease condition. Case exemplars have also made an impact on ethical discussions in the social sciences. Novas and Rose use the example of HD to argue persuasively that rather than inducing fatalism and resignation, predictive testing is linked to the *creation* of new forms of subjectivity and 'genetic responsibility'.[29] Rather than viewing genetic knowledge as objectifying and repressive, they argue that practices of 'genetic subjectification' (i.e. the creation of subjects through knowledge/power relations) are in fact aligned with the norms of advanced liberalism, which explains why principles such as autonomy are frequently used in ethical discussions. They propose that genetic knowledge is operating in a political field where subjects are constructed as autonomous, prudent, responsible and self-actualising.

So what kind of exemplar might we use in the case of genetic susceptibility testing? One candidate for discussion is Alzheimer's disease (AD). For the last 20 years, there

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has been consensus among researchers that rare autosomal dominant genes are strongly associated with the 'early onset' form of dementia. However, in 1993 the apolipoprotein E (ApoE) ε4 allele on chromosome 19 was found to be associated with an increased risk for the common 'late onset' form of AD.[30] The presence of ε4 increases risk of AD up to 15-fold compared to other ApoE polymorphisms. The aetiology of AD shows that susceptibility testing is different from predictive testing in that risk information is relevant to a much larger population but is much less certain than predictive testing.[31] Given that there are no treatment options for AD, professionals have cautioned against the routinisation of susceptibility testing in presymptomatic individuals unless to confirm an AD diagnosis.[32] The ethical differences between susceptibility and predictive testing may appear to be differences of *degree* rather than *kind* if we apply principles as our bench mark. However, as Evans has noted, principlism is "a method that takes the complexity of actually lived moral life and translates this information into four scales by discarding information that resists translation".[33] A more informative ethical analysis should consider two things: (i) empirical research that explores the actual accounts of people who are in some way connected with or concerned about AD; and (ii) an assessment of how ordinary people (not just professionals) perceive, describe and recall genetic risk information.

The REVEAL study (Risk Evaluation and Education for Alzheimer's disease) was the first randomised controlled trial designed to evaluate the impact of susceptibility testing using ApoE ε4. The study was conducted at four sites in the USA between 2004 and 2006. At one site, 162 asymptomatic adults who had an affected parent were randomly assigned either to receive or not receive susceptibility testing. Both groups were measured for symptoms of anxiety, depression and test-related distress six weeks, six months and one year after (non) disclosure.[34] The results showed no significant differences between the two groups, although those who received a negative result showed significantly lower levels of test-related distress than did the positive group.[35] A separate study compared the results of the REVEAL subjects with those who received monogenetic testing;[36] subjects who learned that they were positive for the susceptibility gene experienced low levels of distress similar to those who tested positive for the monogenetic test. They also found that "both susceptibility and deterministic genetic testing appeared to be well-tolerated by using disclosure protocols that provided screening, education, counselling and follow-up".[37] In the ethnographic arm of the study, Locke et al. raised questions about the relevance and comprehension of testing:

> Among the majority of people whom we interviewed in this project, the late onset of the disease and the pressures of daily life, often involving care giving, combined with the inherent uncertainty of the scientific knowledge, encourage most people to set aside worries about what the future has in store for them.[38]

We can draw a number of inferences from this preliminary data. It is widely recognised that epidemiological information has a small impact on risk perception because probabilistic information is not meaningful to people. People often simplify

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or condense complex information in order to retain the essence of its meaning.[39] The characteristics that impress themselves upon risk perception are those which are linked to dread or which are already familiar to people.[40] In the case of predictive testing for Mendelian disorders, the low uncertainty of information coupled with the genetically exceptional nature of the test produces high impact of risk perception and low recall error. For susceptibility testing for complex disorders, the high uncertainty of information coupled with information about lifestyle are likely to dampen the impact of risk perception, resulting in high recall error. There is no empirical evidence at this stage to suggest that susceptibility testing is psychosocially harmful, but the REVEAL study does confirm that receiving a positive result for either the rare or the common gene is 'well tolerated' when disclosure is mediated by genetic counselling.

As tests for multifactorial diseases become increasingly available to the public, it will become important to develop strategies for presenting risk information that can communicate increased levels of uncertainty. The emergence of the personal genomics industry and the marketisation of direct-to-consumer (DTC) genetic testing raise serious concerns that vendors do not acknowledge or communicate the uncertainty of probabilistic risk information. These concerns are especially relevant when DTC marketing blurs the distinction between 'medical diagnosis' and 'health information', between 'health prediction' and 'risk estimation'. For instance, McGuire et al. reported that approximately one-third of all respondents in a survey of social networking users considered the information obtained from personal genomics testing to be a medical diagnosis.[41] Other studies have shown how techniques of argumentation, distraction and persuasion are employed in the promotion of prescription drugs.[42] The major concern is that DTC advertising is more profitable when misleading the public about the effectiveness or safety of health-related products and services. By extension, selling genomic knowledge directly to consumers creates expectations about diagnosis, treatment and prevention which are, as yet, scientifically undeliverable.[43]

In the DTC model of susceptibility testing, the relationship between promise and complexity is configured in such a way that the uncertainty of probabilistic risk information does not seem to impair promises of 'prevention' and 'self-knowledge'; this is because the version of complexity they recruit in their marketing strategies is one that strips out the problem of non-linear or stochastic interactions between genes and environment. The uncertainty of risk information is merely 'complicated' (partial and incomplete) and assumes that risk profiles will become more accurate as more information is added over time. This, rather impoverished, version of complexity does not account for epistasis, pleiotropy and polygenicity.

Conclusion

At the beginning of this article, I argued that a dialectic of promise and complexity is perhaps a more suitable way of framing recent advances in genomic medicine. Placing the events of the last decade within the discursive poles of promise and complexity seeks to draw attention away from an overly pessimistic orientation based

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on profound disappointment. The completion of the Human Genome Project signalled both the widening of a new research agenda and the enlargement of promise as scientific inquiry oriented its attention to investigating the underlying biology of common complex diseases. In contrast to the unqualified promises made by politicians in 2000, a more circumspect account of progress is found among the accounts of the scientists themselves, wherein gene function and gene expression are described in terms of their sobering 'complexity'. The two case studies I have considered show that the problems of overcoming complexity of common diseases on the one hand, and sustaining promise on the other, require a systematic attempt to augment the supply of human DNA samples to increase statistical significance of large-scale research studies. It also shows the rather limited and controversial attempts to commercially extract promissory value from genomic data.

Whether we see the turn to complexity in the life sciences as a matter of discovery or of construction, the main issue is that scientists' uncertainty about the human genome demands an unprecedented volume of information pertaining to a whole population. This is not just information *about* a population but information *for* a population – public goods that may improve health and prevent disease for future generations. In the last 10 years, we have seen the apparent difficulties of traditional bioethics in meeting these challenges of scale. The rapid global sharing of information is placing increasing pressure on scientists, administrators and ethicists to abandon principles based on individual autonomy (i.e. informed consent) and to adopt more flexible and universal principles based on notions of solidarity, reciprocity and collective responsibility. These issues have been sharply foregrounded in recent debates about the international 'harmonisation' of biobanks. On the one hand, there are pragmatic arguments that relaxing ethical governance to facilitate global flows of bioinformation and international collaboration will assist genomic research.[44] On the other hand, there is a deep mistrust that we are witnessing the remobilisation of technoscientific power and that bioethics is incapable of matching this power.[45]

Perhaps the most significant advance in the last 10 years has been the explosion of genome-wide association studies (GWAS) and the ubiquity of the 'SNP'[46] as the statistical unit of common genetic variation. GWAS have yielded highly robust information, identifying susceptibility alleles for common disorders such as diabetes, heart disease, Crohn's disease and several common cancers. However, the majority of risk factors discovered by this method make up only a moderate contribution to overall risk.[47] Many markers have yet to be discovered, which points to what some have described as the 'missing heritability' of common complex diseases.[48] Such knowledge gaps render the clinical application of genetic susceptibility testing suspect and limited. In the urban zone of personal genomics, there are concerns that the complexity of common diseases, or this missing heritability, will not be properly communicated to the consumer, especially when concealing uncertainty is more profitable. Ethical analysis must distinguish the difference between weakly and strongly predictive testing which, it has been argued, cannot be accomplished by ethical principles alone. If the promise of predicting common complex diseases is the future of genomic medicine, then understanding how people perceive, feel, remember, describe and communicate complex risk information should be on the agenda of future ELSI research.

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Global justice and genomics: Toward global agro-genomics agency

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Abstract

Searching for the specific contribution of the life sciences to global justice in agriculture and food, one is faced with six global problems that haunt the world today. These are: population growth (9.2 billion by 2050); the gap between poor and rich peoples; hunger and obesity; increasing environmental pressures; climate change; and instable power relations and systems. Most of them seem to have a strong connection with the dominant system in agriculture which is high input and capital- and resource-intensive with high energetic output (food), at the cost of other factors important for sustainable development, like food quality, fresh water and liveable temperatures. However, beside this dominant system there is a plurality of other, often local, agricultural systems that don't have these disadvantages or have them in a lesser degree, and they are in particular located in the South. The current prominent perspectives on global justice, like the consequence-oriented one of Peter Singer and the rights- and institutions-oriented one of Thomas Pogge, neglect the importance of plural and local agricultural and food practices for sustainable and fair global development. Partly complementary to these perspectives, Amartya Sen has developed a capabilities approach that emphasises human capacities and the role of democracy. In complementing his approach we develop an agency- and practice-oriented perspective that stresses the importance of networking the agricultural practices that strive to enhance the quantity and quality of food systems. The tasks of the life sciences for agriculture and food would then be to develop technologies that take into account the plural practices of the poor in the production, processing and consumption of food. This whole chain oriented approach requires from life scientists more than just doing research in laboratories; their task is also to connect their laboratory work with farmers' practices and experiments.

Introduction

According to the current UN Special Rapporteur on the Right to Food, Olivier de Schutter, "(o)nly 6 per cent of privately funded agricultural research is focused on developing country agriculture" (p.13, note 18).[2] Add to this the decline in publicly funded research in agriculture, and together these imply that plant life sciences are not considering sufficiently the needs of poor farmers and the hungry and underfed in general. This fact is against Article 25.1 of the Universal Declaration of Human Rights (UDHR): "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control."[3] It is also against Article 27.1: "Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits." The failure of the life

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sciences to meet the requirements of global justice as defined by the UN makes it more urgent to ask: What does global justice require? How far do and should (plant) life sciences contribute to global justice? What directions, what priorities should the life sciences select in performing this task?

In this article, I will try to give some ideas that might help to answer these two questions. First, I will show that anyone who wants to improve global justice will be confronted with at least six big problems that are complex and intertwined. I will show that most of these problems are connected with agriculture and food (production and consumption), and I will therefore outline the current situation of agriculture which is dominated by the 'productionist' system, although alternative agricultural systems can still be identified. The choice between the different systems confronts us with an ethical dilemma. To better conceptualise this dilemma I will give an overview of the different ethical perspectives on global justice, and show that an agent- and practice-oriented perspective has good chances to improve global justice. In the second part of the paper, I will concentrate on the opportunities for and barriers to life sciences research and development in tackling these problems and the dilemma.

Global problems: population growth, poverty, hunger, environmental pressure, climate change, power

Anyone who is concerned about the state of global justice (as defined by the UDHR) and the possible contributions of the life sciences to reduce global injustice is confronted with several continuing and persistent problems.

The first is ever-increasing population growth; it is estimated that by 2050 the world population will have grown from 6.8 billion at present to 9.2 billion.[4] Taking into account the other problems (below), this number makes increasing crop yields a necessity.

Second, the gap between poor and rich peoples is all-pervasive and will become more dramatic than ever. In general, with respect to the use of resources, one can speak of the 10/90 gap: "Only 10 per cent of global health research is devoted to conditions that account for 90 per cent of the global disease burden."[5] The report by De Schutter mentioned earlier also illustrates the '10/90 gap' in agriculture, food and health research, showing that the "needs of poor farmers in developing countries have been comparatively neglected". Given that most poor people are farmers (more than two billion), the decline of agricultural research for the developing world is particularly alarming.

Third, as a consequence, food insecurity is increasing, causing hunger, due both to lack of calories and proteins and to lack of essential micronutrient ingredients. Micronutrient malnutrition is a severe problem because more than half of the world's hungry people are hungry not due to lack of calories and proteins but due to lack of essential minerals and vitamins, resulting in severe disease and poor body function.

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Moreover obesity, also a problem of malnourishment, is increasing in the same areas where hunger lurks.

Fourth, the relationship between humans and their global, regional and local environment is under severe stress. The current system of production and consumption of food has increasingly severe environmental impacts. The production of biofuels, originally a reaction to the depletion and impact of mineral resources is, according to many, a threat to nature, the environment and food production. Extraction of natural resources and appropriation of ecosystem services have in some cases already come to their limits.

Fifth, the latest addition to the environmental constraints concerns the impact of changing climate on agriculture. In a recent study by Federoff et al the impacts are surveyed:

> Widespread adoption of more effective and sustainable agronomic practices can help buffer crops against warmer and drier environments, but it will be increasingly difficult to maintain, much less increase, yields of our current major crops as temperatures rise and drylands expand. Climate change will further affect agriculture as the sea level rises, submerging low-lying cropland, and as glaciers melt, causing river systems to experience shorter and more intense seasonal flows, as well as more flooding.[6]

Sixth, unequal economic, social and political power relations on micro-, meso- and macro- levels produce a lot of tensions and enmities. Successful developmental aid bypassing existing power relations is sometimes possible, but mostly not advisable. For instance, developmental aid bypassing national governments in least developed countries often gives rulers the wherewithal to enrich their followers while remaining unaccountable. Much well-intentioned development aid has had adverse effects by reinforcing existing oppressive power relations[7] or by delivering aid that has adverse effects upon peoples' ability to strengthen their capacities to improve their lives.[8] Developing new national and international institutional structures is therefore a challenge. The current agricultural and food regime is often part of these problems. It is questionable how far the current agri-food system can tackle them.

Current agricultural systems: a very short summary of the global state of the art

The dominant 'productionist' system in agriculture consists of high inputs and high outputs on the basis of agro-life sciences. These life sciences focus on increasing yields by concentrating on plants and their predators, by adding pesticides and fertilisers, and by breeding crop varieties that can grow faster under the influence of chemical inputs. The system needs phosphorus, which is becoming scarce, and the price is soaring as a result. The UK newspaper *The Times* reports: "In the past 14 months, the price of the raw material - phosphate rock - has surged by more than 700 per cent to more than $367 (£185) per tonne."[9]

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The productive reciprocity between chemicals and plant varieties is sought for in elaborate laboratory techniques. Soil characteristics are generally not taken into account by this paradigm of science, and nor are post-harvest events like storage and food processing. This system has been in use since the 1950s, and has had considerable success in increasing yields all over the world, but in particular in the USA and The Netherlands. In their history on rice improvements, Anderson et al confirm that the 'food problem' from the start was reduced to 'yield' and that "low yield was defined as an isolable problem amenable to a scientific solution which could be implemented without prior social and political changes".[10] Intensification by adding chemicals has considerable side effects, like pollution of surface water, deterioration of soil fertility, decrease of (agro-) biodiversity and the establishing of monocultures. The social system intrinsically connected with this intensive system consists of large-scale organisations that push knowledge from the laboratories to the farmers through extension schemes, seed supply organisations and governmental and privately led financing systems for farmers in need of money for the required large-scale investments. Hierarchical, centralised organisations are connected with this large-scale, monocultural system that marginalises the practices of many poor farmers in developing countries and pushes them to slums and unemployment. Although this system can boast considerable advantages (the yields are indeed respectable), is looks as if the price paid is also considerable.

The problems mentioned earlier confront policymakers, scientists and all concerned with the ethical dilemma either to intensify even more strongly the current productionist system or to consider a more plural approach in which several agricultural systems can live next to each other and are encouraged to realise the requirements of the Universal Declaration. Some, indeed, argue for more of the same, ie for including a few more crops than those already in production and for higher intensification inputs (more pesticides, fertilisers and monocultures) to get higher yields; but this strategy runs into the same difficulties. The rich-poor divide, the increasing number of people living in slums (more than 50 per cent of the world's population) and that are hungry and obese, the persistence of malnutrition despite huge aid programmes, and the fact that phosphor will be depleted in 25 years, makes it quite unreasonable to keep to the same path everywhere. However, several alternatives to this 'productionist paradigm' do exist and are currently being explored, whether organic, agri-ecological, low-input high-output or slum (peri-urban) agriculture and Integrated Pest Management (IPM).[11] It should be said that the alternative science and technology trajectories that support these different systems are not very well funded and are underdeveloped.

What to do with this ethical dilemma of various agricultural (life sciences) paradigms from the standpoint of global justice and the UDHR?

Three different ethical perspectives on global justice

Different ethical perspectives on global justice, such as utilitarianism and the rights-based approach, are currently struggling with these severe problems. For instance,

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using the utilitarian framework to calculate benefits and losses of the current system of international relations, Peter Singer pleads for uniform standards and rules that can create equality between human beings and between and inside states.[12] According to his strong cosmopolitan position, there should be international institutions and agencies that can restrain the egotism of national states in defending their interests against poorer states. With respect to common goods, he advocates an egalitarian position that can curb national interests. Many of the problems are global problems and therefore require global solutions (p.199). With respect to agriculture and food, this position seems not to cherish diversity and pluralism of food systems. His position doesn't consider the positive role of diversity at all, and the reciprocal relationship between biodiversity, agricultural diversity, and human biodiversity and local sovereignty of food is not discussed. The dilemma cannot be conceptualised at all in this approach.

Thomas Pogge does pay more attention to the complexities one is confronted with in trying to reduce the growing gap between poor and rich peoples and indeed proposes several measures that could reduce this gap in the field of medicine and medical research.[13] Starting with the obligation of rich peoples to assist poorer peoples to improve their situation, he emphasises the need for institutional reform of current trade and political relationships. Current international relationships very often stimulate and support the oppressive intra-state relationships which keep people poor. Dictators and corrupt leaders are able to flourish in the current international system, which tends to favour the interests of the rich nations and their citizens. Pogge proposes an institutional reform for the international system and appeals to the rich citizens to cease their support for this system and to start its reform and, finally, to give the rights of access of the poor to cheap medicine full attention. His approach is in accordance with that of others, like Onora O'Neill, who states: "Huge numbers of distant strangers may be benefitted or harmed, even sustained or destroyed, by our action, and especially by our institutionally embodied action, or inaction – as we may be by theirs."[14] However important the role of institutions and that of access to cheap products may be, this should not leave the issue of the quality of life and of the farming practices of poor farmers in the dark. In particular, low prices for food products have the adverse effects that the poor (the over whelming majority of farmers are poor) do not get the entitlements they need for a better livelihood. Low prices for food bring farmers to the brink of collapse. Improving access to food (the kind of strategy Pogge recommends with respect to medicine) is different from, and can even have adverse effects on, improving or enlarging entitlements or farming.

The institutional approach neglects the question of how to secure and improve the agency and practices of poor farmers and does not consider their practices as resources for improving their situation. The poor farmers are at the receiving end of decisions taken by companies and agencies headquartered in first-world countries.[15] In this approach the dilemma between large scale intensification of agricultural production versus local and global ('glocal') sustainable practices of farmers cannot be conceptualised.

A third ethical perspective is that of Amartya Sen,[16] who initiated the so-called 'capabilities approach' in attacking the poor-rich divide. He argues that emphasising the rights of the poor is not enough to begin to offer them a comparatively better life, and that the flourishing of individuals in social contexts of respect should be the starting point of global justice practices. Communities don't consist of an aggregation of private interests, and the international and global system should not be reformed top-down without considering the multiple different interests and value orientations of different peoples. Sharing common materials, common values, and common experiences is possible by participation in a society that allows for more variety and diversity than would be possible if individuals were to strive to fulfil their desires and needs on their own. Together with Martha Nussbaum, he is in favour of a kind of moral cosmopolitanism,[17] but not in favour of the priority of global political institutions (political cosmopolitanism) vis-à-vis national states. They both argue for giving civil society organisations (citizens) a stronger position vis-à-vis governments and markets.

Sen argues that food and nature are not only commodities, or output products, but intrinsically connected with social structures of entitlements and conditions of living.[18] Commons and other public goods enhance the communal life, and the personal life of the individuals. The essence of these commons is their support by individuals and their distribution to individuals, although the manner of their distribution is often ethically questionable. These public resources must be seen as opportunities for developing and realising capabilities. Moreover, as Nussbaum argues, "(nutritional) needs vary with age, occupation, and gender. Pregnant women need more protein than a non pregnant woman. Women's literacy in many parts of the world will require more resources than men's."[19] Vulnerabilities like disease, poverty, hunger, war, or power relationships are not equally divided. The issue is in how far the poor (in all these aspects) have special rights to be redressed for the unequal distribution of resources and how these resources can be used as opportunities to develop the capabilities of the poor.

Confronted with the at least six substantive, complex and intertwined problems and the dilemma of agricultural production, these global justice perspectives mostly reduce them and come with single solutions, except the position of Sen. One of the failures of most global justice approaches, like those of Singer and Pogge, is their lack of attention to the complexities of agriculture, which must be seen not as an instrument but as a multifunctional common, even a public good, or in the words of Sen, as an "opportunity of living"[20] that in particular in the poorer areas of the world secures food, health, jobs, income, sustainability and self respect in an ethically acceptable way.

Only the approach of Sen pays attention to agriculture and food, but even he doesn't discuss what improvement of the various functions of agriculture in the developing world might mean, although such an improvement is a requirement to reduce

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inequalities, improve 'capabilities' and enhance the implementation of justice. Improvement doesn't always imply intensification of agriculture, but at least stabilising and making robust current agricultural practices, so that they can cope with climate and price crises, are sustainable and can guarantee the security and quality of food.[21] Technological innovations, like GM or biofuel crops, are with respect to these requirements not always promising, to say the least.

One should expect from global justice approaches that they can help in answering questions such as: in how far have agricultural practices incorporated impulses towards innovations improving the quality and quantity of food? What type of innovation impulses and regimes can be encouraged? How can agriculture contribute to lower environmental costs, less contribution to climate change, minimising the use of pesticides, stimulating intercropping and rotation of crops in the battle against pest resistance? How can the incredible diversity of agricultural practices not be seen as a barrier that is to be removed and replaced by one system (applied 'successfully' in large areas of Idaho): the intensive agricultural system? How can we make an asset of this diversity?

More particular questions with respect to conventional and alternative current systems would be, for instance: What types of organic or non-organic fertiliser, and IPM do such systems use and can they use, and how can they learn from each other? Where and how should we use biological control agents (enemies of our enemies), like pheromones traps? And last but not least, how can we enhance the capacities of communities and their members by stimulating the development of their knowledge, experience and political skills?

Because of the lack of attention paid to agriculture and farming, not one of these ethical approaches gives immediately useful advice in answering these questions, which means that all of them have to be accommodated, combined and complemented with another approach.

Alternative: networking agricultural practices

Sen's approach has one important consideration for the field of agriculture and food: "Political participation and dissent are *constitutive* parts of development itself."[22] The establishment of democratic process on all levels, from local to global, can improve cooperation by taking into account socio-cultural differences between systems of food production and consumption. By considering the agency of citizens in (agricultural and food) practices, and taking into account the deep-seated differences in power and food preferences, we will give an analysis of Sen's words. At the core of the deliberative democratic approach developed here are the concepts of *learning process* [23] with respect to *cooperation* between different value systems and stakeholders,[24] the formation of several *overlapping publics*,[25] the *pluralism of life-*, *farming and food styles* from local to international levels, the interrelationship between debates and decision making process and the necessity of the *reflective* input of experts.[26]

The barriers that prevent global and local coexistence of different agricultural systems bridging the gap between poor and rich can be tackled by taking into account deliberative democratic procedures of deliberations (expressing justice and equality) and substantial concepts (expressing vocabularies of good life).[27]

One aspect of the deliberative democratic approach is the concept of 'ethical room for manoeuvre for farming' (ERM), introduced in 2008[28] and currently being researched in the Department of Applied Philosophy of Wageningen University. The concept urges us not to start with external principles of global justice but with the potential of practices towards a particular end-in-view. Practices of farming, for instance, have to cooperate and exchange ideas and skills; the concept of ERM can be made do-able in multi-level global governance of different agricultural systems by being infused with the concepts of deliberative leadership[29] and of 'in-between level' or 'bridge' organisations. Leadership is necessary in bridging the differences between several practices, whether horizontally or vertically. I call the required type of leadership 'deliberative leadership' while the deliberative qualities of the intra-practice interaction have to be retained in the inter-practice interaction. The same holds for the concept of 'bridge organisation', which acts as a kind of broker between the practices of one level to that of a 'higher' social level. Many NGOs and farmers' organisations act as a kind of bridge between local farmers and translocal policy and company levels, and negotiate between different groups. They contribute to networking the different practices across the various social levels.

An important aspect of this approach is the emphasis on practices and the agency of constituent members. People, here farmers, are seen as agents who try to live up to the standards of excellence inherent in the practices, and who contribute to improving those standards in response to new challenges. Practices are collectives that combine social, material and cultural aspects, like managements styles, materials to be handled, like soils, plants and animals, and values (standards) to be sought after. The different factors that are covered by the managerial capacities of farmers are soil, water, vegetation and animal management.[30] Practices are shaped as answers that address the challenges emerging from, for instance, the following dimensions: local versus global; one use versus another of a resource; minimal biodiversity versus long term biodiversity; poor versus wealthy and powerful; flourishing versus lack of freedom; and intensive technologies and extensive use of technologies. The competencies, capacities and strivings of farmers can be stimulated and improved by scientific research that is closely connected with those competencies, capacities and strivings.[31]

Potential of life sciences in tackling problems of global justice

In view of the six big issues global justice is confronted with, it is clear that current life sciences have to focus on realigning themselves to try to achieve a more just world.[32] One of the first things to do as a step toward greater global justice is to put into practice a strategy for agenda-setting for these problems. The overall task of agri-science in agenda setting, be it upstream priority setting, or midstream and downstream innovation trajectories, is to consider more pluralism, to be poor-focused and whole chain-oriented. It would mean that the life sciences put themselves in the service of different agricultural systems, not only of the dominant system. I will concentrate here on agriculture and the potential contributions of the life sciences, mostly plant and soil life sciences. Plant life sciences currently cover technologies such as genetic analysis (sequencing, marker technology used in traditional genetically engineered forms of breeding, genetic engineering) and phenotype analysis (involving physiological, biochemical, or morphological features). All these technologies can be applied to reduce biotic and abiotic stress and to enhance the quantity and quality of harvests. Plant life sciences mostly concentrate on improving the seeds of certain staple crops, and try through either conventional breeding or genetic modification and other biotechnologies (like marker assisted breeding) to increase yields and certain micronutrients in the crop.

However, this pre-harvest-oriented research direction neglects important features of agriculture. First, with respect to growing crops, very often crop management technologies are neglected, like intercropping against pests, root technologies (intercropping of crops with long and short roots, to better use different nutrients from the soil), soil technologies, and push-pull technologies.[33] Indeed, most of these technologies, which can be improved by life sciences research, belong not to the currently dominant intensive high input agricultural system, but to another, low input, adaptive system.

Second, more criticism can be levelled at the neglect of the ensuing problems in the fields of agriculture and food processing, sustainability, and consumer and farmer acceptance. These approaches are very often developed in defining research agendas and research strategies without seriously taking into account the circumstances that lead to food shortages and malnutrition. The innovation trajectories to produce enhanced and biofortified crops are formulated as ‘end of pipe’ solutions.[34] Golden Rice is a typical example, in which post-harvest problems are set aside as ‘practical concerns’ that can be handled afterwards, as uncritically stated by the Task Force of the ILSI International Food Biotechnology Committee:

> Though not directly related to safety, there are matters of practical concern that should be addressed as part of a comprehensive release strategy. While theoretically capable of supplying nutritionally relevant levels of carotene after processing, storage, and cooking needs to be determined before efficacy is demonstrated. Moreover, some have questioned if yellow rice will prove acceptable to people who traditionally eat white polished rice.[35]

When local circumstances are not seriously taken into account and when thought is not given beforehand as to how far research instruments are suitable for enhancing crops in their local contexts, these approaches very often lead to severe failures. These strategies make people dependent on buying enhanced seeds yearly, which they probably cannot do their whole lives, and moreover, very poor people can not afford to buy these things at all. The programmes do not start with the indigenous knowledge and practices of farmers but are formulated from a technology push position. How far the enhanced crops will push out poor farmers, and are only affordable to rich farmers, is not considered, and agronomic and environmental issues like water scarcity and land and soil resources are not taken into account.[36]. Alternative strategies (such as those discussed by Wekundah[37]) could have more impact (see also Altieri[38] and Crocker[39]).

Third, with respect to the post-harvest aspects of agriculture, it is very often doubtful how far the enhanced properties of the crops retain their features in storage (for example, certain fungi that act as pests), cooking, preparing and in digesting (bioavailability and digestibility). To consider the whole spectrum of agricultural activities that maintain the current state of hunger and malnutrition is also to consider the way harvesting is carried out, how crops are stored and processed, and how and which long-term management decisions are made by farmers. According to an FAO report about prevention of post-harvest food losses:

> Post-harvest losses of food grains in the developing world from mishandling, spoilage and pest infestation are put at 25 per cent; this means that one-quarter of what is produced never reaches the consumer for whom it was grown, and the effort and money required to produce it are lost-forever. Fruit, vegetables and root crops are much less hardy and are mostly quickly perishable, and if care is not taken in their harvesting, handling and transport, they will soon decay and become unfit for human consumption. Estimates of production losses in developing countries are hard to get, but some authorities put losses of sweet potatoes, plantain, tomatoes, bananas and citrus fruit sometimes as high as 50 per cent. Reduction in this wastage, particularly if it can economically be avoided, would be of great significance to growers and consumers alike.[40]

It is interesting to see that these quite important (management) technologies are not, on the whole, addressed in reports about the potential improvement of agriculture. Even the quite broad Royal Society overview of crops technologies does not address post-harvest issues.[41] Yet farm management strategies can be improved, for example in the way farmers schedule their time in planting, harvesting, obtaining seed, and in how far they get basic information about food and agricultural trends.

Life sciences can make a difference; for example in examining and improving soil root interactions and in analysing storage possibilities (for instance, against fungi) and preparation of foods.[42] However, one should warn against a top-down approach here. The complexity and variety of soils, climate, management capacities and human cultures always necessitates finding out what the local practices are and what incentives can stimulate farmers to improve the quantity and quality of their crops. For example, the famous search for drought-resistant plants can give rise to the idea that there is only one method to make a plant drought-resistant. This is a mistake, because, as is Pollack has spelled out, a rice variety that can live longer in dry circumstances has difficulty surviving situations of sudden wetness: “After several generations, the crops are indeed more resistant to drought. But there is a downside in that they often turn out to have lower yields when there is plenty of rain."[43] So, no single approach is likely to suffice for all types of dry conditions; even such an apparently straightforward decision about how to make a plant drought-resistant has several 'how's and needs therefore to be made dependent on the local practice. The same holds with respect to life sciences technologies that can be used for better storage and processing.

All these examples demonstrate that plant life sciences need to develop as a technology that does research and innovates for different agricultural systems. The current practice, however, is that only the dominant system is supported, with detrimental results, because that maintains the gap between poor and rich and is not sustainable. Nevertheless, the opposing agricultural and food systems and their social, technological and epistemological differences require new democratic arrangements on all levels for support from the side of the life sciences.[44] The barriers that prevent coexistence of different agricultural systems, whether globally or locally, a coexistence that can bridge the gap between poor and rich, can be tackled by taking into account deliberative democratic procedures.[45]

The current mismatch between the research trajectories of the agricultural life sciences, their assumed high-input, seed-oriented context and the actual agricultural context of food problems in Africa, calls for researchers to redefine their research agendas. The issue is not: shall we develop life sciences to reduce the gap between the rich and the poor; but: which type of life sciences, in connection with other measures, can be developed fruitfully, efficiently and ethically in reducing this gap? The researchers in the developed world should cut across the usual distinction between local and global and pay more attention to the research needs of the poorest peoples and realign the research agenda of multidisciplinary life sciences projects with their needs.

Conclusion

In this paper on the contribution of life sciences to global justice, we first have sought out what global justice requires from the point of view of generally accepted international declarations and from an ethical point of view. Second, we tackled the question of how far life sciences can contribute to global justice and what directions and what priorities of life sciences research should be selected to help perform this noble task.

Taking seriously the problems I have sketched, the tasks of life sciences as an agri-science would be: to reckon with several agricultural and food systems (agri-pluralism); and to develop technologies that take into account the practices of the poor to produce, process and consume food. This whole chain-oriented approach, from production (ie. harvesting) to storage, processing to consumption, requires that life scientists do more than just doing research in laboratories but also connect their work with farmers' experimentations.

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Genomics in Industry: issues of a bio-based economy

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Abstract

What value does genomics hold for industry? Ten years after the White House Press conference where the human genome sequence was first presented, we ask in which ways and to what extent the developments in genomics have been integrated into industry. This enables us to assess whether this integration has been as successful as expected, but also which unexpected developments in genomics advances have triggered additional benefits for industry. Genomics has contributed to the beginning of a global transition to a bio-based economy, but there have been and there still are hurdles to be cleared. The hurdles are not merely of a technological nature, since the objectives are a complex between economic progress, environmental and global climate concerns, and energy security. Therefore, they are at the same time technological, societal and environmental in nature. These categorisations fall short of articulating the many issues that arise, such as economic development (for emerging economies), public opinion formation and scientific and technological progress. We argue that to make this transition happen, industrialists, policy makers and the wider public have to be prepared to be more actively involved in the debate, weighing the pros and cons and taking responsibility in creating the desired sustainable world.

This paper will examine the advances of genomics in the industrial context, the role of these advances in current attempts to find sustainable solutions to a variety of problems, the enthusiasm with which they have been picked up, the implications for industrial innovation and the accompanying discussion about possible consequential social and ethical issues. It will also sketch out the nature of this ongoing establishment of a bio-based economy, the parties that are currently at the negotiation table, and whether the current situation has an impact on the way societal debates emerge.

Introduction

The identification of the structure of the genome provided a glimpse of the complexity and interrelatedness of the components of living matter. Not long after the introduction of the first DNA chips, biotechnology companies started to embrace the technology. They regarded genomics as a new tool for their R&D and increasingly realised that it also provided the basis for a new strategy for research and innovation. Genomics provides a wealth of data that, arguably, creates much more opportunity for applications in innovation than the study of the minute details of a certain metabolic pathway. It also necessitates new interpretation tools.

Genomic innovations yield applications in different types of industry: medical diagnostics and pharmaceuticals; chemical and food fermentation; and seeds and crops. In the medical field, human genome information and the genomics of pathogenic organisms promises to increase options for genetic screening and testing, developing diagnostics with higher sensitivity and tailor-made therapeutics, and for exploring 'nutriceuticals'. Further understanding of the workings of the genome, transcriptome, metabolome and proteome (including epigenetics) could provide us with insights into processes such as ageing, disease development (including cancer) and disease protection mechanisms. In the field of industrial biotechnology, genomics promises further understanding of the microorganisms employed for the production of fine chemicals, such as enzymes for use as catalysts in industrial processes as well as household detergents and pharmaceuticals. It could provide better products but also more robust production systems which are better adapted to cheaper feedstock and therefore enable an extension of the product range to bulk chemicals. In the food industry it promises new leads to finding naturally occurring organisms that could produce valuable health or taste components without having to rely on the genetic modification routes less accepted in Europe and developing countries. Genomics was, of course, embraced at an early stage by the plant breeding community as a support tool in the selection of novel varieties.

While the 'new tools' led to more precise, cheaper or better adapted ways to develop new products, they also led to changes in companies' approaches to innovation. This is especially true for the field of industrial genomics, where the technology is used to increase the range of products which use biomass rather than fossil fuels as resources. When these new technologies are deployed for bulk chemistry they lead to novel partnerships in the production chain. The increased need for biomass also necessitates large scale changes to infrastructure, such as trade, transport, biorefineries, etc.[2] This has societal effects, which have not always been projected positively, as demonstrated in the food-fuel debate. Furthermore, given the complexity of such changes and the processes underlying them, many people do not have a clear picture of the scale and nature of these developments.[3] The need for better communication between scientists, producers and users is becoming increasingly urgent. In this respect, it is not sufficient merely to address 'the public' given the wide variety of stakeholders involved, including industry, scientists from a wide variety of disciplines, policy makers, national and international organisations involved in regulation and legislation, smaller and larger companies, domestic farmers and farmers abroad, local communities, etc.

To be able to discuss the societal issues involved in the introduction of genomics to industry it is important to distinguish between the different processes and uses of genomics, in view of the fact that they involve different stakeholders and give rise to different issues.[4] Each industrial field shows its own characteristics in integrating genomics platforms. These characteristics determine the feasibility of the applications of the genomic data, their economic viability in the business environment and the societal acceptance of the evolving products. As we have seen in earlier debates on the implementation of new technologies, issues of concern to the public are more closely linked to the field of application than to the industrial use of the technique.[5] There are many non-governmental organisations that have entered the debates on single issues, leaving the other topics (eg medicines) untouched in their crusade for or against certain uses of the new technologies.

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This paper will focus on developments in the fermentation industry, later called 'industrial' or 'white' biotechnology. 'White' in this respect has come to refer to the environmental advantages of these production methods even though it was originally used to distinguish it from 'green' (environmental and agricultural uses) and 'red' (used for humans and animals) biotechnology. It is the area that focuses mainly on developing new production processes for pharmaceutical ingredients, chemical compounds and biomaterials. The industry has suffered some negative characterisations recently because of a perception that its production of biofuels from food crops comes at the expense of producing food. These public controversies potentially slow down the innovation process as well as its implementation in society. This is problematic because the potential of these processes for sustainability is expected to be high, and the impact of the developments involved cannot be simply sketched out as a simple and inevitable trade-off between food and fuel: by engineering organisms to convert a basic feedstock into a higher value product, industrial biotechnology allows a more sustainable chemistry to be developed, both reducing the chemical industry's dependence on petrochemical products and allowing smaller scale, more local production to take place. By concentrating on using byproducts as feedstock rather than using a primary (food) product, the technology has the potential to create high-value fine and bulk chemicals and pharmaceuticals from what may otherwise be waste materials. This potential also furthers several agendas of society as it has the potential to decrease emissions of greenhouse gases and decreases the (political) dependency on fossil fuels. These societal drivers can, if the communication process is organised in an effective fashion, increase societal acceptance of the technology.

Industry will not be able to accommodate all societal issues involved in a self-evident manner. In fact the transition from a fossil-based economy to a biobased economy requires the active involvement and change of many parties. A one-directional communication process would therefore not be sufficient, as this would not engage people as participants in such a transition to a biobased economy. It is in the interest of all parties including industry to be involved in an early dialogue on these societal issues. This would help shape the innovation agenda and strengthen societal awareness, both of which are necessary in order to change present unsustainable practices while maintaining economic viability. This means that a more democratic structuring of both the communication process and the innovation process would be in the interests of both industry and society. Awareness of these advantages needs to increase. We will explore the societal dimension of this growing industry where novel technologies and societal drivers have arguably paved the way to what has recently been claimed to be the largest transition since the industrial revolution.[6]

Microbial Genomics for Industrial Production

Microorganisms are used to produce valuable chemicals and materials from renewable sources such as sugar. Genomics provides a strong possibility of adapting these microorganisms so that they can use other renewable biomass, such as wood sugars and celluloses, which are much cheaper than sugar and which do not necessarily compete with food usage. Due to its complexity and large infrastructural demands, innovation in white biotechnology is currently embedded in specific

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organisational structures. When the potential of genomics became evident, the fermentation industry was interested in sequencing its own already established ‘specially selected’ production microorganisms. The industry soon recognised that collaboration with academia and other genomics expertise would increase the success rate and industrial potential of novel, but very expensive, techniques. Various collaborations were established in different countries, such as: the Energy Bioscience Institute in the USA, set up with $500 million from BP; the UK Centre for Sustainable Bioenergy, supported by the UK Biotechnology and Biological Sciences Research Council (BBSRC); the Porter Alliance, including the University of Cambridge and Imperial College London; the Kluyver Centre for Genomics of Industrial Fermentation and the Centre for Biobased Ecologically Balanced Sustainable Industrial Chemistry (BE-Basic) in The Netherlands; a number of German centres supported by Länder government funding; the Portuguese MIT initiative; and a series of projects supported by the Knowledge and Bio-based Economy (KBBE) Programme of the European Commission.

The availability of genomic techniques was certainly not the only driver for the success of industrial biotechnology. Much stronger political drivers were the desire to mitigate climate change, to increase sustainability, to provide energy security, and to prepare industry for the inevitably depleting stock and increasing costs of fossil oils.[7] Mitigation of climate change can be achieved by the reduction of CO_2 and other greenhouse gases and this can be achieved by using biomass as a renewable source for manufacturing. Most bulk products such as plastics and chemicals are usually produced from fossil oils, but their use rapidly releases enormous amounts of CO_2. Replacing these fossil sources by plants, whether as the primary crop or as waste from other crops, avoids the additional release of CO_2 as plants bind CO_2 from the air in their growth process, which is then released when they are used as sources for production (figure 1).

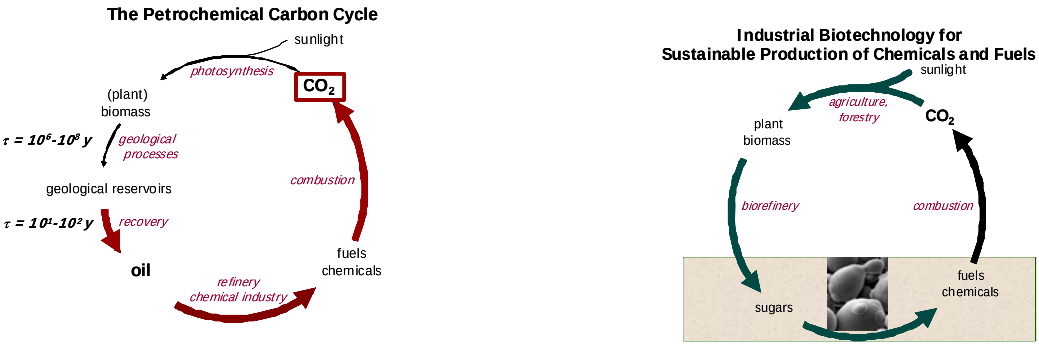

Figure 1. The petrochemical and industrial biotechnology cycles showing the CO_2 storage times. When plants are immediately used for fermentation, CO_2 is bound and released in the same time frame. When fossil oils are used, CO_2 is released which was bound many years ago.[8]

Biomass can be grown at many locations throughout the world, so that when biomass is used for energy or chemical production, it decreases political dependency on oil-producing countries. Furthermore, biomass provides a continuously renewable source, while fossil sources are rapidly depleting. Thus, apart from the potential offered by genomics to increase profit for industry, it also contributes to goals that are supported widely in society and in the political arena.

An example of these initiatives is the new genomics research programme launched by the Dutch government in 2002. A number of international Netherlands-based fermentation companies specifically requested certain university research groups in microbiology and bioprocess technology to jointly establish a centre of excellence in genomics research. The Kluyver Centre for Genomics of Industrial Fermentation started in 2002 as a collaboration between 11 companies and eight universities and research institutes, with a budget of more than €50 million over five years. Of that budget, €17 million was contributed by the government's Netherlands Genomics Initiative. A total of 25 per cent (€13 million) came from industry, while the remaining budget was provided by the participating universities and research institutes and by the projects they brought in. Together, the participating companies at that time represented a joint turnover of €10 billion per year, which made the Kluyver Centre an important economic feature for The Netherlands. The Centre's mission[9] as stated in its Business Plan was: "To provide scientific excellence in microbial genomics for quantum-leap innovations in industrial biotechnology aimed at improving sustainability and quality of life." Genomics would be used to improve microorganisms so that more products from renewable sources could be made economically viable. This would be the foundation for a bio-based economy. Here, we examine to what extent these promises have been realised and whether they have succeeded in addressing the societal dimension of the developments in question.

In the mid-term review carried out in 2006 it became clear that the Kluyver Centre had delivered on a number of its promises.[10] The government invited the Centre to present a new research plan which was prepared in close collaboration with the industrial partners. Boosted with a new grant of €21 million for the 2008-2012 period and an overall budget of €55 million, the Centre's focus has now extended to study specific industrial conditions and to develop genomics techniques for mixed cultures of microorganisms which are often used, for example in the dairy industry, rather than cultures of single organisms. Understanding the complex relations between these organisms will increase opportunities for tailoring and optimising their use for specific applications. The Centre increasingly collaborates with other international centres such as the Chinese Academy of Sciences and the number of international partners has grown steadily and now represents an annual turnover of around €120 billion. As of 2010 the Centre has produced 42 patents, for which 61 licences are provided, more than 500 publications, and employs more than 100 young researchers.[11]

In the autumn of 2009 the participating companies were asked to quantify the benefits of the partnership for a submission to the Netherlands Genomics Initiative Valorisation Award.[12] One small company calculated that its link to the Centre contributed to 60 per cent of its financial turn-over in one way or another. Those members with limited availability for staff networking activities also valued the

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international exposure highly. Larger companies cited early access to interesting leads providing the opportunity to be ahead of competitors, education and networking opportunities, access to expensive infrastructures and to a knowledge base for handling social issues.

In spite of the benefits that genomics can bring to industrial biotechnology, large-scale implementation of biorenewable production may also result in adverse societal responses. The public is concerned about the effects of industry on the environment and public health and, without proper communication strategies, such concern may hinder public and political support for the aforementioned innovation trajectories. Furthermore, the technology-internal language used in science and industry does not fit well with the vocabularies used in politics and public debate,[13] creating a fertile ground for further public concern. Early identification of 'hot' issues and early communication with the public on intended innovation paths may help adjust industrial agendas as well as pre-empting potential resistance.

First steps to integrate societal issues in industrial innovation agendas

The Kluyver Centre carried out a series of workshops in 2004, 2005 and 2006 to identify ethical, legal and societal issues in industrial biotechnology. Experts in industrial genomics, business innovation, environmental sciences, ethics, communication, governance, and policy studies came together for three three-day meetings to analyse likely future issues and to discuss challenges and best strategies for communication with stakeholders, politicians and the public at large.[14] After consulting a number of case studies and reports and considering media patterns and NGO priorities, they identified five issues which they considered likely to feature in any coming public debate (Table 1).

Issue	Considerations
Safety	Plants producing pharma ingredients: issue of co-existence
Land-use	Food-energy conflicts: food prices, rain forest degradation
Energetics	Eco-efficiency: uncertainty in scientific reports
Environmental pressure	Biodiversity, soil quality, water usage, mono-cultures
Economic feasibility	Oil price versus sugar price, uncertainty for investment

Table 1. Possible future issues on industrial biotechnology identified by experts in Kluyver Centre workshops 2004, 2005 and 2006.[15]

The political and public demand for sustainability was recognised as a most important driver of the development of industrial biotechnology. Yet this obscures a number of relevant considerations. For example, there exists no common understanding of the complex concept of "sustainability" and the challenges inherent in achieving a single definition are substantial. Beyond this, there are enduring concerns about the nature of public engagement regarding emerging technologies.

The substantial need for biomass which is used as feedstock to develop such sustainable products was seen as a major issue. Also, it was recognised that the debate tends to focus on biofuels, yet for most chemical products the use of bio-renewable

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sources is the only option to replace fossil-based sources and that would necessitate the use of only a limited area of agricultural land. For example, the annual global demand for plastic, which is currently around 100,000 tons, could be produced using 100 km^2 agricultural land while it is estimated that 5000 million km^2 is available for production worldwide. So the total world plastic demand could be produced on a tiny percentage (0,000002 %) of the total arable area.[16]

Indeed, the biomass needs for the production of bioenergy for both electricity and transport fuels would be much larger than for transport fuels alone. This is a result of the quantities used for transport and the growing global demand for energy.[17] The experts considered the use of other sources for renewable energy which are regarded as sustainable, such as wind and hydroelectric generation. Although these are often seen as a preferred option, long-distance road and air transport will probably depend on diesel and kerosene fuels respectively for a considerable period of time. The experts therefore concluded that the development of biofuels especially was expected to be of considerable political and public interest. At the time when these workshops were held, biofuels were only produced from food and feed sources such as corn (maize), sugar cane and soya. While there is great variability in the efficiency of converting these crops into fuels, these first-generation' biofuels can create competition with food and feed production. However, recent innovations appear to alleviate this problem.[18]

Public debates about novel technologies often aim at reaching some type of consensus to be able to come up with a generally agreed opinion for policy makers. When such debates depart from statements that are already accepted by the majority, they do not manage to go much beyond stating the obvious, or affirming long-established policy lines, based on already deeply entrenched interests and opinions. When dealing with much more complex issues, as described above, it would be preferable to have a deeper analysis and a clearer view on the issues that are at stake. Starting from *dissensus* may then be much more fruitful. To that end, it is important to invite as many different stakeholders as possible to the negotiation table, and also to explore different issues such as vested interests, and views on economic development and moral values. The problem with current debates over sustainability issues is that marginalised voices are often not taken into consideration. At the Kluyver Centre workshops it was recognised as a core issue to encourage a wide variety of stakeholders to collaborate and to manage the inevitable opposing opinions to reach some outcome that may yield positive effects.

This was taken on board in the fourth workshop, which focused on biofuel development and was held in October 2008. International stakeholders on scientific development, industry, trade and financing issues were invited together with ethicists, politicians, NGO representatives and specialised consultants. The objective was to analyse the contribution of novel genomic techniques to biofuel development and to make policy recommendations for the sustainable development of biofuels. With new genomic techniques it was by then possible to make microorganisms such as yeast that could convert agricultural waste products into ethanol as a biofuel. Oil-producing plants could be improved to produce biodiesel while a great deal of attention was focused on algae as efficient cell factories for biodiesel production, especially as they can grow in saline water, obviating direct competition for land used for food production. These so-called 'second generation' biofuels could help resolve the issue of using crops which would otherwise be used for food for energy production. The workshop was preceded by an analysis of issues in biofuel reports published by various stakeholders (eg the Food and Agricultural Organization, The World Bank, Worldwatch, the International Energy Agency, Greenpeace, Friends of the Earth),[19] which revealed uncertainty among scientific experts and other stakeholder clusters, as different reports presented different facts and figures, and highlighted different societal, legal and ethical issues.[20] The Centre also organised two public debates held in The Netherlands during September 2008 to identify issues of concern to the public.[21] The first debate, organised in Amsterdam, was aimed at defining sustainability criteria. This event was attended by a few invited stakeholders, but did not attract large audiences, which presumably indicates low public interest in this subject at the time. The second debate, organised in Rotterdam, looked at the practical implementation of such criteria and focused on its impact for local business and the Rotterdam Harbour. It drew an audience of about 60 people. Although the practical implementation of sustainability criteria is an important factor in the establishment of a bio-based economy, the definition of such criteria is crucial. It has become increasingly apparent that this issue deserves greater attention and greater public awareness, despite the widely recognised difficulty of achieving a common understanding of this concept. However, greater awareness could facilitate the development of a common understanding and definition through shared language and reference points.

Further presentations in the workshop focused on the importance of market development, financial investments and trade issues. The issues identified in the previous workshops were revisited and amended to include the latest developments (Table 2).

Issue	**Considerations**
Safety	*Plants producing pharma ingredients: issue of co-existence**
Land-use	Food-energy conflicts: food prices, rain forest degradation
Energetics	Eco-efficiency: uncertainty in scientific reports
Environmental pressure	Biodiversity, soil quality, water usage, mono-cultures
Economic feasibility	Oil price versus sugar price, uncertainty for investment
Issues added in 2008	**(focus on biofuel development)**
IP and multinationals	Open source versus patent protection
North-South distribution	Ownership of development, neo-colonialism
Cultural values of nature	Western values for sustainability pressed upon developing nations

Table 2. Possible future issues on industrial biotechnology identified by experts in Kluyver Centre workshops 2004, 2005 and 2006 amended with focus on biofuel development in 2008.
* Safety was not regarded as a relevant issue for biofuel development.

To prepare the workshop debate on policy recommendations and to increase depth of analysis, participants were interviewed before the event about their viewpoints on

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sustainability and economic development and about their own vested interests. This revealed that different participants have different opinions on sustainable choices for society, but a clear link between interest and opinion could not be established. During the workshop participants were asked to make 'value trees' at different points in time. Several participants changed their opinions on values for sustainable development and implementation as a result of new information received during the presentations and discussions.[22]

After three days, the meeting produced a generally agreed statement with recommendations[23] to policy makers which was presented and discussed with European Parliamentarians in a debate co-organised with the Science and Technology Options assessment of the European Parliament (STOA). It took place at the European Parliament[24] in November 2008. The meeting also published a formal report to provide input into the global initiative Lausanne Round Table on Sustainable Biofuels (RSB) which aims to produce a global vision on sustainable biofuel production.[25] The most important conclusions presented in the recommendation were:[26]

- Development of sustainable and secure alternatives for energy need governance
- More emphasis should be given in policy making to the need for a secure and reliable supply of sustainable energy
- The public debate should be improved to include issues of security supply and energy savings
- Future fuel, fibre, feed and food production will be intimately linked to agriculture and forestry which necessitates a comprehensive agro-industrial policy
- Development of alternative energy sources requires a level playing field for all agricultural and forestry products
- Policy measures should stimulate efficiency improvements in agriculture
- Priority should be given to the development of global standards for monitoring and certification systems
- Policy measures need to recognise investment options
- Biofuel development needs priority in the short-term while the development of alternative infrastructures with alternative energy sources is stimulated for the long-term
- Attention should be given to addressing the growing world population

Since this series of workshops, the issues of direct and indirect land use changes and of eco-efficiency and sustainability have received considerable public and media attention. Many newspaper articles and TV documentaries have argued that land used for biofuel or bioenergy production undermines food security. Others, including *An Inconvneient Truth*, a documentary about former US Vice-President Al Gore's climate change campaign,[27] claimed that biofuel production should be employed to make our world more sustainable. They spread conflicting messages while referring to individual reports produced by a variety of organisations including those from reputable organisations such as the United Nations, the World Health Organization, the Food and Agricultural Organization and the World Wildlife Fund.[28] Currently,

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there are many conflicting reports with lists and shortlists of sustainability criteria, produced by a multitude of NGOs, charities, companies and governmental bodies. There is, however, no clear view on how these different lists of criteria are or may be picked up either by policy makers or by industry. To gain more clarity, the Kluyver Centre's societal programme conducted the aforementioned meta-analysis of 32 reports on biofuel development published by NGOs, industry, governmental organisations, etc.[29] This analysis mapped how various issues, from fair trade to eco-efficiency and from economic development in developing countries to protection of local ecosystems, were brought to the foreground by different stakeholders, how these different reports relate to each other, and whether there is a similarity in approaches detectable per stakeholder category. The initial findings indicate uncertainty among scientific experts and other stakeholder clusters. From this analysis, it appears that there is still a great need for better communication between different stakeholder groups.

Pros and cons of a bio-based society

Current debates provide no clarity in the argument regarding transition to a bio-based society, and show considerable disagreement among experts about the merits of such a transition. For example, biofuels are blamed by some for the deforestation of rain forests in Brazil and Asia. This is rejected by others who claim that only 0.4 per cent of the agricultural land in Brazil is used for biofuel production while 25 per cent is used for pasture and the raising of beef cattle.[30] Strict government regulation in Malaysia restricts the land area covered by palm oil plantations to no more than 5 million hectares (50,000 km^2)[31]. In fact only 3 per cent of global palm oil production is used for biofuels. The majority is used by the cosmetics and food industries.

Issues of food security are even more complex.[32] The European Commission's Group on Ethics published its Opinion on sustainable agriculture in December 2008.[33] It reported that Europe has shifted its focus from food security to food safety. The Opinion declares that availability of, access to and quality of food is a human right. It also states that we should protect the disadvantaged and that we should govern and protect a sustainable supply of food, ensuring a food supply for future generations:

> Production, processing, storage and distribution of food and agricultural products are generally accepted as routine parts of everyday life all around the world. Therefore, these activities have rarely been addressed within the realm of ethics. But food and agriculture, and the economic benefits derived from taking part in the associated system, are means to an inherently ethical end: feeding the world's population and preserving the Earth's food-producing capacity and natural ecosystems for future generations. (page 48)

Biofuel development is seen as beneficial and potentially able to help to open markets that would create access to food for more people. The Group points out that factors other than biofuel development are much more important for food security such as warfare, political leadership, lack of markets, mis-managed food aid programmes, protection of European and US farmers, increase of meat intake, etc.

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In addition to the lack of clarity in the sustainability arguments, there is scientific uncertainty, especially related to the lack of validated measuring tools. Modelling, the art of predicting future land use, specifically poses issues of uncertainty.[34] Sustainability criteria have been developed in abundance.[35] More than 70 sets are suggested by different organisations such as the Lausanne Round Table on Sustainable Biofuels[36] and the Netherlands initiative under the name of "Cramer Committee"[37]. The problem is that some criteria relate to ideologies or values which are immeasurable, while others are difficult to measure, such as indirect land-use changes or soil fertility.[38] Table 3 provides a summary of drivers and ethical arguments and concerns.

Mapping, predicting or quantifying issues of sustainable development is problematic due to issues of scientific uncertainty and of scientific and social complexity. The uncertainties do not only concern the 'state of the art' of novel technologies and what uses are technically possible, but also include the socio-economic context, societal evaluation and environmental impact of different applications.[39] In principle, genomics should be an important contributor to sustainable development, but because of these issues one cannot expect industry to come up with a clear-cut solution to the problems of the production of sustainable energy sources and sustainable materials. Particularly in this important area of research and development, it is necessary to align the technologies involved to societal infrastructures during the process of innovation.

Drivers	**Applications**	**Ethical arguments**	**Social Concerns**	**Scientific uncertainty**	**Clarity in argument**
Mitigate climate change (sustainability)	Use bio-renewable materials in-stead of fossil oil	Distributive justice (food security)	Eco-efficiency of 1st generation biofuels	Yes, in reliability measuring tools	No, debate focuses on urgency climate change
Energy security	Use waste materials from agriculture, pulp and paper industry and households	Governance, ownership of land and IP	Land use	Yes in lack of measuring tools	No, debate focuses on policy models
Replace depleting fossils	Use dedicated energy crops	Interfere with nature	Power to multinational seed and herbicide industry	Limited, in ecological models and in figures for remaining fossils	No, ideologies are maintained on landscapes

Developing agricultural markets	Use of overproduction of biomass for new bioenergy market	Economy models	Environmental pressure	Yes, lack of economic models for regional development	No, debate on single issues

Table 3. Drivers, application, ethical arguments and social concerns for the development of a bio-based economy considered for clarity in argumentation and scientific uncertainty. Sources: Media releases and stakeholder reports.

Conclusions

As society confronts the challenges of finding suitable alternative energy sources, it becomes clear that genomics will provide an important contribution to the development of economically viable and sustainable production of food, materials and energy. However, the development of a sustainable society can not occur based on scientific developments alone. Active engagement and involvement by the public and other stakeholders is essential. Yet, this engagement must occur in a way that optimises informed input. We also need to acknowledge the potential of dissensus as a starting point for in-depth analysis of the issues involved, rather than 'taming the tiger' by framing debates in such a way that consensus is both the point of departure and arrival. Such approaches only serve to illustrate the obvious. A transdisciplinary approach involving different stakeholders could help to clarify the different values of different groups and then to evaluate the options for resolution. These stakeholders should ideally agree on the institutions who will take the initiative in public dialogue, keeping in mind that trust and leadership are crucial elements in governance for communal objectives.

Currently, the debate suffers from scientific uncertainty, lack of clarity in arguments for policy direction, strongly opposed views and a lack of robust involvement of a larger public. Additionally, the food versus fuel controversy persists, as does a lack of agreement on key terms, such as 'sustainability'. A number of international initiatives have started to address these issues. The Global Biorenewable Research Society (GBR) was established in 2009 with the aim of providing trustworthy, peer-reviewed sources of information similar to the IPCC.[40] The Global Sustainable Bioenergy project (GSB) initiated by Professor Lee Lynd aims to answer the questions of whether we need to or can actually produce enough biomass to deliver a substantial contribution to our global energy needs.[41] These initiatives hope to provide clarity and reduce scientific uncertainty. The outcomes will need to inform the stakeholder

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discussions and public dialogue. This will not be simple, given the complexity of the issue of the development of a sustainable society strongly related to individual values.

What is clear is that we need to find ways to involve people in sustainability issues so they can make informed and considered choices. The forum for these discussions must be accessible and inclusive. The usefulness of advances in genomics and the substantial role that this technology could play in furthering societal environmental, economic, and political agendas are in large part dependent on societal understanding, acceptance and uptake of applications of this technology. It is therefore crucial that greater attention be given to the nature, process, and substance of the debate about a bio-based economy and our sustainable futures.

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Towards an eco-centric view of human existence: Implications of genomics for the environmental zone

HUB ZWART[1]

During the weeks and months preceding the gala televised Human Genome Project press conference on 26 June 2000, the human genome sequencing effort had turned into a massive spurt, involving competing teams who were almost dashing towards completion.[2] The press conference, involving President Bill Clinton as well as the main competitors Francis Collins and Craig Venter as plenary speakers, was the climax of an avalanche of promissory discourse, the tremors of which are still noticeable today. It was proudly announced, for instance, that humankind was about to unveil the core of its identity, and it was even considered conceivable that "our children's children will know the term cancer only as a constellation of stars".[3]

Reflecting on the press conference 10 years later, the Human Genome Project (HGP) seems a glaringly self-centred endeavour, not only because it firmly positioned science at the centre of the stage (as the driving force in human history), keeping the natural and the social at a distance as it were, but also in the sense that the project was presented in an overtly anthropocentric vein. While quoting the words of Pope that "the proper study of mankind is man", genomics seemed to display a basic predilection for human beings as its favourite model organism. The speeches presented at the event were 'speciesist' to a high degree in that they focused almost exclusively on human beings and human health, while possible untoward side-effects were solely formulated in terms of risks for humans.

This also goes for the anniversary series of articles published by *Nature* – 'Ten Years After' as it were - in which several authors (including the two key players, Francis Collins and Craig Venter) reflected in retrospect on the meaning of the human genome sequencing effort and its outcomes, as well as on the train of events it set in motion.[4] Again, the focus is clearly on the human genome. The 4,000 or so other species whose genomes have likewise been sequenced, are mentioned only in passing, by Craig Venter.[5] The "narcissistic insults" of the Copernican, the Darwinian and various other scientific revolutions have passed without leaving much impact.[6] We still seem to regard ourselves as the most important of all species on earth, as the ultimate 'model species' of our will to know, as if planet Earth can still be regarded a safe haven of anthropocentricism.

This anthropocentric bias seems as problematic as it is inevitable. Parry and Dupré, for instance, agree that it may appear anthropocentric to foreground the HGP to such an extent, in view of the large sets of viruses, bacteria, fungi, plants and animals whose genomes have likewise been sequenced, while applications in animal husbandry and ecological conservation may eventually eclipse and prove far more weighty than the still pending applications in human healthcare.[7] Nonetheless, they argue that it was the *human* genome project which "galvanized" the genomics revolution and played such a pivotal role in mobilising and channelling resources into

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genomics, thus having ramifications across the wider field of study. This ambivalence concerning the legitimacy of anthropocentrism is omnipresent in genomics discourse. On the one hand, the time has come, so it seems, for decentring of the human once and for all in assessing the implications of genomics for the social, the cultural and the natural. On the other hand, we are undoubtedly the major actors when it comes to implementing and assessing the repercussions of genomics research for life on earth.

Meanwhile, genome sequences continue to proliferate. Sequence information covering thousands of species is collected under the heading of the Genomes OnLine Database (GOLD). From a psychoanalytical perspective, the acronym used here is a highly symptomatic one. These enormous databases can be seen as spates of informational excrement (spat out by sequencing machines with superbly productive intestines) that at the same time represent something of significant value, something 'pure'. It is the symbolisation of life, focused on bioprospecting, on turning messy life into its purified essence, into pure gold, and eventually into financial gain: genome sequencing as a contemporary gold rush, with the genome as our genetic 'metal' to be tested. Like the press conference described above, the sequences on display actually conceal the more muddy and messy aspects of the natural, as well as of laboratory life. Thus, genomics represents a cleansing and dematerialisation (or rather defluidisation) of bodily existence.

The ambivalence continues. In view of the proliferation of genomes, anthropocentrism might seem an uncertain ally. If one pivotal message can be distilled from genomics research during the past decade, it is that we cannot begin to understand its implications as long as we focus solely or even predominantly on human beings and human health. The broader implications of the HGP can only be meaningfully assessed if we are willing to move beyond the dichotomies and bifurcations of traditional metaphysics, in the context of which humankind is time and again singled out from the rest of the living world, the 'non-human'. Indeed, Nietzsche already argued that, when discussing such issues as "man *and* world", the very framing already obscures that we are, in every single molecule of our bodies, part of nature.[8] Yet, the self-centred, anthropocentric view of life is a legacy of long standing and is bound to reassert itself, even in the era of genomics, if only because (unlike, for example, eating vegetables or meat) the sequencing of genomes is an exclusively human endeavour.

Thus, genomics has reinforced a basic uneasiness that scientists, philosophers, novelists and many others have been facing since the first narcissistic insults mentioned above have 'decentralised' the human by indicating that we should stop seeing ourselves as something ontologically privileged and unique. Through scientific discoveries we realise that (from an astronomical, anatomical, physiological, neurological, evolutionary and genetic perspective) we are quite similar to other life forms when it comes to the basic constituents and processes of life. We are not only subject to the same physical laws as other entities on earth, but also to the same evolutionary laws and biomolecular mechanisms. Yet, at the same time, these very insights seem to underscore our uniqueness. As far as we can tell, we are the only

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entities on earth (or, for that matter, in the universe) involved in questioning and exploring the origins and functioning of life in general and of our own existence in particular. Only human beings seem able to explicitly address issues of descent, as well as questions of identity. Besides living our life, we have been producing a discourse of astonishing magnitude on what it *means* to live a life, a performance without precedent in nature, and this prolific discourse has had a tangible impact on human existence, has ‘materialised’ in countless efforts towards regulation and reform of life. Our self-consciousness has become a major factor affecting life on earth. The very fact that we are able to *talk* about endangered species as ‘endangered species’, for instance, has consequences for their prospects of survival.

What is the basis for this openness towards ourselves and the world around us? What is it that makes our self-consciousness possible? The human genome sequence in itself fails to provide answers to such questions. As a genome sequence, it underscores continuity between humankind and ‘the rest of nature’, but as a chapter in the history of knowledge, HGP stresses science as a uniquely human endeavour, also from an evolutionary perspective, significantly transcending the type of information provided by our sense organs. Through research, we have tremendously expanded our temporal and spatial horizons, whereas other (closely related) species persistently focus on the local here and now.

Yet, when it comes to understanding the societal impact and cultural significance of genomics, it would be a fatal mistake to focus our attention on the *human* genome only. If one philosophical lesson can be drawn from genomics at all, it is that we can only come to terms with our own identity and history (as human beings) if we see our existence and our history as part and parcel of a much broader narrative: the history of life on earth and of living nature. In order to make sense of our genome, we need these 4,000 or more other genome sequences as well. The HGP incites us to embark on the paradoxical task of developing an *eco-centric anthropology*, a decentralised narrative of humankind, redefining our self-understanding in eco-centric terms, in terms of multiple-species narratives. First of all because the currently known genomes of other animals are a testimony to our basic affinity with them, notably on the molecular and biochemical level. Comparative genomics tends to stress the marginality of differences between species, and this includes differences between human and ‘non-human’ genomes. Second, because the genomes of cultivated plants such as rice, grain and potato on the one hand, and of domesticated animals such as cow, horse, pig, camel, dog, on the other, may serve as source books or archives containing valuable information about *human* history, not as a single-species narrative, but as a story-line that is embedded in a much broader multiple-species narrative frame: the history of domestication as a multiple species history.[9] Notably, these genomes contain informative archives concerning the vicissitudes and histories of the - to a certain extent - man-made, but nonetheless multiple species agricultural ecosystems called villages that began to emerge 10,000 or so years ago: the agricultural village as an evolving multiple-species ecosystem.

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And finally, genomics not only points to the importance of including plants and animals into our history, but also indicates the necessity to include microbes more explicitly in our view of nature and of ourselves. Genomics research underscores the cardinal insight that Earth is basically a microbial planet and that the guts and cavities of our own bodies may be regarded as environments for the plethora of life forms by which we are inhabited. Genomics has made it much more explicit than ever before that we are not 'individuals' in the sense of insulated, self-sufficient entities. On the contrary, our bodies can be seen as environments in their own right, hosting floating swarms of micro-organisms responsible for a broad range of biochemical processes that are usually listed under the heading of 'metabolism' – processes moreover that as a rule are attributed to the activities of our own bodies and organs, rather than to the silent, invisible and unacknowledged labour of the billions of guest organisms that dwell within us as a symbiotic workforce.

From the very outset, it has been an important objective of the HGP to deepen our understanding of ourselves. More than 25 centuries ago, a famous admonition was inscribed in the forecourt of the temple of Apollo at Delphi in ancient Greece by one of the seven Sages, namely "Know thyself". Self-knowledge was regarded as the ultimate goal in human life, the basic objective of all knowledge-directed activities - from pilgrimages to holy sites in ancient Greece up to genome sequencing efforts in present-day genomics facilities.[10] The ancient admonition was taken up by the neo-classicist poet Alexander Pope, in his *Essay on Man*: "Know then thyself, presume not God to scan / The proper study of mankind is man".[11] As mentioned above, these lines were subsequently quoted by Francis Collins during the 26 June 2000 press conference.[12] After a long journey of exploration, we were finally expected to be able to know and explore ourselves. Thus, Collins described the human genome as "our own instruction book" and as "the draft of the human book of life". Moreover, he expected that this tremendous leap in self-knowledge would provide us with effective tools, enabling us significantly to improve the human condition.

In various ways, these expectations proved overstated. Rather than a series of answers and solutions, from which humankind in general, but notably patients suffering from cancer, were expected to benefit, the HGP produced a "deluge" of data and a "labyrinth" of new questions.[13] Yet, perhaps the real significance of the HGP must be sought first and foremost in its *cultural* relevance. By this I mean the impact the HGP has had on our understanding of ourselves and our history, in close relationship and interaction with "the rest of nature". On 26 June 2000, the implications of the HGP were still defined in humanistic and anthropocentric terms. Now, genomics is increasingly shifting its attention towards areas such as environmental genomics, microbial genomics and metagenomics. This raises the question (somewhat neglected in current ELSI genomics discourse, I think) of how genomics in general and the HGP project in particular have affected our views on our position within the living world. I will argue that genomics has deepened our understanding of the embeddedness of human existence in the web of life, and that this might make new forms of relationship, more sustainable "covenants", as it were, with our natural environment possible.

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In order to address this rather broad range of topics, I will focus on a number of specific issues. First of all, I will outline how genomics has enriched our understanding of human history, notably the history of agriculture and domestication ('The Genesis of man-made, multiple-species ecosystems'). This broadens a self-centred view on human existence into a more eco-centric view. Subsequently, the scope will once again be broadened by shifting the focus from domesticated plants and animals (as our companion species) towards microbial life forms and their importance, both in our external environment ('Microbial planet') and in our internal environment ('The microbial unconscious'). Finally, I will outline how genomics is redefining our policies towards the natural world, especially when it comes to "genome management" of endangered species (notably mammals). A new genomics-based covenant with nature appears to be emerging (The return of the Ark).

The Genesis of man-made multiple-species ecosystems: towards a genomics-based genealogy of village life

The Bible book *Genesis* contains a fascinating legend: the story of the Ark. Against the backdrop of an ecological disaster - a sudden dramatic climate change unleashed by chronic and massive human (mis-)behaviour - a protective contrivance is built, a kind of lifeboat for supporting and ensuring the survival of a limited number of favoured and carefully selected human beings and animals. They are, so it seems, set on the trail towards domestication and self-domestication. After the Flood, they are allowed to repopulate the land. In various ways, the story of the Ark can be seen as a model narrative for framing important events, such as periods of climate change and mass extinction in the recent or distant past (as studied and uncovered by geology and palaeontology), where the Ark symbolises what is nowadays called a survival bottleneck (a genetic window into the future in times of mass extermination). But it may also serve as a narrative scheme that allows us to frame and assess what is happening in the present (the genomics era) in terms of conservation policies to ensure survival of favoured and yet endangered species, allowing them to accompany us in our journey towards the landscapes and environments of the future. Thus, the Ark provides an archetype for framing the narrative of the interaction between humans, animals and other organisms. The Ark has proliferated into a world-wide network of regulatory lifeboats and survival sites in order to counteract the massive killing fields that endanger biodiversity on earth.

Archaeological research has made it abundantly clear that the Ark really existed, namely in the form of the primordial agricultural village, an ecological lifeboat in a challenging, threatening and rapidly changing environment when the Pleistocene era gave way to the current Holocene period. Perhaps the most decisive event in human history, the so-called Neolithic, or agricultural, revolution, began some 10,000 years ago in various parts of the world more or less isolated from one another, such as Mesopotamia and Egypt, North and South China (along the Yellow and the Yangtze Rivers), the Indus valley, West Africa, Mexico and the Andes highlands.[14] From there it gradually spread to other areas, such as Europe. The face of the earth began to

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change as humankind began systematically to modify its natural environments through wilderness clearing and reclamation. It was a moment of awakening, as it were, of mankind as a whole.

The simultaneity and common pattern of these worldwide changes suggest a common external factor in terms of global climate change.[15] As humans and animals found themselves united in their effort to circumvent post-glacial draught, former hunters became cultivators and domesticators in their retreating oases.[16] Thus, emerging villages provided a lifeline for endangered species (including Homo sapiens) under the leadership of humankind. We as a species had firmly taken the lead in the drama of evolution and survival. The village represented a protective environment or Ark amidst environmental perturbation and flux. Every region involved produced its own typical domesticated plant form - a plant that gave the area in question an identity, a face, so to speak - making use of the wild types available: wheat in the Middle East, millet in the northern parts of China, rice in South China, maize in Mexico. The civilisations concerned became wholly dependent upon a small number of key species.[17] Eventually, around 5,000 years ago, extended parts of the world including China and Europe became real *agri*-cultures, that is areas where agriculture flourished and constituted the basis of societal existence[18].

As a consequence of the agricultural or Neolithic revolution, a number of other transformations of pivotal importance took place as well, such as the emergence of states, of cities and of written language. Until recently, scholars relied on linguistic, archaeological and other “traditional” sources to reconstruct these largely pre-historical transformations. Now, however, genomics has redefined the field. Jones, for instance, describes how DNA information has transformed archaeology in a very profound way, - has transformed it into bioarchaeology.[19] The focus of attention has shifted from analysing artefacts such as pottery or ornaments and tools, to analysing DNA fragments in organic remains (seeds, animal bones, human bones, etc.) as sources of information concerning the life, health status and nutritional habits of ancient rural communities. The focus of interest for bioarchaeologists is on the plants these rural communities cultivated, on the animals they domesticated, on the “biotechnologies”[20] they relied on and on the man-made ecosystems they created. Due to this shift, archaeologists became “DNA hunters”, and archaeology evolved into a merger of humanities and hard core technoscience. Eventually, genome sequencing is bound to become an important branch within archaeology as a field

Indeed, the DNA revolution in archaeology has only just started and is bound to continue well into the future. Besides analysis of DNA samples recovered on archaeological sites, another source of information has presented itself, namely the DNA of *contemporary* organisms (plants, animals and humans that are currently alive) as “archives”. Genomes are the Rosetta Stones of (the history of) life. This first of all applies to humans. Luca Cavalli-Sforza and Allan Wilson’s Human Genome Diversity Project (also known as the “second” Human Genome Project) as well as the HapMap project and the Genographic Project[21] of National Geographic and IBM are shedding new light on early human history and have re-opened a number of debates in archaeology, palaeontology, language studies and cultural anthropology. In this manner, genomics is affecting our understanding of early human existence - which is basically the history of early human migration - as well as the origins of human society and culture.

But again, it would be wrong to solely focus on *human* genomes in this respect. Indeed, it is impossible to come to grips with the dynamics of early human history as long as we disregard the evolutionary pathways of our fellow-travellers and accompanying species, in whose genomes we find our common histories reflected. These genomes contain the records and footprints of our own activities. Thus, bioarchives may be consulted as mnemonic devices and recordings of multiple-species trials and tribulations reaching far into the distant past. We have been evolving, not as a single “species” in competition with others, as Darwin and his followers thought and think, but rather as members of multiple-species networks and symbiotic constellations, in environments such as villages and cities. The story of agriculture is a multi-species narrative that has greatly affected the history and evolution of other species besides humans.

Moreover, the agricultural revolution is a story to which a substantial number of species have contributed besides Homo sapiens. Early agriculture consisted of the creation of artificial environments or ecosystems in an era of climate change and environmental stress, initially in the form of small man-made “islands” surrounded by natural wilderness. A select number of plants were cultivated and a select number of wild animals were domesticated, a process that greatly influenced their conditions of existence and (eventually) their genomes. Micro-organisms were used for processes of fermentation and food conservation. As a result of agriculture, human beings created their own life-world. Rather than being dependent on the food that was provided by natural surroundings, humankind began to produce its own food products and thus increasingly to control its own food policies and food intake. Yet, in doing so, we significantly relied on a wide range of “biotechnologies” developed by tiny organisms such as yeast in the course of evolution.

The agricultural village was designed to function as a protective shell and relatively safe haven, allowing its inhabitants to flourish more exuberantly compared to populations (of humans, animals and plants) that remained “outside”. Although moments of catastrophe and crisis (in the form of famine and the spread of infectious disease) did occur, eventually this new way of life became a success story. Whereas humans, plants and animals involved in the domestication program tended to flourish, their wild type cousins or ancestors declined and often became extinct. Indeed, domestication is neither a history nor a story, but rather a programme that still continues to unfold. Generations of human farmers have left their fingerprints on genomes they selected and eventually altered. Therefore, we have come to realise that, in order to understand our own history, the genomes of other domesticated species - together with the genomes of animals such as the mammoth or the indigenous American horse, whose extinction coincided with the transformation of our own history from a merely biological evolutionary pathway into a success-story of our own

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making - should be consulted as well as a kind of source book for early human history.

The systematic sequencing of the genomes of species that were involved in this grand narrative, in this ongoing programme, adds a whole new dimension to our understanding of it. A promising new source of complementary information becomes available, often allowing us to fill in some of the gaps and lapses in the various archaeological, anthropological and linguistic records that had survived. Recently, for instance, the draft sequence of the cow genome became available.[22] This sequence is not only bound to provide important information concerning health, nutrition and disease that can be put to use in the context of animal husbandry, but it may also allow us to reconstruct more accurately the various domestication events over the past millennia by studying the impact of selection and husbandry on the cow genome.[23] Although this type of research is still in its infancy, the idea is that the imprints of domestication and breed development on the genomes of livestock will help us to improve our understanding of the common history of cows and humans during past millennia, notably by studying the bottleneck signatures associated with domestication and selection.

When the human genome ‘map’ was announced in 2000, the hype was predominantly about the new medicines and cures for human diseases that would emerge as a result. Yet it has been argued that genomic findings have had a much greater impact on for instance animal husbandry. They have “revolutionized” dairy farming,[24] through tailoring diets to genomes (animal nutrigenomics) and through targeted selection procedures (producing “farmyard supermodels”[25]), as well as through boosting resistance against disease. Yet, besides these utilitarian outcomes and economic benefits, valuable cultural and historical insights are provided by the sequenced genomes of cows and other domesticated animals.

Likewise, the sheep genome is claimed to provide valuable insights into the history of sheep domestication, one of the first animals to be invited into the man-made rural enclaves of the Neolithic revolution. Marginalised descendants of early waves of domestication are like relics of the past. By unravelling their genomes and by comparing the genomes of various sheep varieties, new insights can be acquired into the history of pastoral societies whose economy depended on sheep husbandry.[26]

What goes for the genomes of domesticated animals also applies to the genomes of cultivated plants such as rice, potato, grapes and wheat. The importance of the sequence of the rice genome, for instance, does not reside only in the fact that rice as a crop is a staple for more than half the world’s population - hundreds of millions of people depend on it for their daily living. It is also important because the rice genome is the outcome of a long and winding history of cultivation. Traces of this history can be found throughout its genome.[27] Thus, genomes contain the annals, written in the “alphabet” of DNA, of the Neolithic revolution and the introduction of agriculture, spreading throughout the world like a biotechnological epidemic, with humans as carriers, significantly affecting the earth’s flora and fauna. The genomics of cultivated

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plants such as rice, potato or cereals and of domesticated animals such as cows can be read and put to use as complementary archives whose histories, recorded in their DNA, mirror our own.

Microbial planet

Besides allowing us to reconstruct the outlines of the primordial agricultural Ark, genomics also incites us to look upon our own bodies as vessels, floating through a microbial web of life and providing a hospitable environment for the species that inhabit us.

Contrary to the (outdated) idea that we inhabit a predominantly *human* planet, whose human and mammalian inhabitants (as dominant species) are threatened by micro-organisms as infectious agents – germs that in a future, utopian world are bound to become exterminated, as H.G. Wells wrongly anticipated in his novel *The Time Machine*[28] - we now realise the predominance of microbial life forms, not only from a temporal perspective (microbial evolution covers the lager part of the process of evolution as such), but also from the perspective of biodiversity and sheer biomass.

Microbes have been the only forms of life on Earth for something like 80 percent of its history and remain even today by far the commonest living things. Even their biomass still exceeds that of multicellular organisms if structural plant material is excluded.[29] We ourselves are like tiny entities or floating islands temporarily nestling themselves in these dynamical microbial mires of Gargantuan proportions. Genomics entails a narcissistic offence, not only because the human genome contains only 22,500 or so protein-coding genes, and is almost indistinguishably similar to the genomes of the chimpanzee or the laboratory mouse, but also because it is difficult to uphold that in the grand narrative of life on earth we should be regarded as the principal character or key player, and the emergence of human beings as the principal focus event. As Lynn Margulis and others have argued, during the first two billion years or so of evolution, microorganisms have developed the "biotechnological toolboxes" of life we are only beginning to unravel.

In her book *Microcosmos* as well as in a number of subsequent publications, Margulis and her co-author Dorion Sagan describe how our own life as human beings is nourished by and dependent upon the presence of a worldwide microbial "superorganism", providing and maintaining the conditions that support and sustain life on earth, a microbial *web of life*.[30] The earth's microbial biosphere emerges as a "communicating and cooperating worldwide community of interdependent entities".[31] For Margulis, the key idea of the life sciences is the idea of a global microbial communicating and cooperating *network* that constitutes our indispensible bio-environment and that also lives *in us* and *through us*. It has been able to survive all cataclysms of the past and can be regarded as virtually immortal. In similar terms, Nobel Prize winner Christian De Duve speaks about the Earth being enveloped in a colourful "web" of throbbing life.[32]

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Margulis also subscribes to the idea that our own bodies (like the bodies of other organisms) can be "read" as archives containing annals and reminiscences of lost worlds and decisive geographical and evolutionary events. Indeed, our bodies contain "a veritable history of life on earth". Our cells, to begin with, maintain an environment like that of the earth when life began, similar to the environment of the early seas. Our bodies preserve the atmosphere of an earlier earth.[33] This converges of course with the idea, already outlined above, of our body as an archive in which the genomes of humans and other species are regarded as records of primordial events.

Besides redefining the Earth as a microbial planet, the history of the human body is likewise reframed in microbial terms, giving rise to a genomics-based view of world history in which the role and functioning of micro-organisms is duly acknowledged. An important contribution in this direction is the best-seller *Guns, Germs and Steel: The fate of human societies* by Jared Diamond, in which the decisive contribution of microbes to major events on the world historical stage is brought to the fore.[34]

Diamond sets out to develop a new perspective on world history based on the avalanche of novel forms of information coming from scientific disciplines that were traditionally seen as somewhat remote from the analysis of human history, such as genetics, molecular biology, and biogeography. First of all, his "tour of human history on all continents" reveals that during the beginning of village life and the early days of plant and animal domestication, the availability of suitable species provided some areas with a head start over others, a fact of life which Diamond subsequently uses to explain the differences between various cultures on various continents. But the real key players of his book are germs. Their history is closely associated with the history of domestication, since the major killers of humanity have been infectious diseases that evolved from diseases of domesticated animals with which humans co-existed, often even under the same roof. Notably, the ships used by invaders sailing to the New World were like Arks carrying not only humans and animals but also microbes across "the tumbling billows of the main" towards promising shores.

There is a strong historical connection between colonialism, violent collisions and germs. Soldiers and voyagers have always been notorious for their role as carriers of deadly germs. Until World War II, more victims of conflicts died of the illnesses caused by war-borne microbes than from battle-wounds. Diamond underscores the decisive role of microbes during transcontinental collisions, such as between the Old and the New World. Although the numbers of Native American victims of European colonisation were substantial, they were dramatically outnumbered by victims of European microbes. Diamond calls this Europe's "sinister gift" to other continents: the germs evolving from Europe's long intimacy with domestic animals. The exchange of germs was almost exclusively one-way. Microbes paved the way for European expansion, but not always: malaria, yellow fever and other diseases of tropical Africa, South East Asia and New Guinea furnished the most important obstacle to European colonisation in those tropical areas.

Yet, microbes do not only flourish in our external environment. Genomics research also sheds new light on the role and importance of microbes dwelling and flourishing in our internal environment. Genomics invites us to look upon ourselves as incubators, as it were, for symbiotic and cooperative microbes, rather than as vehicles for "selfish" genes.

Love is a microbe... The microbial unconscious

"Microbes thrive on us: we provide wonderfully rich and varied habitats, from our UV-exposed, oxic and desiccating skin to our dark, wet, anoxic and energy rich gut that serves as a home to the vast majority of our 100 trillion microbial (bacterial and archaeal) partners." (Ley et al).[35]

Love is a microbe… At times I have attacks of melancholy and of atrocious remorse; but you know, the fact is, that when all this discourages me and gives me spleen, I am not ashamed to tell myself that the remorse and all the other things that are wrong with me might possibly be caused by microbes too, like love… (Vincent van Gogh)[36]

The HGP was not exclusively devoted to sequencing the genome of humankind. Contextualising this large-scale endeavour, and as a preparatory exercise as it were, the genomes of other species such as C. Elegans and Drosophila were sequenced and published before taking on the human code. Moreover, as outlined above, in the wake of the HGP an exponential number of genomes has been added to the list. Some of them have a close relationship with agriculture and anthropogenesis, as we have seen. Their histories, recorded in their genomes, are an integrated part of the collective multi-species narratives that constitute our common eco-centric biography.

But domesticated plants and animals are not our only "companions". Our bodies constitute a rich environment, an often forgotten realm of life. Genomics research has given due attention to this hidden world. An important role is played by the Human Microbiome Project (HMP), a metagenomic initiative to sequence the genomes of all the microbiological flora collected from a variety of body sites. Through such research initiatives, we are becoming more aware of the vital role played by the indigenous microbial metagenome in human physiology.[37] From this perspective, the human body is seen as an ecosystem in its own right, containing multiple ecological niches and habitats in which a variety of cellular species collaborate and compete. Human beings are redefined as superorganisms that incorporate symbiotic multiple-species colonies.[38]

One way of framing it might be to say that this web of microbial life existing within our internal environment is our "unconscious", first of all in the sense that we tend to be unaware of its existence. We tend to believe that digestion, for instance, is carried out by our own internal equipment, our own biotechnological toolbox, and fail to realise our dependence on this vast army of labouring companions. Microbial life usually becomes visible and noticeable only through symptoms or pathologies whenever something is ill-functioning or wrong with "us". Then, all of a sudden, we become aware of the fact that we are pervaded by microbial life forms.

Yet our internal microbial world may also be regarded as our "unconscious" in a more psychoanalytical sense of the term, namely in the sense that, even though we are apparently aware of its existence, we are hesitant or even resistant when it comes to really acknowledging its presence and importance. As soon as these embedded biota are uncovered, the awareness of their existence is bound to become obscured or repressed once again. From the very moment that Anthony van Leeuwenhoek for the first time opened up the microbial realms of life to human perception, using self-built microscopes as windows into this miniature world, humankind subsequently tended to forget about this biosphere again and to lose sight of it once more, pushing the microbes beneath the surface, so to speak. Time and again, microbes had to be rediscovered. After the days of Van Leeuwenhoek and Robert Hooke the interest in microbiology declined and for many decades only a few people studied bacteria.[39] Until Louis Pasteur and Robert Koch ushered in the 'golden era' of microbiology (the second half of the 19th century), interest in and awareness of the importance of microbes had more or less come to a standstill. Microbes were virtually forgotten, even by the scientists themselves, until Pasteur and Koch rediscovered their existence. It took the "crusading spirit of Pasteur, his zeal and skill as a polemicist, to drag the microbes out of the obscurity into which they had passed once more".[40] He brought them back to life again. The era of Pasteur and Koch was a moment of Renaissance and rediscovery. Microbes are recovered and subsequently forgotten, time and again.

Yet, Pasteur and Koch allowed microbes to emerge *in a certain manner,* namely predominantly as a threat looming from the outside. Microbes were seen as entities that indicated their invading presence notably through symptoms of disease. Likewise, for Freud, their psychic counterpart, in the form of the unconscious, was a kind of looming Id, a hidden entity that engulfed people's minds and hampered their effectiveness.

Contemporary genomics-based microbiology, however, allows microbes to emerge in a completely different and much more positive light, namely as a symbiotic source of energy. Thus, insofar as our microbiome can be regarded as our "hidden realm", as our "unconscious", we now discern that we should not think of it in terms of the 19th century "threatening" unconscious, as framed in the writings of Freud, but rather in terms of a "productive" unconscious, as is done in the writings of authors such as Gilles Deleuze and Felix Guattari who reframed psychoanalysis during the final decades of the 20th century. Although Freud can be credited with discovering the unconscious, just as Pasteur and Koch can be credited with (re)discovering microbial life, he more or less lost touch with it again, these authors argue. For them, the unconscious is not something which is blocking or hindering us, interfering with our societal or erotic performance. Rather, they reframe it in terms of productivity. "It (the unconscious) functions, it is basically productive, and on an molecular level."[41]

Our bodies are pervaded by the molecular productivity of desire. We are biochemical factories and assemblies of organic machines. Whereas according to Freud our unconscious activities and desires must be restrained by the prohibitions of society, preventing us from satisfying our desire and resulting in a sense of guilt and chronic malaise, Deleuze and Guattari rather argue that this scheme basically reflects the 19th century Victorian objective of domesticating one's desire, the anxious striving towards taming nature, notably the unconscious sides of it. Human life thus became a kind of anthropocentric stage where triangular (oedipal) relationships between humans as *individuals* were played out. What tended to be forgotten, left out of the picture, was the world of labour and productivity, the transformation and circulation of matter, both on the societal level and on the level of bodily existence. According to Deleuze and Guattari, the unconscious must now be seen as a biochemical factory rather than as a stage setting and should be spoken of in terms of productivity and biochemistry rather than in terms of (neurotic and suffocating) triangular relationships. There is continuity, rather than discontinuity, between libido as a molecular and biochemical phenomenon on the one hand and the world of labour, art and scientific research on the other. Instead of a domesticating approach of unconscious desire, Deleuze and Guattari stress the productive and dynamic nature of bodies, organs, cells, amino acids, genes and – last but not least - of microbes, the silent labourers in the factory of human life.

Their understanding of the unconscious was explicitly inspired by the new life sciences emerging in the latter half of the 20th century, exemplified by authors such as Jacques Monod. When Vesalius opened up the fabric of human anatomy, microbes were still subliminal entities. In the course of the 20th century, however, we became aware of the plethora of processes in which they are intimately involved. They are the "masses", the millions of anonymous workers who are operating our molecular machines. Microbes are the unconscious at work, as a part of nature in the sense of *natura naturans*, producing human activity and human desire. Modern genetics and biochemistry, rather than Freudian reinterpretations of ancient Greek myths, allow us to come to terms with it.

The quotation taken from the letters of Vincent van Gogh, cited at the beginning of this section, may be seen as an articulation of this view. Van Gogh was pondering over his brain and wanted to find out what was wrong with it. Conversations with psychiatrists served as an important source of inspiration. Whereas nowadays psychic phenomena are explained in terms of the functioning or misfunctioning of neurotransmitters such as dopamine, in those days pathological moods were attributed to the presence of microbes in human brains. In the era of Pasteur and Koch, diffuse ideas concerning the microbial unconscious were beginning to spread. At a certain point they reached the letter-writing artist in his secluded psychiatric ward. For him, the insight that various phenomena of human life are the outcome of microbial processes, and that microbes are involved in our basic physiology and psychology, was, it seems, a liberating one. Apparently, his aberrant moods involved the work of microbes. What for Van Gogh was something of an artistic intuition can nowadays in the microbial genomics era be articulated and explored much more explicitly in biochemical language. How do these new views of life allow us to reformulate our position in the living world, notably in terms of our responsibilities towards other living beings?

New covenant with nature?

With just 1,600 giant pandas estimated to remain in the wild, Chinese scientists have led the task of immortalizing the charismatic critter's 2.25 billion base pairs of DNA… Although it is unlikely to have any significant effect on conservation, the work is a proof-of-principle for next-generation sequencing technologies… Indeed, one tactic for researchers hoping to win funding may be to sequence similarly patriotic symbols."[42]

As genomics reveals and underscores our chronic and fundamental dependence on other living beings, it may have a significant impact on our relationship with the rest of nature. We could call this the "cultural" impact of genomics. The "genomics world view" may give rise to a more humble vision of ourselves, fostering a more sustainable attitude towards life on earth. But of course the very opposite may also be the case, in the sense that genomics provides us with novel opportunities to adjust our natural environment to our benefits and interests. The moral message of this paper is *not* that human existence submerges into the grand mire of life, but rather provides us – *in principle*, that is - with a broader understanding of the often detrimental impact we are having on the ecosystems that surround us. Whereas genomics entails a decentring of the human in genetic and biomolecular terms, our uniqueness as moral agents who are explicitly challenged to consider the consequences of our way of life is basically reaffirmed. On the basis of genomics information, we may develop an even more detailed view of our history and place in the world and this could strengthen the awareness of our responsibilities vis-à-vis other life forms.

Genomics libraries may help us to deepen our understanding of processes of extinction and to improve our programmes directed towards ecosystem management and population management of endangered species. At the same time, this may strengthen a rather "bureaucratic" view of nature, governing nature on the basis of assembled genomes rather than on the basis of real-life interactions and first-hand knowledge. Knowledge is power. This was already true for the practical knowledge of the first domesticators, but it is also true for contemporary genomics-based conservation programmes. Thus, although we cannot meaningfully think about the implications of genomics for humans without taking the environment into account, the mapping through genomics research of the environmental zone brings to the fore the impacts of our disturbances as well. Genomics challenges us to think about *ourselves* from the perspective of an ecocentric anthropology, and about our *environment* from the perspective of an anthropocentric ecology.

On top of the archetypal village, new types of high tech Arks have emerged more recently, such as DNA banks as informational Arks: storehouses of genomes, DNA collections and barcodes, complemented by tissue samples, cell lines, seeds and

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various other bio-objects. Thus, not life as such, but rather its genetic 'quintessence' is stored and preserved. Assembling the genomes of more than 4,000 species into our digital Ark, some of which are on the verge of extinction, does little to change the fact that concrete contributions to sustainability and biodiversity are limited as yet. As exemplified by the quote at the beginning of this section, for a species such as the panda to have its genome sequenced does not significantly enhance its prospects for survival. This rather depends on a complex constellation of practices, including deforestation. Also, the focus on a single species would be at odds with the ecocentric perspective engendered by genomics. Survival is a multiple-species phenomenon. Basically, it is an ecosystem that survives.

Most concrete examples of the contribution of genomics to biodiversity and sustainability come from bioremediation. Armies of microbes with optimal genomes for performing certain ecosystem services are injected into soil or water for ecosystem restoration and ecosystem management. Microorganisms can aid environmental restoration by oxidising, binding, immobilising, volatilising or otherwise transforming contaminants.[43] Microbial remediation is generally regarded as more nature-friendly than non-biological options. Yet once again, an ecocentric perspective is pivotal. What may work in particular environments may not work at other sites. Moreover, new possibilities for bioremediation may have detrimental side-effects as well. It may encourage new projects and experiments in the realm of geo-engineering and hazardous extractions of resources, hoping our new microbial allies will restore the damage afterwards. But what will inserted microbial invaders do to existing ecosystems? In other words, the genomics of particular microbial biota has to be combined with ecogenomics: the development of a broader, more comprehensive view of the functionings and vulnerabilities of real-life ecosystems instead of purely utilitarian uses of genomics. Most advances in genomics-based bioremediation are still experimental studies in vitro. Given the astounding complexities of ecosystems – and there is a tendency to underestimate the complexities and vulnerabilities of the ecosystems involved - genomics-based bioremediation is still in its experimental or trial-and-error stage. Here again, the promise of genomic technology remains something of the future rather than a present-day reality.

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[1] Radboud University Nijmegen – Faculty of Science; Institute for Science, Innovation & Society; Department of Philosophy & Science Studies - Centre for Society & Genomics. h.zwart@science.ru.nl

[2] "The race to complete the first human genome sequence had everything a story needs to keep its audience enthralled – right down to a neck-and-neck sprint for the finish by two fierce rivals. In the end, the result was basically a tie". Editorial: The Human Genome at Ten. *Nature* 1 April 2010; 464 (7289): 649-650; Cf. H. Zwart. The Adoration of a Map. Reflections on a Genome Metaphor. *Genomics, Society & Policy* 2009; 5 (3): 29-43.

[3] http://www.genome.gov/10001356

[4] The Human Genome at Ten, *Nature* special issue; notably: F. Collins. Has the revolution arrived? *Nature* 1 April 2010; 464 (7289): 674-675

[5] "Sequencing centers turned to zoology, and the number of sequenced genomes of non-human species grew to today's tally of more than 3,800." J.C. Venter. Multiple Personal Genomes Await. *Nature* 1 April 2010; 464 (7289): 676-677.

[6] Cf. Freud (1917) cited in H. Zwart. 2007. Genomics and Self-knowledge. Implications for Societal Research and Debate. *New Genetics and Society* 2007; 26 (2): 181-202; Derrida (2003) cited in R. Twine. 2010. Genomic Nature Read Through Posthumanisms. In *Nature after the genome*. S. Parry and J. Dupré, eds. Malden / Oxford: Wiley-Blackwell: 175-194.

[7] S. Parry and J. Dupré. 2010. Introducing Nature After the Genome. In Parry and Dupré ibid: 3-14.

[8] "Wir lachen schon, wenn wir 'Mensch und Welt' nebeneinandergestellt finden, getrennt durch die sublime Anmaßung des Wörtchens 'und'!" Nietzsche, *Die Fröhliche Wissenschaft* V, 346. [We laugh as soon as we encounter the juxtaposition of 'man *and* world', separated by the sublime presumption of the little word 'and'." F. Nietzsche. 1887/1974 *The Gay Science [Die fröhliche Wissenschaft]*. Transl. W. Kaufmann. New York: Vintage Books.

[9] H. Zwart and B. Penders. Genomics and the Ark. An Ecocentric Perspective on Human History. *Perspectives in Biology and Medicine* 2011; 54 (2): 217–31.

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[11] A. Pope. 1924. Essay on Man, Epistle II, 290-291. In *Collected Poems*. B. Dobrée, ed. London: Dent; New York: Dutton 1959: 189.

[12] http://www.genome.gov/10001356. This phrase has subsequently been cited in a series of strategic documents, such as the Position Papers of the Standing committee for the Humanities and of the Standing Committee for the Social Sciences, entitled *Vital Questions.*

[13] E. Hayden. Life Is Complicated. *Nature* 1 April 2010; 464 (7289): 664-667.

[14] L.L. Cavalli-Sforza and F. Cavalli-Sforza. 1993/1995. *The Great Human Diasporas. The History and Diversity of Evolution*. New York: Basic Books.

[15] L.L. Cavalli-Sforza. 2000/2001. *Genes, Peoples, and Languages.* North Point Press, New York,.

[16] V.G. Childe. 1936. *Man Makes Himself*. London, Watts & Co.

[17] M. Jones. 2001. *The Molecule Hunt. Archaeology and the Search for Ancient DNA*. London: Allen Lane / The Penguin Press.

[18] H .Zwart. Biotechnology and Naturalness in the Genomics Era: Plotting a Timetable for the Biotechnology Debate. *Journal of Agricultural and Environmental Ethics 2009*, 22: 505–529.

[19] Jones, op.cit. note 17.

[20] "Biotechnology" is a highly contentious concept. Can it be applied to modification of living organisms in general, for instance in the context of the Neolithic revolution, so that it includes pre-molecular science, or should its use rather be restricted to a specific set of technologies developed quite recently in the form of bioengineering and genetic modification? Or should its scope of application be broadened even further so as to include molecular processes that evolved during the early microbial epochs of evolution, as Margulis and others have argued? I have addressed this issue extensively elsewhere (op.cit. note 18.). In this paper, references to pre-molecular "biotechnology" are placed between quotation marks.

[21] https://www3.nationalgeographic.com/genographic/

[22] (The) Bovine HapMap Consortium, Genome-Wide Survey of SNP Variation Uncovers the Genetic Structure of Cattle Breeds *Science* 24 April 2009; 324: 528-532.

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[25] M. Harvey, Animal Genomics in Science, Ssocial Science and Culture. *Genomics, Society and Policy* 2007; 3 (2): 1-28.
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Book Review

It Takes a Genome. How a clash between our genes and modern life is making us sick
Greg Gibson
Financial Times Press Science/Pearson Education, 2010

BART PENDERS[1]

Books about science for the general public are abundant. They are either written by scientists, keen on explaining what it is that they do and why this is so important, or by (science) journalists and writers, attempting to convey insight into how the world works. The former are sometimes bad writers and the latter are sometimes badly informed. Equally, the opposite is often true. However, Greg Gibson is a full professor of genetics both in the USA and in Australia. He knows his science and he demonstrates this by including a very long list of references. Furthermore, he is not at all a bad writer. The problem of this book is of a different character.

Let us first turn to the book's content and the claims Gibson makes. The book's mission, in Gibson's words, is "to explain how our genes make us sick. Secondly, it is to advance the thesis that they do so in large part because the genome is out of equilibrium, with itself and with the environment." (p. ix) Not only is this an ambitious goal, it remains somewhat unclear what Gibson means by this. His attempt to clarify is not very helpful: "Our genes are 'not in a happy place.'" (p. ix) The author promises a lot of examples though, which might help shed some light on the matter.

Before Gibson embarks on a discussion of many classes of diseases, he introduces the notion of the *adolescent genome* to the reader. The adolescent genome is not the genome of an adolescent, but rather an indicator, Gibson's evaluation of the evolutionary status of the human genome as compared to other species and their surroundings. Gibson argues that the human genome is not yet suited for the environment humans live in - as opposed to, for instance, the crocodile genome and the crocodile habitat. The key is in the 'yet': Gibson ends his book by suggesting that "if we come back in a few million years, perhaps we will find that our adolescent genome has evolved to a more mature equilibrium" (p.149). The analogy is confusing, especially since the path from adolescent to adult is, biologically, fixed, while the evolutionary trajectory the human genome will take is unpredictable at best. While the notion of the adolescent genome and the proposition that equilibrium can be attained make for very interesting discussions in theoretical evolutionary biology, they are confusing in a book that attempts to "explain how our genes make us sick".

The body of the book is devoted to discussion of a number of classes of diseases. Gibson visits, in order, cancer, diabetes and obesity, asthma, infectious diseases, mental illness and Alzheimer's. Many of these diseases act as exemplars for others. For instance, asthma invites the author to venture into autoimmune diseases. Given

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the variety of these classes of diseases, unsurprisingly, the role of genes and genomes in each of these is very different. Gibson provides scores of examples of genes and discusses the basics of how epidemiological research generated knowledge about the gene, what it does, which alleles exist in which ratios and much more. We hear, for example, about TCF7L2, a gene that emerged from whole genome scans. It codes for a transcription factor and a particular variant of the gene may account for "20 per cent of the incidence of diabetes in Africans and Europeans" (p.59).

The chapters are by no means symmetrical discussions. In fact, they are hardly comparable, since the genetic or genomic element is radically different. In his discussions of AIDS, Gibson fails to "explain how our genes make us sick". He shows how susceptibility varies according to genomic variation – a strategy he also uses in his discussion of mental illness.

From time to time, sticking to his main argument appears to be hard going. Gibson makes some creative interpretations and resorts to statements such as, "Depression is one of the most genetic illnesses there is, yet paradoxically no one has been able to find a gene for depression." (p.109)

It Takes a Genome presents us with an interesting yet quite chaotic collection of genetic epidemiological facts. Each of these facts is an interesting snippet of information, and combined they may lead us to reflect upon how our genomes and ourselves relate to one another. One would expect this to leave room for multiple positions. Gibson, however, has set up his book as a college textbook. Each chapter starts with half a dozen claims that will be discussed and, apparently, ought to be remembered (do we get a test?). For instance: "Type 1 diabetes. The rare form of diabetes arises because a child's own body destroys the pancreatic cells that make insulin" (p. 41). Additionally, throughout the text, Gibson highlights key phrases. He decides what the important facts are and what is worth remembering. The book suggests that there is only one way to read and remember it properly.

This leads us to an important observation. The design resembles a text book, yet college students will not be impressed. They presumably know all the facts, or at least where to find them. The analogies, the context of information and the method of presentation vary enormously. Gibson talks down to the more informed reader by referring to genes as petty criminals, and making fun of their boring names. He spends significant parts of each chapter listing which celebrity suffers or suffered from which disease. (To those interested in celebrity genomes, a warning to the European reader: many of the American sports celebrities I had never heard of.) In the chapter on "Genetic AIDS", Gibson deviates from listing celebrities at the start of the chapter. He sticks to a single fictional patient: Tom Hanks' character in the movie Philadelphia.

In other instances, he estranges those who might be less informed. He suggests that people go and look for themselves at publications on PubMed. While GSP readers, for instance, may find that worthwhile and perhaps even exciting, it will simply be out of reach of most of Gibson's readers since most of the academic texts require expensive subscriptions – not to mention the amount and complexity of information PubMed hosts. More striking is his explanation of what DNA is. In a book on the human genome one would expect a proper introduction, especially considering the numerous

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references in the book to mutations, deletions, codes, codons and SNPs. Yet Gibson refers to DNA as "consisting of four letters, A, T, G and C, strung together in long molecules" (p.15). That seems a bit brief.

Aside from all sorts of genetic epidemiological facts, Gibson focuses mostly on a single take-home message: the human genome is in disequilibrium with itself and its environment. But what does this mean? He argues that our genome is young, yet our lifestyles are a lot younger. The young genome 'explains' the internal imbalance, while our even younger lifestyles ought to 'account for' the imbalance between genome and life. By 'internal imbalance' Gibson seems to mean that a number of characteristics of the human genome are not optimal, including, but not restricted to, that genes work and collaborate improperly, or that certain alleles exist in unexpected ratios, thereby allowing unwanted characteristics to proliferate.

The posited imbalance between genome and lifestyle is more complex. Our environments can make us ill: pathogens and toxins surround every one of us. Depending on your lifestyle, you may or may not have frequent exposures to them. Gibson's point seems to be that it is our genome's responsibility to deal with these threats in such a way that no disease arises. This leads me to wonder whether this is the balance he refers to? It hardly seems reasonable to wait another 10,000 generations for our genome to evolve to such a state, especially considering that by then our lifestyles are likely to have changed exponentially. The equilibrium Gibson craves is utopian. I would have preferred Gibson to invest in a sensible and reflexive evaluation of our lifestyles against the backdrop of our genome. Gibson's equilibrium may make (some) sense from an evolutionary point of view, but it completely disregards the social realities of our lives.

Gibson succeeds in showing that the genetic component of disease is always only a component. Without explicitly mentioning it as his goal, he debunks notions of genetic exceptionalism and genetic determinism. Especially in his discussion of cancer, he spends a significant amount of time explaining the difference between heritability and genetics – well worth the effort. However, these strengths are outweighed by the book's weakness: *It Takes a Genome* offers something to many audiences, but not enough to any one of them. It meanders between a text book on genetic epidemiology, a lay guide to the genome, a theoretical evolutionary genetic argument and a gossip guide to celebrity genomes. It combines an ambitious claim with a chaotic execution and I would have to test my imagination to determine to whom to recommend it.

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Book Review

Ordinary Genomes: Science, Citizenship, and Genetic Identities
Karen-Sue Taussig
Duke University Press

MASAE KATO[1]

Ordinary Genomes is an ethnography of clinical genetics practice in the Netherlands, written by US anthropologist Karen-Sue Taussig. By looking at the case of the Netherlands, this book aims to illuminate the way specific scientific knowledge – in this case genomics – which is generally presumed to be universal is in fact understood, interpreted and practised in local cultural contexts. Taussig stayed in the Netherlands between 1993-1994 to conduct field research. She traces the interplay of genetics and local culture through everyday experiences of Dutch people as they encounter genetics in both their personal and professional lives. Her field research sites thus include dinner tables and bus journeys, as well as participatory observations at a genetic clinic.

Taussig selects the Netherlands as a field of study for two reasons. First, the country clearly illustrates the way genomics can be a site for articulating national identity and demonstrates the way such phenomena are incorporated into genomics as it is integrated into daily life.

Second, the choice of the Netherlands is a good attempt to go beyond the traditions of conventional anthropology. It challenges the attitude frequently prevalent in anthropology to view the West as a monolithic construct and not as a category of analysis (pp. 6-7). By looking at the Netherlands in this way, she also challenges the tradition of genomics as an academic discipline. Genomic knowledge is usually believed to be neutral. But in this book Taussig explores the notion that genomic knowledge is also culturally made, showing interactions between local values and the practice of science through her anthropological field research method.

In short, Taussig's book is an attempt to say something new in the fields of both anthropology and genomics.

Field research

One central focus of Taussig's ethnographic analysis is based on her participatory observation at the weekly meeting, known as the audit, held among the geneticists in the genetics clinic where she conducted her field research. There, she observes the way their clinical practice is produced. She contends that: "The clinical practice is produced through a convergence of medical practitioners' desire to identify and pathologise difference, Dutch practices of recognising and bounding difference, and Dutch values about ordinariness."(p. 85) She pays special attention to the way difficult cases are diagnosed. According to Taussig, clinical geneticists in the Netherlands tend to try to fit the person into a scientifically or medical defined category in which she or he may be perceived as normal, rather than classifying an

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individual with a genetic anomaly as abnormal (p. 87). This process produces multiple categories of normal, each of which is contained within distinctly classified genetic conditions. Taussig explains that this attitude of normalisation is not only observed by clinical geneticists but also practised by patients. For example, she cites a pregnant woman who says she would not mind if her child has difficulties in learning, because "We aren't very intelligent either. It would be very difficult for us to have a child who was very clever. It would be worse for us if you told us that we should expect a child that is very smart." (p.131) This example is intended to demonstrate the way that testing facilitates the possibility of making and maintaining groups of people with genetic abnormalities who are 'ordinary' and just like anyone else.

She further contends that viewing everything as ordinary, or normalising, is an attitude practised in every corner of daily life in the Netherlands. Using a casual conversation with friends as evidence, she tells us, for example, that in the Netherlands people are regarded equally whatever their academic achievement, which is not necessarily the case in other countries. She suggests that this attitude of Dutch normalisation goes back to 'pillarization', the history of the Dutch way of dealing with religious pluralism.

Pillarization and "the production of ordinariness"

The term 'pillarization' (*verzuiling* in Dutch) was first used by the political scientist J. P. Kruyt to describe the peculiar nature of the social structure and political institutions in the Netherlands. During the 20th century, Dutch society was divided by cross-cutting class-based and religious cleavages into four dominant interest groups or blocs – Catholics, Protestants, Socialists, and Liberals – around which virtually all politically and socially relevant organisations and group affiliations were formed. The bloc which shared the same religious and political relevance is called a pillar. Both religious blocs incorporated sections of the working and middle classes, whereas the secular forces divided along class lines (working-class Socialists; middle/upper-class Liberals). Separate political parties represented each bloc (two for the Protestants) and politics was characterised by bargaining and accommodation between them. Many other social institutions were similarly constituted across the trade unions, media, voluntary associations, social welfare, and education. Patterns of social formation and social relations such as friendship, marriage and job recruitment were also affected. In each pillar, common values were strictly maintained, although they might differ widely from values in another pillar. In this system, each of the different sets of values could still be regarded as normal/ ordinary.

Towards the 1970s, as religion became less central to Dutch life, the pillars ceased to function in quite the same way. Yet the way Dutch society deals with sameness and difference is much the same, according to Taussig. Under the system of pillarization, she argues, ordinariness imposed consistency by situating all individuals within a group and demanding that they conform to characteristics that are socially understood. Thus, not to be different, or to be '*gewoon* (normal)' in the group you belong to, is important in Dutch society. She contends that this is exactly the practice within the genetic clinics when abnormal cases are encountered, namely, creating a category and fitting the case in there to render it ordinary.

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Dutch practice of tolerance

Although the history of pillarization dates back to long before the Second World War, what was seen as uniquely Dutch prior to the occupation was strengthened after the war in the process of nation-building, and the exercise of pillarization during the post-war period is a case in point. Taussig argues that the practice of normalisation is reinforced by the Dutch shared memory of Nazi Germany.

She uses the example of posters distributed by local animal protection activists protesting against biotechnologies using humans and animals, contending that these echo Dutch cultures of ordinariness and tolerance. For example, one poster against the genetic manipulation of animals bears the phrase, 'Soon with Blond Hair and Blue Eyes?', reminding us of Nazi ethnic cleansing. "[T]he explicit reference the posters make to genetic manipulation and their implicit allusion to eugenics … arouse Dutch memories of the Second World War and antipathy toward Nazi science."(p.162)

In other words, Taussig suggests, the protest poster is telling us that biotechnologies should not manipulate genes and that animals (and humans) should stay as they are, because they are normal as they are. Taussig further contends that a practice of ordinariness is supported by a cultural value of tolerance. The Dutch ideal of tolerance, she argues, is constructed in opposition to the intolerance they perceived in the Nazi program of ethnic cleansing. Taussig contends that the Dutch facilitate a cultural value of tolerance by segregating and containing differences in order to minimise their social threat. It is within this peculiarly Dutch way of practising tolerance that they deal with the meaning of genetic difference. Taussig concludes that genetics may "serve as a powerful negative symbol of contemporary life … through its association with popular understandings of the legacy of Nazi science and the potential transgression of socially valued categories such as tolerance" (p. 186).

The book's premise can be summarised thus: the cultural identity of the Dutch, including national memory, transforms and influences the nature and functioning of the Dutch approach to and practice of clinical genetics as well as the Dutch understanding and perception of this practice. Genetics may transform society, Taussig concludes, but society also transforms genetics.

Discussion

In that there is not much work in English written so intensively about the Netherlands, and as a basic introduction to Dutch history and cultures, this book is certainly of value. The history of pillarization is succinctly summarised.

However, I wonder to what extent this analysis is applicable to contemporary Dutch society. Society in the Netherlands has changed drastically since 1993 and 1994, when Taussig was undertaking her field research. The assassinations of Pim Fortuyn, a politician against multiculturalism, in 2002 and of Theo van Gogh, a film maker outspoken against Muslim culture, in 2004, were shocking incidents which escalated xenophobia and fear of multiculturalism. The establishment of overtly right-wing political parties – The Party for Freedom (de Partij voor de Vrijheid: 2004) of Geert Wilders and Proud of the Netherlands (Trots op Nederland: 2007) of Rira Verdonk for

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example – is a case in point. Values of tolerance and ordinariness have drastically changed in the Netherlands during the last decade. Dutch society is rapidly moving to eliminate differences as part of a new search for national and cultural pride, as well as for Dutch identity. In the field of health care, too, an increasing number of disorders, including some psychiatric disorders, are being put outside health insurance cover, which is a sign that more disorders are seen to be the individual's responsibility. They are seen as a deviation from the what is 'acceptable' and 'normal'.

In a book which focuses so strongly on notions of multiculturalism and tolerance, I must challenge an important point. The author focuses only on mainstream White Christian Dutch in her book: all the names of interviewees are European. The Netherlands today has more than 20 per cent of non-Dutch citizens, or '*allochtoon*'.[2] This is high compared to, for example, an ethnically rather homogeneous society such as Japan, which has only 1 per cent of foreigners in its population.

In other words, the question of who is Dutch is not asked. In contemporary Dutch society, the situation is not so simple as to say that Dutch are composed of Catholic or Protestant Dutch. There are a number of ethnic groups which do not fit in the 'pillars'. Even if more recent arrivals, such as Moroccan or Turkish people, are disregarded, what about Indonesian and Surinamese people, who have a long history of residence in the Netherlands? These issues need to be mentioned in the methodology, together with an explanation of why the author chose to define 'Dutch' as mainstream Dutch, and why she chose not to look at these minorities for her analysis.

Ideas about tolerance or what is normal (*gewoon*), key analytical concepts in this book, echo the way the 'mainstream' Dutch describe themselves. Living in the Netherlands one notices that the self-images of the Dutch people do not always correspond to their behaviours or to the way the society is governed. So, if ethnic minority Dutch were included, the idea of *gewoon* might look quite different, and so might what the Dutch see as 'tolerance'. Moreover, theoretical definition of these terms is necessary. Tolerance can be interpreted in many different ways.

Taussig's argument nevertheless provides an interesting case study of the interplay between science, culture and society. The book will be of particular relevance to scholars in medical anthropology, science and technology studies and health studies. This book will be of use to anyone seeking to explore the dynamics of history, religion, culture and their impact on the making of knowledge in natural science.

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[2] According to the Dutch Central Bureau of Statistics (CBS), the term *allochtoon* is defined as: 'a person of whom at least one of the parents is born in a foreign country': http://www.cbs.nl/nl-NL/menu/methoden/begrippen/default.htm?ConceptID=37.Aaccessed 7 March 2011. According to the Centraal Bureau voor de Satistiek (CBS), 3,433656 are *allochtoon* out of 16,663,562 Dutch population: Accessed on 7 March 2011.

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Book Review

Asian Biotech: Ethics and Communities of Fate
Aihwa Ong and Nancy N. Chen (eds.)
Duke University Press 2010

SORAJ HONGLADAROM[1]

Asia has become a global force not only in terms of the sheer size of its economy and population, but also as an increasingly strong player in the field of production of scientific knowledge and technological capabilities. In this collection, editors Aihwa Ong and Nancy Chen attemp to delineate the rather complicated picture of this emergence of science and technology in Asia, especially in biological sciences and biotechnology. A theme that recurs throughout this volume is that science and technology do not exist in a vacuum; rather, they are intricately interwoven with social, historical and cultural contexts, or “milieus”, a word that is often used in the book. As life sciences and associated technologies deal directly with human bodies and their biological components, they have a way of entering into these social and cultural contexts, including the distinctive value systems of the cultures across the Asian continent.

The main objective of the book, then, is to chart the interplay between bioscience and biotech on the one hand and these distinctively Asian characteristics on the other. Thus the book makes a valuable contribution to science studies, not least because it focuses on a rather neglected topic of how technoscience is embedded in a non-western context which is at the same time quite economically advanced. There is also an added dimension of how the economies in Asia co-opt biotechnology in order to advance their agenda of economic development and “catching up” not only with the countries in the West but also with each other.

There are many dimensions involved in looking at the effect of biotech upon Asia. Each chapter explores a question addressing a different social or cultural dimension: how India became a hub for clinical trials by the so-called Big Pharmas from the West; how human blood is imbued with deep cultural meanings associated with the very essence of “Chineseness”; how traditional Thai hospitality is employed as an asset for medical tourism in Thailand; how DNA becomes a tool in configuring national ethnicity in the case of Taiwan and China; how genetically modified food becomes a nationalistic tool in China; how the race to produce cutting-edge findings in stem cell research is imbued with deeply different priorities and values in Singapore and South Korea; how embryo and stem cell research is viewed with ambivalence and according to cultural specificities in Japan; and how international pharmaceutical companies create demand in a way that relies on cultural attitudes in India. The major countries of the continent, namely China, India, South Korea, Singapore, Taiwan, and Thailand, are represented here, but one wonders what the situation would be like in other Asian countries such as Vietnam and Indonesia, and

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looking at the Islamic countries in the Middle East would be interesting. But that would clearly call for another volume.

In her introduction Aihwa Ong argues for a “situated” ethics in which ethical considerations and discussions are not based on universalist assumptions, as is often the case among traditional ethicists, namely those who are trained in philosophy. According to Ong, ethical considerations should pay attention to social and cultural milieus, looking at how these milieus shape and are shaped by the use of science and technology rather than comparing the practice against a universal standard. However, a philosopher might reply that what Ong does is to ask a different question from the one usually asked by philosophers. Instead of asking whether a practice is right or wrong and whether the standard by which the practice is judged is tenable or not, Ong asks how the practice is part and parcel of the situated cultural and social milieu.

For example, in her discussion of cord blood banking in Singapore, Ong, an anthropologist, understandably looks at how the practice is imbued with meanings and how it engages in an interplay with values which are distinctively Singaporean and also Chinese. She explicitly states that her intention is not to discuss the ethical value of the practice – whether depositing cord blood for use when a future need arises for cells which can be developed from the cord blood, or even having another baby so that its tissues can be used to help treat a sick sibling, is ethically right or wrong according to some universal standard – but instead investigates how cord blood banking plays a role in understanding how Singaporeans think and feel. Thus Ong’s “situated ethics” seems to be less an author making ethical judgments and more an empirical investigation of a people’s cultural inclinations. Here “ethics” takes on another meaning which is more akin to how a group of people accord a set of values to a range of practices, reflecting their beliefs and cultures.

Ong also criticises bioethics as it is commonly practised, saying that it does not pay adequate attention to the situatedness of the practice. However, bioethicists might reply that looking at the situatedness of a practice or action is not the purpose of bioethics. When it comes to devising a guideline which should be accepted globally, a guideline for conducting therapeutic stem cell research, for example, some kind of more or less universal standard seems to be in order. There are two levels of philosophical argument: the content of the guideline itself and the justification of the content. One can certainly conduct anthropological investigations into how the debates purporting to lead to contributions to the international guideline are imbued with cultural values, but that is different from investigating the cogency of the justification of certain viewpoints on a practice.

For bioethicists, perhaps the most interesting topic in the volume is that of stem cell research in Singapore and South Korea. In her chapter, Charis Thompson details how the practice of stem cell research in those countries is interlaced with cultural and social components that are distinctively Asian on the one hand and purposefully international on the other. Hwang Woo-suk’s rapid rise to scientific stardom and his equally rapid fall and disgrace is common knowledge. What is perhaps less well

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known is that Hwang's research activities were cast in a distinctively Korean manner. Hwang cultivated his Buddhist belief in order to underline the way in which Buddhist, and hence traditionally Korean, values informed his research.[2] As a country which has undergone so much turmoil in its history, South Korea is conscious of the need to assert its national identity amidst its powerful neighbors in China and Japan. And in South Korea Buddhism is tied up with national values, with "Koreanness", so to speak. Thompson reports that Hwang's female assistants voluntarily donated their eggs "for the sake of the country", putting Hwang in the position of a national hero, and shows that it was only when his lab aspired to become a worldwide hub for therapeutic cloning research that he met with resistance from whistle-blowers who uncovered the scientific fraud which led to his downfall. For Thompson, Hwang's rapid rise and fall is symptomatic of a nation that demands recognition and acceptance from the world. The hope of the entire nation that South Korea would have the first laboratory in the world to succeed in conducting human cloning experiments rested on Hwang's shoulders. It is quite understandable that this pressure contributed to the rush to produce results that eventually led to Hwang's downfall.

Thompson gives a very different picture of practices surrounding stem cell research in Singapore. Instead of tying up the research in a university, Singapore built a large complex called 'Biopolis' to attract investors and scientists from around the world. While both Singapore and South Korea share the aspiration of using stem cell research to put themselves on the list of countries with advanced technological capabilities, Singapore tried to attract foreign scientists rather than cultivating its own, as South Korea did. Biopolis is a gleaming complex of buildings which equals the best biotech research institutions in the world. This international dimension of the Singaporean enterprise is enhanced by the fact that Singapore set up a very demanding set of ethical guidelines which are clearly intended to put the research activity in the country on a par, both ethically and scientifically, with that in the West. Similarly, the ethical standard in Singapore is intended to align perfectly with that of the international community of scholars. Thompson remarks that this is one clear difference between stem cell research in South Korea and in Singapore. While in the former ethical standards have sometimes been shunted aside in the rush to produce national glory, in Singapore national glory is achieved through aligning with the prevailing ethical standard of the global community. This attempt to align itself with the global community reflects the desire of Singaporean leaders to set the island nation up as a global hub of advanced scientific research, a position which will translate into a leading position in today's knowledge economy.

Ethics is clearly but differently involved in both the South Korean and Singaporean cases. In Hwang's case in South Korea ethics was somehow bypassed in the rush toward national pride; however, in the Singaporean case, an ethical standard was actively cultivated as a means by which Biopolis gained international acceptance. Here, one is not talking about ethics in the usual way of judging whether an action is right or wrong and for what reasons, but ethics as an instrument by which the locals attain their goals. This is a clear example of Ong's situated ethics. There is also a connection between ethics as practised by bioethicists and philosophers on the one

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hand and ethics as a tool observed and analysed by anthropologists on the other. The strict observance of international ethical guidelines in the Singaporean case seems to show, at least as hinted in Thompson's paper, that ethics functions not so much as a set of principles that informs the work of those involved in stem cell research, but more as a tool by which the local site gains international recognition. One could reflect upon the very ethics of using ethics as a means to gain recognition. Furthermore, in the South Korean case, one also sees how ethics itself is embedded in a larger context. Apart from the scientific fraud, which is unforgivable, the willingness of Hwang's female assistants to donate their eggs for the cause of national glory could be a subject of ethical debate. Thus one sees how these two ways of looking at ethics can themselves be brought to bear on each other.

Bioethics and the social sciences, therefore, do not appear to be as separated from each other as it might at first seem. At any rate, what bioethicists could learn from anthropological investigations like those presented in this volume is that one should consider the social and cultural contexts in which the practice to be ethically assessed is embedded in order to understand the the practice more thoroughly. And it is this more thorough understanding which will lead to a more nuanced and better refined ethical judgment. It is easy to judge Hwang's conduct as unethical, but when one considers the pressure and the weight of expectation he was under, one gains a more complete understanding of what he went through. Of course this does not exonerate his wrongdoings, but we gain a wider perspective on why he did what he did.

Another interesting paper in the volume looks at how the demand for clinical trials of newly developed drugs has spurred the development of sophisticated specialised organisations in India. Kunshik Sunder Rajan discusses the emergence of clinical research organisations (CROs) in response to the demand from multinational pharmaceutical companies for outsourced clinical trials. Here Ong's situated ethics is at work again. In order to gain international acceptance and certification and to meet global standards, these CROs need to follow closely the guidelines set up by the international community. One cannot fail to notice the similarity of this case with the Singaporean one mentioned earlier. In the Indian case, the CROs follow strictly the guidelines governing research protocols on research on human subjects. Rajan describes how the physical set-up of a typical CRO, its choice of research participants and its conduct of the trials, all follow the guidelines very closely. This is necessary because the CROs want to be on the map as viable service companies for the global pharmaceutical industry. Rajan, however, mentions (several times) that ethics here means nothing more than collecting informed consent forms. What is left unmentioned in his paper (perhaps intentionally) is the contrast one perceives between the letter of the ethical guidelines and the actual lives and subjectivities of the Indian research participants themselves. Rajan makes sure that his analysis yields a more nuanced picture than just to portray global pharmaceutical companies as exploiting the poor Indian villagers. , yet it is nothing but the strict observing of the ethical guidelines that makes the picture more nuanced. CROs try to meet international standards by following ethical guidelines, which according to Rajan are constituted by nothing more than the informed consent form. Here one senses a thinly veiled criticism of ethics itself,. Ethics is presented more as a part of the international procedure whereby the organisation meets the standard than as a principle that governs the value of the action of the CROs and the global pharmaceutical companies themselves.

By criticising ethics, or more accurately by criticising the way ethics has been co-opted by CROs, Big Pharmas, and the international research ethics community itself, we find again a possible congruence between the ethics of philosophers and bioethicists and the kind of situated ethics that Ong and Chen present in this volume. The criticism of the appropriation of international ethical guidelines as a means to gain international standard means that ethics has ceased to be the governing principle of one's own action and decision making. In an ideal world ethics should be a part of one's action, such that whenever one makes a decision or performs any action one does so with full consciousness of the rightness of what one is doing, with all the right reasons, or at least the reasons that one is fully and sincerely convinced to be right. But what we see from Rajan's and from other chapters in the book is another matter. Ethics has ceased to be the governing principle in the minds of the performer of the action, and has become a mere tool, a mere front-end, by which one presents oneself to meet whatever standards or guidelines are required by the global community. Yet by the very act of raising this point, the authors in this volume show that ethics as a normative discipline, as a tool by which the value of an action or a set of practices may be criticised, is still viable after all. The sheer description of what is taking place in these Asian countries and the description of how ethics has been appropriated, can indeed be viewed as part of an *ethical* judgment in itself, something that philosophers have been doing all along.

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[2] Tae-Ho Kim, "Is Religion Hostile to Biotechnology?: The Case of South-Korea," paper presented at the International Workshop on "Asian Biopoleis: Biotechnology and Biomedicine as Emergent Forms of Life and Practice, January 6 – 8, 2011, Asia Research Institute, National University of Singapore.

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Book Review

Frameworks of Choice: Predictive and genetic testing in Asia
Margaret Sleeboom-Faulkner (ed.)
Amsterdam University Press 2010

CARLA VAN EL[1]

This edited volume offers a rich collection of case studies on predictive and genetic testing in Asia. Referring to the growing body of bio-ethical scholarship in Asian countries, editor Margaret Sleeboom-Faulkner argues that this book makes a case for a social science approach. This, she suggests, would allow for a better understanding of the context and implications of new genetic technologies and would put bioethical reasoning into perspective. For the theoretical analysis of the findings some key concepts are introduced, such as *frameworks of choice*, which draws attention to the circumstances and socio-economic background delimiting and conditioning the choices of individuals, families and communities. How people deal with their choices in the light of their experiences and their ways of coping with disease is referred to as *ramifications of choice*.

The chosen format will appeal to a wide audience because each chapter addresses different aspects and examples of genetic testing and screening in countries as diverse as Sri Lanka, India, Japan and China. The accounts, which are based on original field work or interviews, draw upon a range of cultural, economic, political and historical factors relevant for genetic testing. In the concluding chapter the editor summarises overarching themes and discusses general trends, such as the rise of commercial services and direct-to-consumer genetic testing. In the aforementioned countries, with the exception of Japan, genetic services are not widely available. In larger cities, hospitals and sometimes commercial enterprises offer genetic services and counselling that may not be available for the majority of the urban and rural population because they are too expensive or too far away. If genetic services are available, often infrastructure or funding for follow-up and treatment or interventions are lacking.

The 'therapeutic gap' is, for instance, discussed by Simpson in a chapter on screening for Down syndrome in Sri Lanka. In this context this term refers to the lack of intervention available after testing, because abortion is officially forbidden in Sri Lanka. In some cases women may obtain illegal abortions after an unfavourable test result. In Kumar Patra and Sleeboom-Faulkner's account of genetic screening for sickle cell disease in rural and tribal communities in India, the therapeutic gap becomes painfully clear. Sickle cell disease is a haematological disorder that does not raise problems in carriers (heterozygotes), but children of two carriers have a one in four chance of developing the disorder. Kumar Patra and Sleeboom-Faulkner discuss several screening programmes that are offered by state or private initiative, including charities. People that come to the hospital or screening centre are tested and periodic screening camps can be organised in a region, sometimes in combination with health check- ups. In some cases whole villages are tested after agreement with the village community leaders. But in cases where test results show that a person has the disorder, treatment is not always available. Test results may be communicated in ways that allow other villagers to learn each other's carrier status. A host of ethical issues arise: privacy and informed consent are not guaranteed; the test result may be misunderstood by confusing

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carrier status with having the disorder; and carriers may be stigmatised, making it difficult for them to find a marriage partner.

Discrimination and stigma are a relevant theme in many accounts. Having a disabled child or family member may have serious consequences for other family members. In a chapter on testing for Duchenne muscular dystrophy, an untreatable childhood disorder, Sui and Sleeboom-Faulkner discuss how this affects genetic counselling in China. Genetic counsellors initially avoid being too explicit in explaining the hereditary character of the condition. Although the mutation can occur spontaneously, in two-thirds of cases it is passed on via the mother. Counsellors fear that the family of the mother may be held ‘responsible’ for passing on the disorder. If mothers were to be abandoned after a positive test result, their prospects would be grim.

Several authors discuss how religious beliefs may ‘explain’ a genetic condition, for instance the belief that a person or a family must have done something wrong in a previous life. Though this may further stigmatise those with the condition, they sometimes seem to express acceptance of it as being something they ‘need’ to experience. It would be interesting to compare these concepts with Western accounts of having a disabled child or family member. Although religious frameworks may differ, concepts such as destiny, fate and the notion of being ‘tested’ may show convergences in relation to coping strategies.

Kato discusses the complex context of prenatal testing in Japan. On the one hand, discrimination and stigmatisation occur when people have a handicapped child, which may lead to a greater uptake in prenatal testing. On the other hand, there is a strong coalition of feminists and the disabled rights movement opposing prenatal screening and testing as a form of eugenics. As Tsuge discusses in a chapter on experiences of prenatal testing in Japan, this opposition is grounded in experiences under the Eugenic Protection Law in force between 1948 and 1996, which limited the rights of disabled people to have children and allowed abortion of affected foetuses. Given the sensitivities in Japanese society regarding these recent eugenic policies, doctors are sometimes reluctant to inform pregnant women or prospective parents about prenatal testing nor, as far as maternal serum screening is concerned, are doctors required to inform them, thereby in fact lowering public knowledge and the uptake of prenatal tests. Kato suggests that it may also be the case that the whole idea of testing is more or less ignored by prospective parents as a strategy expressing faith in the strength and health of the family (including forefathers) and avoiding being associated with having bad genes.

The issue of free or autonomous choice, the cornerstone of genetic services in the West, surfaces in many chapters of this book. Raising a handicapped child is costly because of expenses for treatment and because it reduces the amount of time parents, particularly mothers, may spend earning a living. Families in Asia are often closely knit and for financial reasons as well as to avoid stigmatisation parents, parents-in-law or other family members may exert pressure to opt for predictive genetic testing for a late-onset disorder, or prenatal testing and abortion in case of an affected foetus. This is evident in the chapter by Gupta on genetic testing and screening in India and in the chapter by Saxena et al on genetic services in the same country. In the latter account it becomes clear that standards for quality assurance, such as laboratory standards, as well as guidelines for predictive testing do not always function. For instance, when a couple travels a long distance to the clinic, there simply is not much time for reflection between an initial counselling session and the performance of a test, as is recommended and standard procedure in many countries.

The issue of free choice is also prominent in Döring's chapter on prenatal sex selection in China and the abortion of female foetuses. The Chinese government strictly prohibits prenatal sex selection, in this case limiting free choice from the best of intentions. The alleged free choice considering this and related practices such as female infanticide and neglect of girls itself should be considered in a historical and social context, as Döring shows. The preference for males, especially in rural areas, is attributed to their qualification to continue the family lineage and their labour power. This is significant because in the 1980s the system of rural cooperatives and healthcare infrastructure at the village level collapsed. Though the consequences of these developments are not explained in detail, this probably made living conditions in rural areas more difficult. At the same time technological innovations such as ultrasound became available. The one-child policy had a further impact. In rural areas couples eventually were allowed to have a second child in case the first one was a daughter, but then a second daughter would be regarded as less desirable. It would have been interesting to learn more about the micro level of Chinese couples and health care workers performing prenatal screening, especially since Döring suggests there are signs that a family of four consisting of parents, son and daughter is becoming a preferred model. In some other chapters interviews work well in illustrating the arguments people use to justify their choices in a particular situation.

The role of the state, for instance in establishing regulatory frameworks, is explored in Porter's chapter discussing the lack of regulation for insurance companies in Japan on how to deal with genetic test results. Clients of medical insurance companies may be held responsible if they fall ill with or are diagnosed with a genetic disorder after the start of their contract. One of the drawbacks, which has also been observed in Western countries, is that people may not undergo testing out of fear of losing their insurance. Porter argues for a fair balancing of the interest of insurance companies to apply risk selection with the interest of the public in obtaining life and health insurance.

Market forces also feature in a chapter by Wallace on direct-to-consumer nutrigenomic testing. The idea is to test a person's genes in order to give tailored dietary advice or prescribe dietary supplements. However the validity of this advice is questionable, and may needlessly alarm people that they need certain food supplements to prevent illness. The relation between genetic variants and common disorders is complex. Genetic and environmental factors interact, and food metabolism only adds to this complexity. Wallace notes that the marketing of nutrigenenomic tests is seen by researchers in the field as premature at best. Another prominent concern raised in this chapter is that the research focus on nutrigenomics and the development of perhaps useless tests is not contributing in any way to the real problems of malnutrition and lack of food across large parts of Asia, and has a potential to undermine healthy eating messages.

A similar perspective examining globalising political and commercial forces is present in a chapter by Lee on pharmacogenomic research in different populations. There is at least some scientific evidence that genetic variation may be associated with response to certain drugs. Much research has focused on so-called slow versus rapid metabolisers, implying that the dosage of certain drugs may be adjusted to a person's individual genetic make-up. In some cases an alternative drug might be prescribed in the presence or absence of a particular genetic variant. Although the aim is personalised medicine, an important research strategy is to detect genetic variation in populations. As Lee argues, the International HapMap Project included individuals of Chinese, Japanese and north European descent, and Yoruba from Africa. Genetically speaking the Chinese and Japanese would not differ that much. Though for scientific reasons a greater diversity might have been better, both China and Japan could contribute to the investment and infrastructure necessary for the project. In this way a model of the 'Asian' genome is produced while many other specific populations in that part of the world are excluded from the research. This also holds for subsequent efforts to find specific 'national' genomes in the most prosperous countries, such as in China, Japan and Korea, linking national identity, race and biological specificity. Lee points out problematic social ramifications, such as defining who is, for instance, genuinely Korean. But a major concern is that populations would be unable to reap the pharmacogenomic benefits from a skewed 'Asian' genome. Lee therefore suggests focusing on individual rather than population genetic variation. One could argue, however, that with the advent of increasingly cheaper next generation sequencing, by comparing individual genomes from a variety of populations, we will increasingly be able to detect relevant genetic variation that may subsequently be tested at the individual level.

This volume provides the reader with valuable, detailed and localised information on the ramifications of genetic and predictive testing in a variety of settings. At the same time it bears testimony to the fact that in many cases we are not simply dealing with dissemination of a 'Western' technology in another part of the world. On the contrary, various countries and regions in Asia have become part of the global commercial and scientific mainstream. It is telling that in March 2011 newspaper headlines reported that Chinese scientists had obtained second place in the ranking of the number of articles published in scientific journals, authoring about 10 per cent of all scientific articles. Japan holds the fourth position and India the 10th. Learning more about the everyday practice of using genetic technologies in this part of the world is essential for everyone interested in the dynamic relationship between genetics and society.

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