Science as Culture
Vol. 00, No. 0, 1–25, Month 2009

Routledge
Taylor & Francis Group

Infrastructure and Scaffolding: Interpretation and Change of Research Involving Human Genetic Information

PETER J. TAYLOR

Programs in Science, Technology & Values and Critical & Creative Thinking, University of Massachusetts, Boston, MA, USA

ABSTRACT *This essay addresses the relationship of interpretation to change, at two levels. One level concerns the revolutionary claims of molecular biology and biotechnology about using genetic information, read literally or with a minimum of interpretation, to reshape human life. The other level concerns the relationship in social studies of science and technology (STS) between interpreting projects in the life sciences and influencing their direction. On that level, the essay is experimental, employing a series of vignettes that introduce themes and questions—scaffolding—intended to stimulate readers to make their own connections between interpretation and change, in science, STS, and society. The vignettes in Part 1, which range from treatment of individuals with PKU or MAOA genes to personalized medicine and biobanks, indicate in different ways that the use of genetic information always requires social infrastructure. Once attention is given to the actual or implied social infrastructure, the prospect of reshaping life using human genetic information raises more questions than it answers. This thread carries over into Part 2, which speaks to an area of STS that needs more development, namely, conceptualizing the structure of the social context of scientific and technological developments and the nature of human agency in the ongoing restructuring of that context. The vignettes create a picture in which the influence on science of an STS interpretation will, like any effort to produce change, depend on how it links with other engagements and with the heterogeneous components that make up ongoing, intersecting processes of science in society.*

KEY WORDS: Embryology, epidemiology, fundamentalism, genetic testing, heterogeneity, IQ, intersecting processes, life-course development, participation, racial differences, teaching, uneven development

Introduction

Gessen's genetic counselors recommended an oophorectomy. But Gessen balked . . .

Correspondence Address: Peter J. Taylor, Programs in Science, Technology & Values and Critical & Creative Thinking, University of Massachusetts, Boston, MA 02125, USA. Tel.: 617-287-7636; Fax: 617-287-7656; Email: peter.taylor@umb.edu

0950-5431 Print/1470-1189 Online/09/000001-25
DOI: 10.1080/09505430902946649

> Our culture doesn't yet have the infrastructure to handle the consequences of the recent revolution in genetic testing. But we'll need it ... [Review of Gessen (2008), *Blood Matters*, in *International Herald Tribune*, 10–11 May 2008].

In 1845 the young Karl Marx proclaimed that the 'philosophers have only *interpreted* the world, in various ways; the point, however, is to *change* it'. But what mode of interpretation should guide people in effecting change? That's no simple matter. Marx himself spent the following 40 years of his life elaborating his interpretation of historical and ongoing social transformations.

In 1865, Francis Galton sought to promote social progress by interpreting patterns in data drawn from human relatives. As Galton proclaimed early in his 40 years of research:

> If a twentieth part of the cost and pains were spent in measures for the improvement of the human race that are spent in the improvement of the breed of horses and cattle, what a galaxy of genius might we not create! ... Men and women of the present day are, to those we might hope to bring into existence, what the pariah dogs of the streets of an Eastern town are to our own highly-bred varieties (Galton, 1865, pp. 165–166).

Fast forward to 2008. Genomics entrepeneur, Craig Venter, and science communicator, Richard Dawkins, converse about change that flows, almost without interpretation, from information about organisms' genes:

> Venter: [W]e isolated the chromosome from one bacterial species and transplanted it into another one. The chromosome in the species that we transplanted into was destroyed, and all the characteristics of one species went away and got transformed into what was dictated by the new chromosome ... This was a precursor to being able to now design life ... And we have major problems we're trying to overcome by looking for solutions, changes in modern society.
>
> Dawkins: It's more than just saying that you can pick up a chromosome and put it in somewhere else. It is pure information. You could put it into a printed book. You could send it over the Internet. You could store it on a magnetic disk for 1,000 years, and then in a thousand years time, with the technology that they'll have then, it will be possible to reconstruct whatever living organism was here now. So, this is something which was utterly undreamed of before the molecular information revolution ... This is a major revolution. I suppose it's probably 'the' major revolution in the whole history of our understanding of ourselves (Venter & Dawkins, 2008).

This essay addresses the relationship of interpretation to change, at two levels. One level concerns the revolutionary claims of molecular biology and biotechnology about using genetic information, read literally or with a minimum of interpretation (construing the term broadly), to reshape human life. The other level, less grand in ambition, concerns the relationship in social studies of science and technology (STS) between interpreting projects in the life sciences and influencing their direction. Claims like those of Venter and Dawkins are fantasies, they involve worlds envisaged and mentally inhabited so as

to escape the practical difficulties of action (Robinson, 1984). In the material world many diverse materials, tools, and other people have to be engaged to realize any enduring result. Social *infrastructure* has to be built if human life is to be reshaped. This perspective matches interpretations in STS that emphasize the *heterogeneous engineering* or *construction* involved in establishing knowledge and making technologies reliable (Latour, 1987; Law, 1987; Clarke & Fujimura, 1992, pp. 4–5; Taylor, 2005, 93ff). However, two shortcomings in such interpretations concern me: more self-conscious attention is needed to how such interpretations are intended to influence change in science or technology and in society. In particular, more development is needed in the conceptualization of the structure of the social context of scientific and technological developments and of human agency in the ongoing restructuring of that context. (Readers: feel free to read *structuredness* in place of structure if the latter term connotes social systems, e.g. economics or the family, determining our action, for this is not my intended meaning.) This essay does not, however, spell out an argument about these shortcomings as much as it *distributes* them by supplying readers—scientists and interpreters of science alike—with pieces of *scaffolding* that might help them contribute to building infrastructure in their local situation that relates to reshaping the sciences of life. Before laying out those pieces, let me provide a little more introduction and motivation for this approach. (I add to this in the middle of the essay.)

For some time I have been concerned with a tension between simplicity and complexity, specifically between accounts built around simple themes that are readily conveyed and digested by a wide audience and accounts of the particular complexity of the diversity of things scientists do and the diversity of resources they use in the process of making science (Taylor, 2005, 167ff). I will return to the simple side shortly. On the complexity side, since the 1980s STS has highlighted the ways that scientists employ or mobilize equipment, experimental protocols, citations, the support of colleagues, the reputations of laboratories, metaphors, rhetorical devices, publicity, funding, and so on (see references above). My personal experience pursuing applied scientific research matched this picture. This led me to explore the idea that anyone wanting to influence developments in some area of science would benefit from having some kind of map of the complexity of resources or practical commitments involved in knowledge construction in that area. By exposing multiple places at which concrete alternative resources could be mobilized, such maps allow a range of researchers to identify specific changes that they could effect given their own particular background and interests (Taylor, 2005, 93ff, 148ff). In this way, a diversity of engagements that might change science can be guided by interpretations of the diversity of things scientists do in practice.

A consequence of this kind of interpretation is that each case of science-in-process has its own idiosyncratic complexity. However, in order to gain the attention of an audience wider than the group of specialists interested in the particularities of the given case, complementary approaches are called for. Suppose, as teachers and writers we still want our students or readers to delve into the complexities of particular areas of scientific activity with which they are engaged. It is hardly possible to provide maps of the complexity that each member of intended audiences faces, but we might aim to guide or inform the choices that they go on to make as they shape their paths into that complexity. It is in that spirit that I have employed one pedagogical/expository approach of using cases or scenarios to motivate themes of a certain kind: these cases are readily conveyed and digested at the same time as they open up questions and point to further work needed to grapple with

the complexities in particular cases (Taylor, 2005, 176ff). Another approach I have employed is *reciprocal animation* (borrowing here from philosopher Max Black's account of metaphor): close examination of concepts and methods within any given natural or social science can raise questions about the diverse social influences shaping that science. Analysis of social context can, in turn, suggest alternative lines of scientific investigation. This two-way interaction between science and the social contextualization of science significantly enlarges the sources of ideas about what else could be or could have been in science and in society. As an experimental variant of these two approaches, this essay presents two sets of vignettes intended to stimulate readers to make many different connections between interpretation and change, in science and in society.

Part 1: Critical Thinking about the Sciences and Technologies of Human Genetic Information

PKU: Responding to Genetic Conditions Requires Social Infrastructure(s)

> The man of the moment [was] J. Craig Venter, Ph.D., whose pioneering work to sequence the human genome—our essential code for life—had whetted public appetite for medical miracles in the diagnosis, treatment and prevention of even the most complex of common diseases. 'Imagine a world where families leave the hospital with their newborns and take their baby's complete genetic profile with them on a CD-ROM', Venter told his audience. 'And imagine a world where your physician has as part of your medical record your genetic code, which can be used to determine, for example, your risk profile for side effects from drugs or other medical treatments. These might be possible in a genomics-based medical system in the near future' (Massoglia, 2003).

'Imagine a world . . .' If the case of phenylketonuria (PKU) is any guide to our imagination, significant complexities should be expected to arise once neonatal diagnosis and advice about protective measures become widespread. PKU is a condition that many teachers about biology in its social context invoke to demonstrate that genetic does not mean unchangeable. Until the 1960s people with the PKU gene always suffered severe mental retardation, but now the brain damage can be averted through detection of newborns with high levels of the amino acid phenylalanine followed by a special phenylalanine-free diet. Yet, as Diane Paul's (1998) history of PKU screening describes, the certainty of severe retardation has been replaced by a chronic disease with a new set of problems. Screening of newborns became routine quite rapidly during the 1960s and 1970s, but there remains an ongoing struggle in the USA to secure health insurance coverage for the special diet and to enlist family and peers to support PKU individuals staying on that diet through adolescence and into adulthood. For women who do not maintain the diet well and become pregnant, high levels of phenylalanine adversely affect the development of their non-PKU fetuses. This so-called maternal PKU is a public health concern that did not previously exist. In short, a more complex picture of development in a social environment is needed for anyone to make use of the knowledge that the fate of individuals with the PKU gene is not determined at birth.

As we move towards the imagined world of abundant genetic information, we can anticipate debate about who is responsible/who is to blame if a baby is diagnosed,

protective measures are not taken or are not sustained, and the child becomes a retarded adult or mother of a child with maternal PKU. Scientists or interpreters of science who want to contribute to improving the lives of people affected by PKU will need to consider where we are prepared to get involved. Would the best point of engagement be around reduction in false positives or negatives, diagnosis of variability in effects of exposure, personal motivation and understanding of people with some mental deficits, support groups for individuals and families, insurance coverage for the special diet and for counseling, paid family leave, or . . .? In summary, a diversity of engagements are opened up—or, we might say, a diversity of interpretations of the genetic information are possible—depending on the scaffolding that different people can assemble to build or adjust the relevant social infrastructure.

Human Quadrupeds: Social Infrastructure (or its Absence) Makes Genetic Conditions Hardwired

'Family That Walks on All Fours' is a popular science documentary on the United States Public Broadcasting Network (2006). Five offspring of a couple in a remote area of Turkey have grown up walking quadrupedally on their hands and feet. The documentary describes various angles of research on the siblings: MRI brain scans show a reduced cerebellum, the region of the brain controlling balance and movement; genetic analysis identifies a mutation in a gene on chromosome 17 influencing cerebellum development; and evolutionary biologists try to link this gene to the evolution of human bipedalism three million years ago. Indeed, other deleterious effects of the gene are depicted as reversing the progress in fine motor coordination and intelligence that accompanied human evolution. Scientific disputes arise over these interpretations, but then it is also observed that no medical treatment or physical therapy has been available since the children failed to shift from crawling to walking upright. Following the introduction of a simple walking frame, then exercising between parallel bars, the quadrupedal adults learn to walk upright.

The quadrupedal condition may have been genetic in origin, but it was the social infrastructure—or lack thereof—that made it hardwired. Adjustments to that infrastructure then softened that wiring. Could the corollary also hold: the application of genetic knowledge to reshape human life will always involve reconstruction of the social infrastructure? Under what conditions—or crises—will that reconstruction become possible?

MAOA: Interventions through and in Social Infrastructure Implied by Knowledge about Gene by Environment Interaction

In 2002 Avi Caspi, Terrie Moffitt and colleagues published two articles in *Science* that examined psychological traits in relation to measured genetic and environmental factors. In one of them they reported on antisocial behavior in adults in relation to the activity of monoamine oxidase type A (MAOA) and childhood maltreatment (Caspi *et al.*, 2002). Their results are summarized in Figure 1. For people who experienced severe childhood maltreatment and have low MAOA activity, the average antisocial behavior was higher than if they had only one of the conditions and much higher than if they experienced low or no childhood maltreatment together with high MAOA activity. In other words, MAOA deficiency was a strong predictor of aggressive behavior only when the child had also been maltreated.

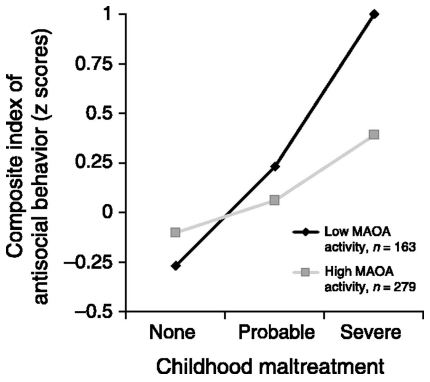

Figure 1. Average adult composite antisocial behavior score in relation to levels of MonoAmine OxidaseA and level of childhood maltreatment for a sample from Dunedin, New Zealand. *Source*: Caspi *et al.* (2002, p. 852), reproduced with permission.

The authors conclude that their results 'could inform the development of future pharmacological treatments' (Caspi *et al.*, 2002, p. 853). In the context of research on childhood experiences in relation to adult behavior, the implication of their conclusion is that, if low MAOA children could be identified, prophylactic drug treatment could reduce their propensity to antisocial behavior as adults. Or, to be more precise, such treatment could reduce their vulnerability to childhood maltreatment precipitating undesired adult outcomes. An easy rejoinder would be that, if childhood maltreatment could be identified and stopped early, this action could reduce their vulnerability to low MAOA levels leading to undesired adult outcomes. Indeed, eliminating childhood maltreatment would seem to be unconditionally positive, while prophylactic drug treatment may have side effects, and some of these may not emerge until later in life. The rejoinder is too easy, however. The social infrastructure needed to detect and prevent childhood maltreatment would intrude into many households, require surveillance, monitoring, and intervention by state agencies, divert government budgets from other needs, and so on. The specific outcome may be positive, but the means are not unconditionally positive to all. How would decisions about investment in the social infrastructure be decided? How would individuals decide where to engage with that social infrastructure once it is established?

Once the issue of social infrastructure is brought into the picture, more significant problems emerge with the idea of early detection and intervention on the basis of MAOA status. Notice that the points plotted in Figure 1 are the averages for the respective categories of people. Within each category people show a range of antisocial behaviors. It turns out that, among children who experienced probable or severe maltreatment, the ranges overlap, that is, some of the high MAOA individuals ended up with higher antisocial behavior scores than some of the low MAOA individuals. The potential for misclassifying people as ones who may end up antisocial is not eliminated by adjusting what counts as antisocial. If we count as antisocial only those individuals whose score exceeds some value that is higher than the upper limit of the range for high MAOA individuals, this increases the numbers of low MAOA individuals who do not end up counting as antisocial. If we lower the cutoff score, many high MAOA individuals end up with behavior classified

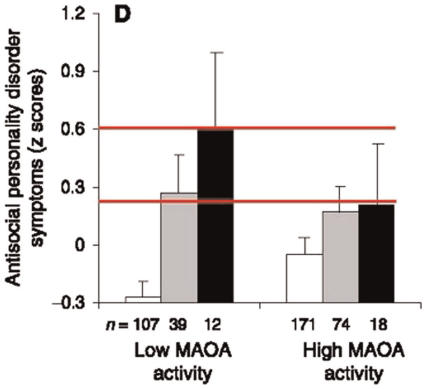

Figure 2. Average and standard deviation for adult antisocial personality disorder score in relation to levels of MonoAmineOxidaseA and level of childhood maltreatment for a sample from Dunedin, New Zealand. *Source*: Caspi *et al.* (2002, p. 852), reproduced with permission. Horizontal lines indicate the misclassification effect of a low and high cutoff for labeling a person as antisocial (added by author; see text for discussion).

as antisocial (Figure 2). Indeed, playing around with the cutoff score, the best that can be achieved with Caspi *et al.*'s data is a little more than one-third of children correctly classified on the basis of their MAOA status (i.e. low MAOA ending up counting as antisocial and high MAOA ending up not).

The issue of misclassification is especially troubling because, once the resources are invested to screen children for MAOA levels, attention would be focused on all low MAOA children. Indeed, how could this stereotyping be avoided if we do not know from a childhood MAOA assessment whether any particular individual is one who would go on, after maltreatment, to be an antisocial adult? Additional research would be needed to identify other characteristics that differentiate among the low MAOA children (and perhaps help predict who among the high MAOA children are also vulnerable). If that research were successful, additional resources would have to be invested to customize the way that parents, teachers, doctors, social workers treated the different low and high MAOA children and to educate everyone not to treat children according to their MAOA group membership. Just as in the PKU case, the meaning of new genetic knowledge (in this case in combination with environmental knowledge) is contingent on the presence or absence of social infrastructure; the positive benefits depend on extensive social reconstruction.

The Path to Personalized Medicine May Run through Social Stereotyping

Suppose the MAOA example concerned not antisocial behavior but a less charged condition, say, some specific adult disease. What kinds of conditions would receive the necessary investment in pharmaceutical and sociological research, screening, and preventative treatment/monitoring to address the conjunction of genetic and environmental factors involved? Well-organized parental advocacy groups may secure funding to address the prenatal diagnosis and postnatal treatment of rare debilitating genetic disorders (such as PKU). However, public and corporate policy would more likely focus on

conditions for which the number of vulnerable people times the average benefit of ameliorating the effect of the genetic difference would be large. (More precisely: the focus would be on conditions for which the benefit minus the costs of research, screening, and treatment were largest.) In such cases, if the MAOA case is any guide, if the effect of the genetic difference depends on identified social or environmental factors, and if variability within the groups that have on-average high and low vulnerability produces a problem of misclassification, pressure would arise to differentiate among individuals within the groups. Until additional research succeeded in identifying distinguishing characteristics, parents, teachers, doctors, social workers, insurance companies, policy makers, friends, and the individuals themselves could do no better than treating individuals according to their group membership. Indeed, if the additional research is not conducted or not successful, or if the cost of differentiating among individuals is too high, we might never get beyond treating individuals according to their group membership.

The scenario speaks to the prospect of personalized medicine. In its simplest form, this involves the use of genetic information to predict which patients with a given condition (e.g. heart aryhthmia) will benefit from a particular drug treatment (e.g. beta blockers). More ambitiously, personalized medicine promises to inform people of their heightened vulnerability (or resistance) to specific environmental, dietary, therapeutic, and other factors early enough to adjust their exposure and risky behaviors accordingly. If the MAOA analogy holds, the path to personalized medicine will, ironically, pass through a phase in which large numbers of people are treated according to their group membership. Moreover, this phase may not be a passing one. What conditions—what social infrastructure—can ensure that the information and resources needed to move beyond it are forthcoming?

The IQ Paradox: From Social Stereotyping to Developmental Pathways whose Heterogeneous Components Differ among Individuals

Flynn (1994) has pointed to large gains in average IQ test score between generations (now called the Flynn effect). No environmental factor, or composite of factors, such as diet or years of education, has been shown to be associated strongly with the generational differences (Flynn, 2007; Neisser *et al.*, 1996). At the same time, according to the current consensus, heritability of IQ test scores is high (Neisser *et al.*, 1996; but see Taylor, 2007). In parallel with this generational difference, persistent large differences in average IQ test score exist between racial groups. No environmental factor, or composite of factors, seems to be associated strongly with the group average differences (Flynn, 2007; but see Fryer & Levitt, 2004). This has led many psychometricians and human behavioral geneticists to make a two-part argument: the high heritability of IQ test scores within racial groups *coupled with* a failure of environmental hypotheses to account for the group differences supports—or lends plausibility to—explanations of mean differences in terms of genetic factors (even if these factors have yet to be elucidated) (e.g. Jensen in Miele, 2002, 111ff). There must, however, be a problem with this logic because it would also lead us to favor explanations of *generational* differences in terms of genetic factors, yet the change in gene frequencies in a human population over one generation is negligible. What is wrong with the two-part argument? Moreover, once it is discarded, how can large differences between generations (or racial groups) in this highly heritable trait be explained? These questions constitute the IQ paradox to which Dickens and Flynn (2001) draw our attention.

The logic that makes this a paradox is, however, flawed. Estimates of heritability derive from statistical analysis of variation in traits among related and unrelated individuals; this analysis involves no reference to measurable genetic or environmental factors involved in the development of those traits. Translation from this analysis to validated hypotheses about the underlying factors is difficult, even in agricultural or laboratory breeding where the variety of organisms and environment can be controlled and replicated (Taylor, 2006a). Indeed, heritability does not provide evidence that genetic factors are more significant than environmental factors in the development of traits (Taylor, 2006a, 159ff). Once this distinction between heritability and genetic factors is recognized, the two-part argument about average group or generational differences dissolves into a symmetrical situation: no environmental factor is associated strongly with the group or generational average differences, and no genetic factor is either (Nisbett, 1998, pp. 89–90).

Still, the large average differences between groups and between generations on IQ test scores remain to be explained. The puzzle becomes: how to expose the mix of genetic and environmental factors associated with those differences. Dickens and Flynn (2001) start by proposing reciprocal causation models, which involve two key features: a matching of environments to differences that may initially be small (e.g. children who show an earlier interest in reading will be more likely to be given books and receive encouragement for their reading and book-learning); and a social multiplier through which society's average level for the attribute in question influences the environment of the individual (e.g. if people grow up and are educated with others who, on average, have higher IQ test scores, this will stimulate their own development).

These models can be taken a step further. Once it is recognized that the potency of social multipliers depends on different groups' capacity to capitalize on historical changes in society, there is no reason to assume that the multipliers apply uniformly across individuals, given their differences in age, gender, geographical location, culture, and so on. It need not even be the case that the multipliers move different individuals in the same direction but at different speeds. To adapt a basketball analogy that Dickens and Flynn employ, the onset of TV coverage of basketball acted as a social multiplier by eliciting greater participation in basketball, but, at the same time, it elicited more couch potato spectatorship.

If researchers envisage developmental pathways whose heterogeneous components differ among individuals at any given point of time, the challenge the researchers face is to develop infrastructure, in this case, in the form of methods to collect and analyze the data so as to discriminate among possible models. Can statistical analysis be an aid, not an obstacle, in addressing such a challenge? After all, statistical analysis at its very foundations depends on comparing differences between averages in relation to the noise or error of variation around those averages.

Racial Group Membership and the Paradox of Emphasizing Heterogeneous Developmental Pathways

For researchers engaged in social change the possibility that heterogeneous pathways underlie the variation in any given human trait leads, in turn, to a puzzle (Taylor, 2006b; Flynn, 2000). If genetic factors are to be included in the models of development of traits, there are good methodological reasons for not categorizing individuals according to racial group membership [e.g. no measurable genetic factor admits a clean subdivision

between whites and African-Americans (Nisbett, 1998, pp. 89–90; see also Taylor, 2006a)]. On the other hand, racial group membership continues to bring disadvantages to African-American individuals and, reciprocally, to bring benefits to white individuals (Flynn, 2000, 142ff)—moderated somewhat, but in a decreasing set of circumstances, by affirmative action policies for African-Americans. Nevertheless, in order to ameliorate the effects of racial group membership for any individual it may still be necessary to have empirical models of the heterogeneous pathways of development, even if all those pathways factor in the effects of racial group membership.

Can researchers shift the focus from group membership to heterogeneous pathways without bolstering the fiction that racial group membership no longer brings social benefits and costs. Conversely, can researchers continue to examine differences between averages for racial groups without bolstering the ubiquitous stereotyping that employs group membership when deciding how to treat an individual? In short, a paradox that applies to the use of IQ test scores in US society seems to be that researchers and policy-makers who want to move beyond explanations and policies based on racial group membership need to take into account the disadvantages and benefits individuals experience because of their group membership.

The situation for research is even stickier once we move from models to analysis of data so as to compare and test those models. The racial categories used in censuses and other surveys continue to change—as does people's identification with those categories (Hirschman *et al.*, 2000)—yet longitudinal analysis depends on data collected under the same categories for extended periods of time. At the same time, various initiatives in the United States have been attempting to prohibit the collection and use of racially classified information by state and local governments (e.g. the failed 2003 Proposition 54 in California). In short, another paradox that applies to the use of IQ test scores in US society seems to be that researchers and policy-makers who want to move beyond explanations and policies based on racial group membership have to use data collected under shifting racial categories; moreover, to defend the continued collection of such data lest there be no information and thus no patterns to push away from.

Galton and Biobanks: The Data Collected Limits the Questions Asked

The data that researchers collect shape the kinds of patterns and hypotheses or predictions they can make. Galton, a founding father of the analysis of similarity among relatives, recognized that those similarities say nothing on their own to distinguish 'between the effects of tendencies received at birth, and of those that were imposed by the circumstances of their after lives' (Galton, 1875, p. 566). However, especially for the traits that concerned him, namely, 'superior faculties' or abilities that were 'exceptionally high' (Galton, 1892 [1978], p. viii), Galton concluded at an early stage of his inquiries that 'nature prevails enormously over nurture' (1875, p. 574). To Galton this was evident in the biographical data he had collected on illustrious men and their kinfolk (1869 [1892, 1978]) and in studies of the life histories of similar and dissimilar twins (1875). His conclusion is not very convincing today. After all, at one point he begs the question by defining the traits he was measuring as those that 'exclude the effects of education' (Galton, 1892 [1978], p. viii). What remains pertinent, however, is that this conclusion meant he saw no need for data on what we would call environmental or social variables. He could investigate heredity through the patterns of similarity among

relatives. Conversely, because Galton did not measure any environmental variables he was able only to reach conclusions about (supposedly) inborn characters.

John Frank (2005), Scientific Director of the Institute of Population and Public Health of the Canadian Institutes for Health Research, has observed an equivalent but more systemic data-determined limitation in this age of genomics. Frank, an epidemiologist, asks what data need to be collected over the life course of individuals so that researchers in say, 30 years, have the information needed to identify the key risk factors and interactions that account for variation in disease incidence and differential age of onset in a population, and for changing patterns for diseases over time. He assumes that 'diseases and conditions of later life occur in some and not others because of intense interactions between particular genetic constitutions and particular sequence of social and physical environments'. There is, however, an uneven playing field. Genetic samples are cheap to collect and store and need to be collected only once in a lifetime. Environmental exposures vary over time so that 'new samples are needed whenever exposure changes', are difficult to store, and are 'getting costlier (as awareness of chemical/physical/biological complexity increases)'. Some epidemiologists have secured resources to follow small cohorts through time and collect a rich array of data on the individuals [e.g. The Southampton Women's Survey (Inskip *et al.*, 2006)], but the major investments are being made in collecting primarily genetic and disease data for large samples (e.g. the UK Biobank). Epidemiologists such as Frank have warned that analyses of such data will depend on crude estimates of environmental factors and be subject to large errors, uncertainties, and non-replicated findings about genetic influences. In the absence of longitudinal data on environmental exposures, biomedicine has almost no option but to emphasize the effects of genetic factors (but see Davey-Smith & Ebrahim, 2007).

Life Events and Difficulties Research: Bio-social Science that Allows for Heterogeneity of Pathways and Meanings

If there is the will and enough effort longitudinal environmental or social exposures can be brought into the analytic picture. A line of research from England, initiated by the sociologists Brown and Harris in the late 1960s, has investigated how severe events and difficulties during people's life course influence the onset of mental and physical illnesses (Harris, 2000). Brown and Harris use wide-ranging interviews, ratings of transcripts for the significance of past events in their context (with the rating done blind, that is, without knowledge of whether the person became ill), and statistical analyses. Because what might be recorded as the same event, e.g. death of a spouse, might have very different meanings and significance for different subjects according to the context, Brown and Harris's methods accommodate events with diverse meanings. At the same time, apparently heterogeneous events can be subsumed under one factor, such as, in explanation of depression, a severe, adverse event in the year prior to onset. In sum, the Life Events and Difficulties methodology integrates 'the quantitative analyses of epidemiology and the [in] depth understanding of the case history approach' (Brown & Harris, 1989a, p. x).

The most sustained research in this tradition involves explaining depression in working-class women. For a district of London in the early 1970s, Brown and Harris identified four factors as disproportionately the case for women with severe depression: a severe, adverse event in the year prior to the onset of depression; the lack of a supportive partner; persistently difficult living conditions; and the loss of, or prolonged separation from, the mother

when the woman was a child under the age of 11 (Brown & Harris, 1978, 1989b). [Subsequent work has added to this picture, but that will not be taken up here; see Harris (2000).] A reconstruction of Brown and Harris's work as it stood in the 1980s by the developmental psychologist Bowlby (1988) suggests how the different aspects of class, family, and psychology can build on each other in the life course of the individual (Figure 3; see also Taylor 1995).

Let me give some simplified and over-generalized examples of such cross-connections: in a society in which women are expected to be the primary caregivers for children, the loss of a mother increases the chances of, or is linked to, the child lacking consistent, reliable support for at least some period. (Bowlby added his own speculation about early childhood attachment problems.) An adolescent girl in such a disrupted family, or sent from such a family to a custodial institution, is likely to see a marriage or partnership with a man as a positive alternative, yet such early marriages tend to break up more easily. Working-class origins tend to lead to working-class adulthood, in which living conditions are more difficult, especially if a woman has children to look after and provide for on her own. And, in these circumstances, accidents and other severe events are more likely. The consequence of a severe event is often, unless there is a supportive partner, the onset of depression (see also Brown & Moran, 1997). Notice, however, that each connection in Figure 3 should be interpreted as one contributing causal link in the construction of the behavior. The lines are dashed to moderate any determinism implied in presenting a smoothed out or averaged schema; the links, while common, do not apply to all women at all times, and are contingent on background conditions not shown in the diagram.

In sum, longitudinal environmental or social exposures are brought into the picture, and the picture helps us think about multiple pathways to the focal endpoint of clinical depression.

Near the end of the Introduction I proposed that 'close examination of concepts and methods within any given natural or social science can raise questions about the diverse social influences shaping that science. Analysis of social context can, in turn, suggest alternative lines of scientific investigation'. The vignettes presented hardly constitute

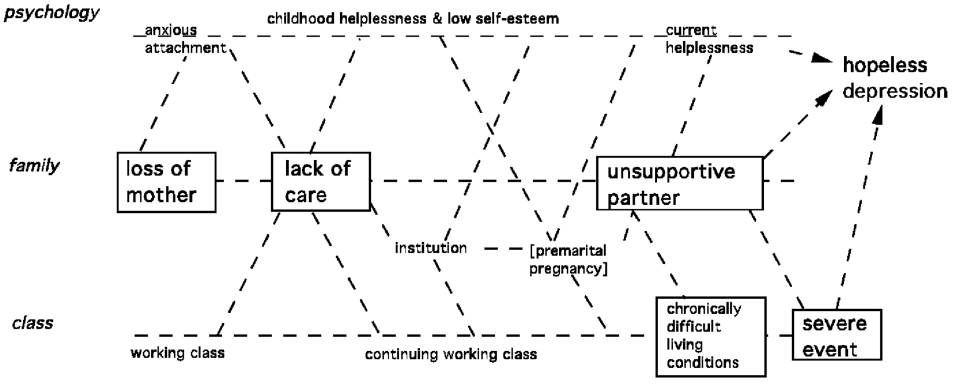

Figure 3. Life development pathways to severe depression identified in Brown and Harris's study of working class women and reconstructed by Bowlby (1988). The dashed lines indicate that each strand tends to build on what has happened earlier in the different strands. See text for discussion and sources.

detailed examination of concepts and methods or analysis of social context. Moreover, although they have raised many searching questions about the concepts, methods, and social context, what can I expect readers or listeners to do with such questions? That question cannot be answered with any definiteness or specificity because the questions I raise constitute only one (potential) resource among many in readers' diverse constructions and reconstructions of knowledge. Let me, however, express some hopes, which will lead into another set of vignettes making up the second part of this essay.

In my classes and pedagogical writing on critical thinking about the life and environmental sciences I draw attention to alternative theories and perspectives. I do not ask students and readers to accept these and reject the standard accounts. What I want them to see is that they understand things better when they have placed established facts, theories, and practices in tension with alternatives (Taylor, 2002). I see critical thinking and creative thinking as linked. Where, after all, do a critical thinker's ideas about alternatives come from? Not out of individual inspiration, but from borrowing and connecting. The more items in your tool box—the more themes and open questions you are working with—the more likely you are to make a new connection and see how things could be otherwise, that is, to think creatively. In this vein, I hope that the vignettes in this essay provide material for readers to borrow from and make connections. I hope that this produces creative thinking out of which crystallizes for readers *in their own particular circumstances* an impetus to mobilize different resources and organize them in new directions. The themes and questions from the vignettes in both parts of this essay are, to repeat the picture given in the Introduction, pieces of scaffolding intended to help readers contribute to construction and reconstruction of social infrastructure.

Part 2: STS Interpretation and Change: Beyond Social-structure-less Sociology of Scientific Knowledge and a Psychology-thin Agency

The essay could have stopped at the end of Part 1, leaving as exercises for readers the task of filling in the connections of interpretation to change. But that would place too much emphasis on the science side of science-in-society. Like Venter and Dawkins portraying advances in genomics as a motor of social change, I would be portraying critical questioning of research as the motor of STS attempts to influence on the life sciences. More attention needs to be given to the society side of STS. Impressive work is already being done, of course (e.g. Centro de Estudos Sociais, 2005; Epstein, 2008). I will not attempt to duplicate or review that work. Instead, the vignettes in Part 2 speak to one area that calls for more development, namely, the conceptualization of the structure of the social context of scientific and technological developments and of human agency in the ongoing restructuring of that context.

SSK and ANT: Social and Political Structure Missing or Pushed Aside

To see that conceptualization of the structure of the social context is an underdeveloped area in STS, consider two influential schools of work: Collins's empirical program of relativism (EPOR) and Latour and Callon's actor–network theory (ANT). Collins describes the first two stages of EPOR as: expose the interpretative flexibility of experimental data; and show some of the 'mechanisms through which the potentially endless debate about interpretation is limited' (Collins, 1981, p. 7). The third stage is: relate the

constraining mechanisms to the wider social and political structure. Yet, neither Collins nor the other authors he reviewed in 1981 has pursued that third stage of sociological and political analysis. In ANT, social structure is not neglected but is actively pushed aside. Latour and Callon describe human, other living beings, and non-living things alike as actors or *actants* (Callon, 1985; Latour, 1987). Human agents are driven only by the need to accumulate resources in reaction to other people accumulating resources, so their psychology is strong, but thin—they are single minded. For human agents to act almost without mental representations means that they are not internally bound—inborn dispositions, cognitive constraints, individual creativity, etc. cannot determine action and belief—and, more importantly, agents are not socially determined—with nothing in the mind of scientists, there is no place for interests, determined by the agents' class (or other) position in the social structure, or for other external influences to reside (Taylor, 2006c). As social theory ANT cannot be sustained consistently. The resilience of at least some, if not most, of the strong networks of actants will ensure their persistence for some period of time. Persistent networks can be viewed as social structure. More subtly, any regularities in the opportunities and constraints that human agents experience invite interpretation as social structure. Pursuing this interpretation, we might ask how human agents' actions generate, maintain, and undermine that structure. Indeed, the agents themselves might consciously identify at least some of these regularities or structure. The issue of social determination of the production of knowledge that ANT pushed aside through its thin version of human agency is thus resurrected, albeit in a *distributed* rather than direct form (Taylor, 1993).

The challenge is to do better than a social-structure-less sociology of scientific knowledge and a psychology-thin agency.

Life Events and Difficulties Research (Continued): A Picture of Intersecting Processes

The three strands of Figure 3 (psychology, family, class) integrate the observations made by Brown and Harris to explain the onset of serious depression. The factors are not separate contributing causes, like spokes on a wheel, but take their place in the multi-stranded life course of the individual. In many ways family, class, and psychological strands of the woman's life build on each other. Let us note also that, as an unavoidable side effect, the pathways to an individual's depression intersect with and influence other phenomena, such as the state's changing role in providing welfare and custodial institutions, and these other phenomena continue even after the end point, namely, depression, has been arrived at.

Suppose now, quite hypothetically, that certain genes, expressed in the body's chemistry, increase a child's susceptibility to anxiousness in attachment compared to other children, even those within the same family. Suppose also that this inborn biochemistry, or the subsequent biochemical changes corresponding to the anxiety, rendered the child more susceptible to the biochemical shifts that are associated with depression. It is conceivable that early genetic or biochemical diagnosis followed by lifelong treatment with prophylactic antidepressants could reduce the chances of onset of severe depression. This might be true without any other action to ameliorate the effects of loss of mother, working-class living conditions, and so on. There are, however, many other readily conceivable engagements to reduce the chances of onset of depression, for example, counseling adolescent girls with low self-esteem, quickly acting to ensure a reliable caregiver when a mother dies or is hospitalized, making custodial institutions or foster care arrangements more

humane, increasing the availability of contraceptives for adolescents, increasing state support for single mothers, and so on. If the goal is reduction in depression for working-class women, the unchangeability of the hypothetical inherited genes says nothing about the most effective, economical, or otherwise socially desirable engagement—or combinations of engagements—to pursue. Notice also that many of these engagements would have their downstream effect on depression via pathways that cross between the different strands. For example, if self-esteem counseling were somewhat effective then fewer unwanted pregnancies and unsupportive partnerships might be initiated; both effects could, in turn, reduce the incidence of single parenthood and difficult living conditions.

The Brown and Harris account of the origins of acute depression in working-class women illustrates the idea of heterogeneous construction or intersecting processes (Taylor, 1995, 2005): without any superintending constructor or outcome-directed agent, many heterogeneous components are linked together, which implies that the outcome has multiple contributing causes, and thus there are multiple points of engagement that could modify the course of development. In short, causality and agency are distributed, not localized. Moreover, the components are linked over time, building on what has already been constructed, so that it is the components in linkage that constitute the causes and it is difficult to partition relative importance or responsibility for an outcome among the different types of cause (e.g. '80% genetic vs. 20% environmental', or 'partly scientific and partly social'). Generally, there are alternative routes to the same end, and things involved in the construction of one outcome are implicated in many others, so engaging in a construction process, even through very focused interventions, will have side effects. Finally, construction never stops; completed outcomes are less end points than snapshots taken of the ongoing, intersecting processes.

In discussing depression among working class women, rather than in other groups, I could be seen as perpetuating a male, professional-class perspective. However, the politics of the case can be viewed quite differently. Although depressed working class women are the focus, the intersecting processes account brings a range of other agents into the picture. While the account does not identify ways to cure the women studied, other girls and women that follow them might seek support from, or find themselves supported by counselors, hospital social workers, people reforming custodial institutions, family planning workers, social policy makers, and so on. Moreover, these agents can view their engagement as linked with others, not as a solution on its own. For example, when women's movement activists create women's refuges as a step away from living in unsupportive households, this makes it possible for therapists who specialize in the psychological dynamics of the woman in her family to consider referring women to refuges as a critical disruption to the family's dynamic. The politics of highlighting different kinds of causes and their interlinkages can be seen as promoting exchange among a distributed set of agents and contributing to the potential re-formation of the social worlds intersecting around the development of any given focal individual or outcome (Hutchins, 1995). The intersecting processes picture supports diverse engagements with the sciences of changing life.

Intersecting Processes: Ongoing Restructuring; Multiple, Linked Engagements; and Meaning-in-Relationship

Social theory has a long history of discussion about how to relate social structure and human agency (Sewell, 1992). In Taylor (2005, pp. 249–250) I provide an initial

sketch of how the idea of intersecting processes provides a basis for moving beyond the structure–agency dualism. Here I want simply to highlight two aspects of intersecting processes: the relations among components are built up over time so that the structure of those relations continues to be subject to restructuring; and there are multiple places of engagement, each one partial and suitable for agents who bring different resources to their own intersecting processes of engagement. These particular places of engagement invite, and are subject to, connections across places.

A biological metaphor that combines restructuring over time with connections across particular, place-centered capacities is provided by the embryological phenomenon of gastrulation. The original ball of cells in an embryo folds into itself and the body plan of the organism-to-be emerges (Figure 4). At the end of gastrulation many of the outside cells have given rise to inside cells. The subsequent fate in development of both kinds of cells depends on their interaction. To tease out some associations of this metaphor: context is not an add-on to the essential thing (e.g. a piece of science) that we are interpreting, but rather the thing only takes it properties (meaning) through its relation with surrounding layers. Moreover, the relationship between layers has an indirect or surprising history. Inside and outside cells that are now neighbors arose from cells some distance apart in the earlier embryo.

Raymond Williams's Loyalties: Militant Particularism versus Translocal Perspectives

In the years just before his death in 1988, the cultural analyst Raymond Williams wrote two books that built directly upon his experience of moving from a childhood in the English–Welsh borderlands into a cosmopolitan world of intellectual exchange: the novel *Loyalties* (Williams, 1985) and an unfinished set of episodes of environmental–historical fiction, *People of the Black Mountains* (Williams, 1990, 1992). I was led to both these works through an essay by the geographer, David Harvey, 'Militant Particularism and Global Ambition' (Harvey, 1995). Here Harvey analyzes these works of Williams and some earlier novels at the same time as he weaves in reflections on his own experience as a professor at Oxford University drawn into a campaign led by militant trade unionists for the preservation of jobs in a local car plant.

Williams's *People of the Black Mountains* resonates strongly with the project of analyzing change in terms of differentiated agents situated in intersecting processes—in this case, socio-environmental change—but it was the novel *Loyalties* that kept me thinking about how to relate social structure and human agency. Through its central characters,

Figure 4. A generalized depiction of gastrulation resulting in two cell layers, ectoderm and endoderm. *Source*: Available at: http://en.wikipedia.org/wiki/Gastrulation. For more dynamic views, see also Shook (2004) and Hardin (2008a, 2008b)

in particular the Welsh Gwyn and his English birthfather Norman, *Loyalties* explores the tension between solidarities forged through working and living together in particular places—militant particularism—and the application of translocal perspectives or abstractions. Moreover, it adds a temporal, trans-generational dimension that is especially significant given my interest in 'self-conscious knowledge-making and social changing' or, in Williams's words, in 'looking, in [an] active way, at the whole complex of social and natural relationships which is at once our product and our activity' (Williams, 1980, p. 83).

When the middle-aged Gwyn and elderly Norman finally meet, Norman pushes Gwyn to acknowledge that his scientific career has taken him away from his birthplace and enabled him to see more about the ways the world is changing than people who remained in the Welsh towns. Political involvement, Norman argues, cannot be a simple matter of Gwyn staying loyal to his roots. Given the 'powerful forces' that shape social and environmental change, we can 'in intelligence' grapple with them 'by such means as we can find' and take a deliberate path of action, but 'none of us, at any time, can know enough, can understand enough, to avoid getting much of it wrong' (Williams, 1985, pp. 357–358). Or, in the words of Norman's close intellectual and political colleague, Monkey Pitter, if we 'go on saying the things we learned to say and it will be just strange talk, in a strange land' (p. 161). People may try to align their work and lives within the prevailing social infrastructure, but they should expect to become misaligned as the infrastructure changes around them.

Participatory Planning: Should Researchers Go Local or Flexibly Engage?

In the late 1990s I attended some facilitation training at the Canadian Institute of Cultural Affairs (ICA). ICA's techniques have been developed through several decades of 'facilitating a culture of participation' in community and institutional development in many countries. Their work anticipated and now exemplifies the post-Cold War emphasis on a vigorous civil society, that is, of active institutions between the individual and the state and between the individual and the large corporation (Burbridge, 1997). ICA planning workshops involve a neutral facilitator leading participants through four phases—practical vision, underlying obstacles, strategic directions, and action plans (Stanfield, 2002). The ICA workshops aim to elicit participation in a way that brings insights to the surface and ensures the full range of participants are invested in collaborating to bring the resulting plans or actions to fruition.

Such investment was evident, for example, after a community-wide planning process in the West Nipissing region of Ontario, 300 kilometers north of Toronto. In 1992, when the regional Economic Development Corporation (EDC) enlisted ICA to facilitate the process, industry closings had increased the traditionally high unemployment to crisis levels. The EDC wanted specific plans, but it also sought significant involvement of community residents. Twenty meetings with over 400 participants moved through the first three phases—vision, obstacles, and directions. The results were synthesized by a steering committee into common statements of the vision, challenges, and strategic directions. A day-long workshop attended by 150 community residents was then held to identify specific projects and action plans, and to engage various groups in carrying out projects relevant to them. A follow-up evaluation five years later found that it was not possible simply to check off plans that had been realized. The initial projects had spawned many others; indeed, the

EDC had been able to shift from the role of initiating projects to that of supporting them. It made more sense, therefore, to assemble the accomplishments under the headings of the original vision and strategy documents. Over 150 specific developments were cited, which demonstrated a stronger and more diversified economic base, and a diminished dependence on provincial and national government social welfare programs. Equally importantly, the community now saw itself as responsible for these initiatives and developments, eclipsing the initial catalytic role of the EDC–ICA planning process. Still, the EDC appreciated the importance of that process and initiated a new round of facilitated community planning in 1999 (West Nipissing Economic Development Corporation, 1993, 1999).

When I learned about the West Nipissing case, I could not help contrasting it with my early experience in applied social research (see Taylor, 2005, 94ff). In that research we undertook detailed scientific analysis of an agricultural region at some distance from those directly affected by the problems of salinization and economic decline. Projections of the economic and ecological future were straightforward as long as they preserved the basic structure of the situation. When innovative possibilities, such as reforesting abandoned land, were considered, the analysis became difficult. The audience for the final analyses was small and attention to the report short-lived. The Ministry was unable to implement the policy change it desired and nothing more then became of the two or three person-years of research.

The West Nipissing plan, in contrast, built from straightforward knowledge that the varied community members had been able to express through the facilitated participatory process. The process had been repeated, which presumably allowed them to factor in changes and contingencies, which might have included the impact of the North American Free Trade Association and the decline in the exchange rate with the USA. And, most importantly, the process has led community members to become invested in carrying out their plans and to participate beyond the ICA-facilitated planning process in shaping their own future.

Some difficult questions for me were opened up by this contrast, given that my own environmental research has drawn primarily on my skills in quantitative methods. What role remained for researchers to insert the translocal into participatory planning, that is, to contribute analysis of changes that arise beyond the local region or at a larger scale than the local? For example, suppose that I had moved to the agricultural region we studied and participated directly in shaping its future. I would still have had translocal knowledge about the government ministry's policy-making efforts, the data and models used in the economic analysis, and so on. Indeed, the local for professional knowledge-makers cannot be as place-based or fixed as it would be for most community members. How, then, can researchers take seriously the creativity and capacity-building that seems to follow from well-facilitated participation, but not to conclude that we have to go local and focus all their efforts on one place?

My reflection on this question led me to coin a term, *flexible engagement*. This seemed to capture a process, rather than content challenge for researchers in any knowledge-making situation: how can we connect quickly with others who are almost ready to foster—formally or otherwise—participatory processes and, through the experience such processes provide their participants, contribute to enhancing the capacity of others to do likewise? The term plays off the flexible specialization that arose during the 1980s, wherein transnational corporations directed production and investment quickly

to the most profitable areas and set aside previous commitments to full-time employees and their localities. Would flexible engagement constitute resistance to flexible specialization, or an accommodation with it? This remains an open question for me as I gradually develop tools for engaging flexibly and thus contribute to the process dimensions of social infrastructure (NewSSC, 2008).

Local, Participatory Planning Revisited: Translocal Provision or Withholding of Resources

Recently I learned that, in late 2002, a major employer in the West Nipissing region, Weyerhaeuser, closed its containerboard plant. A local newspaper article (Haddow, 2003) quoted a Weyerhaeuser spokesperson: '[T]he decision to close the facility is not a reflection on the employees of Sturgeon Falls and their abilities and efforts ... It was made for economic reasons beyond their control'. The spokesperson went on to explain that 'the company's preference would have been to keep all facilities running, but the market changes and current economic conditions forced their hand'. 'If we as a company do not adapt, then we will not survive and none of our employees will have jobs.' The community sprang into action and threatened lawsuits, but the plant closure was not reversed.

There is more to learn about the community's response (and for this I am planning a research visit). In the meantime, discussion with colleagues involved in regional economic development (with a focus on technology-centered experiences and promises) led me to adjust the militant particularism–translocal contrast. The translocal side is not only about perspectives or knowledge, but can also encompass resources that could be brought to a locality or withdrawn and withheld from it. There is room to think about and to explain which aspect of the translocal comes into play—knowledge or resources; contributed or withheld—and how they interact with solidarities forged through working and living together in particular places.

Translocal and Global: Differential Speed and Extent and other Second-order Effects

Weyerhaeuser's action links West Nipissing into transnational or global economic changes. Discussions of globalization tend to highlight the increasing extent of economic and cultural connections or, complementarily, their increasing speed. In STS, the icons of extent and speed are the Internet and the ever accelerating project of genome sequencing. Such discussion reminds me of William Cronon's (1991) widely read account of the nineteenth century emergence of a 'Metropolis of Nature', namely, the city of Chicago. The picture he presents is of ever increasing speed and expanding extent. What he doesn't highlight, however, is that the motor of the changing capitalism he describes is not simply speed and increasing extent, but *differential* speed and extent. The futures market, for example, takes off not simply because telegraphic communication connects the world more rapidly, but because some people in Chicago have access to that information well before and in greater detail than, say, farmers in the hinterland. It could be said that exploitation of differentials, or uneven development (Bond, 1999), is a driver of political economies. In this vein, capitalism depends on moving on and leaving others behind, displacing costs in space and time, and avoiding accountability. In this sense, flexible specialization is not a novel development, but another instance of the

fundamental dynamic of capitalist political economics. This might be called the superstructure, in which any new technological infrastructure, such as in biotechnology, can be built and can be unbuilt.

Shifting attention from speed and extent to differentials in speed and extent points to a more general theme of looking for second-order effects hidden behind or implied by any direct relation or process. For example, as the anthropologist Eric Wolf shows in *Europe and the People Without History* (1982), the history of Western Europe since 1400 is totally bound up with the history of regions and peoples who are given no agency in this history. The idea that there are always groups hidden, but dynamically present, in dominant historical narratives is spelled out by historian Geoff Eley (2007) when, in discussing what is distinctive about our current era of globalization, he questions the standard histories of capitalist progress and of the formation of an organized working class:

> under any particular capitalism wage labour has in any case always continued to coexist with various types of unfree and coercive labour. The salience of such simultaneities—of the temporal coexistence inside a particular capitalist social formation of forced, indentured, enslaved, and unfree forms of work with the free wage relationship strictly understood—needs to be carefully acknowledged. Such simultaneities become all the more salient once we begin conceptualizing capital accumulation on a properly global scale by integrating the forms of surplus extraction occurring in the colonial, neocolonial, or underdeveloped worlds. The West's privileged prosperity, including precisely the possibility of the social-democratic improvements associated with the three decades after 1945, has been founded, constitutively, on horrendous repertoires of extraction and exploitation on such a world scale.

Just as in gastrulation, the meaning of the social-democratic layer—indeed of any layer—of a globalized political economy emerges in relatedness.

Unevenness of Solidarities at Local and National Levels

Second-order effects complicate the militant particularism–translocal contrast. They invite us to pay attention to the unevenness of militant particularist loyalties or solidarities. There will always be locals who are prepared to support people with translocal knowledge and resources, because these locals want, say, to escape the constraints of community values or to avoid being the ones left behind as resources are moved elsewhere. (Indeed, fear of being left behind may be a ubiquitous psychological complement to exploitation of differentials in driving political economies.) The unevenness of local solidarities becomes more obvious when the local scales up. In the biomedical area, for example, commodification of new drugs or procedures often begins with a wedge group, as was the case with testing of oral contraceptives during the 1950s among poor women in Puerto Rico and the promotion of in vitro fertilization to professional couples who could afford the expense of numerous cycles of treatment. (At the same time, local–translocal differentials in knowledge came into play in both cases: the Puerto Rican women were not informed of the experimental nature of the contraceptives or their potential side effects and the first IVF parents were not informed that the technique had not yet resulted in a baby.)

When the local scales up to the level of a nation, the translocal often corresponds to international financial or military knowledge and resources. Naomi Klein's (2007) case studies in what she calls disaster capitalism show that, in the space that crises open up, plans gain traction for restructuring economic arrangements through privatization and other favorable conditions for foreign investors, through drastic cuts in government spending, and through elimination of regulation of labor conditions. As these last two items indicate, the traction always depends on some groups within the nation accommodating and others being disadvantaged or disempowered. Klein shows how this operated: from the military suppression of dissent that accompanied the import of Milton Friedman's economics into Chile after the 1973 overthrow of the Allende government, through the secret meetings of experts and subsequent State of Siege that paved the way for the economic shock therapy in Bolivia in the mid-1980s, to the economic agreements made by the ANC in South Africa as their leaders focused on avoiding a civil war and negotiating the political path to a post-apartheid democracy.

Fundamentalist Erasures of History are Still Interpretations within Historically Located Communities

Klein contends that the advance of free-market plans requires disasters and crises because neo-liberalism belongs among

> the closed, fundamentalist doctrines that cannot coexist with other belief systems; their followers deplore diversity and demand an absolute free hand to implement their perfect system. The world as it is must be erased to make way for their purist invention. Rooted in biblical fantasies of great floods and fires, it is a logic that leads ineluctably toward violence. The ideologies that long for that impossible clean slate, which can be reached only through some kind of cataclysm, are the dangerous ones (Klein, 2007, p. 19).

I find the connection that Klein draws between neo-liberalism and fundamentalism to be amplified by James Simpson's (2007) revisionist account of the Protestant reformation in the early 1500s. The struggle to print and read the scriptures in the vernacular, which pitted Protestant evangelicals against the institution of the Catholic Church, might seem to advance 'the right of the individual reader to read canonical books in freedom, without reference to either history or communities' (2007, p. 2). As such, the Protestant reformation can be seen as the beginnings of modern liberal individualism. Simpson, however, argues that the actual outcome was fundamentalism, in which readers made sense of scriptural complexities and ambiguities by accepting the authority of particular evangelicals to assert, intolerantly, their system of literal interpretation over those of others and to hollow out history so their True Church is there from the beginning.

To observe that interpretation arises within a historically located community is not to apologize for the gradual development of dogma and its forceful imposition by the Catholic Church. To introduce Simpson's account in this essay is not to suggest that it is better to be subservient to the dominant, received understandings of the meaning of biological knowledge or that questioning the dominant developments in science and technology must lead to marginal and schismatic positionings. The point, rather, is that both stasis and change happen within intersecting processes. Dominant paradigms do not persist

because they are right, but because of continuing work that takes place to maintain the links among the heterogeneous components and processes. Moreover, there is no outside position of intervention; the significance of any effort to produce change will depend on how it links with other engagements and with the ongoing, intersecting processes (Taylor, 2005). In Klein's account, neo-liberal/neo-fundamental visions of erasing the previous social infrastructure do not result in plans being realized without also preparing the ground for further crises. As the struggles of families with PKU children and the emergence of maternal PKU indicate, we can expect the same crisis-inducing effect for interventions based on fantasies like Venter and Dawkins' in which genetic information serves, with a minimum of interpretation or social infrastructure, to reshape life and solve social problems.

Conclusion

This essay has addressed the relationship of interpretation to change at two levels. The first level concerns the claims of molecular biology and biotechnology about using genetic information to reshape human life. The vignettes in Part 1 indicate in different ways that the use of genetic information always requires social infrastructure. Once attention is given to the actual or implied social infrastructure, the prospect of life reshaped using human genetic information gives way to the diverse engagements that different people make in building or adjusting that infrastructure. The information that a newborn tests positive for PKU, for example, opens up questions for clinicians about variability in effects of PKU and of the special diet; for healthcare policy makers and activists about insurance coverage for the special diet and for counseling of PKU individuals; for families, friends, and concerned members of the public about how to develop and sustain support groups for PKU individuals and families; and so on.

The second level in this essay concerns the relationship in STS between interpreting projects in the life sciences and influencing their direction. Pulling further on the social infrastructure thread from Part 1, the vignettes in Part 2 respond to STS's shortcomings in conceptualizing the structure of the social context of scientific and technological developments and the nature of human agency in the ongoing restructuring of that context. For example, Raymond Williams's contrast between militant particularism and what I call translocal resources leads me to suggest that 'people may try to align their work and lives within the prevailing social infrastructure, but they should expect to become misaligned as the infrastructure changes around them'.

The relationship in STS between interpretation and change is also explored through the use of vignettes in both parts of the essay. These vignettes were designed as an alternative to describing the idiosyncratic complexities of constructing and reconstructing particular developments in science. Instead, they would 'open up questions and point to further work needed to grapple with [such] complexities'. This is the spirit in which, at the end of Part 2, I link the two parts of the essay by suggesting that the idea that information can be read literally or with a minimum of interpretation (or infrastructure) has a place in the history of fundamentalist doctrines. Such themes and related questions are offered to readers—within STS and the life sciences—as pieces of scaffolding to use as they contribute to the construction and reconstruction of social infrastructure.

Heterogeneous components and pathways; multiple partial joint engagements within intersecting processes; militant particularism versus translocal knowledge and resources

that can be contributed or withheld; differentials and uneven development; meaning-in-relatedness and second-order effects; flexible engagement ... Which of these and other themes and questions from the essay will readers build on? Will the method pursued in this essay stimulate or guide readers as they 'delve into the complexities of particular areas of scientific activity with which they are engaged'? I cannot be sure, of course; I look forward to hearing readers' responses and learning from them. And I invite others to further the experiment. Each of us needs, I suggest, to play as well as work with our concepts and interpretations so as to support our diverse engagements with the sciences of changing life.

Acknowledgements

This essay is based on an invited paper for 'The reshaping of human life', Workshop 3 of the Gulbenkian Foundation series on 'The Life Sciences and Society: Challenges of the Post-Genome Era', Lisbon, May 2008. The support of the Foundation to participate in the workshop and the interaction with the other participants is warmly acknowledged. The essay is partly based on research supported by the National Science Foundation under grant no. SES–0634744. Early thoughts on the second part of the essay were presented to the Responsible Technologies seminar at the University of Massachusetts at Lowell. The author weaves in some material that has been published elsewhere, most notably Taylor (2006b) in the sections on IQ test scores, Taylor (1995) in the sections on Life Events and Difficulties research, and Taylor (2005, 207ff) in the sections on Raymond Williams and participatory planning. The comments of two anonymous reviewers and the editor helped in the revision process.

References

Bond, P. (1999) Uneven development, in: P. O'Hara (Ed.) *The Encyclopaedia of Political Economy* (London: Routledge).

Bowlby, J. (1988) *A Secure Base* (New York: Basic Books).

Brown, G. W. and Harris, T. (1978) *Social Origins of Depression* (New York: The Free Press).

Brown, G.W. and Harris, T. O. (1989a) Depression, in: G. W. Brown and T. O. Harris (Eds) *Life Events and Illness* (New York: Guilford Press).

Brown, G. W. and Harris, T. O. (Eds) (1989b) *Life Events and Illness* (New York: Guilford Press).

Brown, G. W. and Moran, P. M. (1997) Single mothers, poverty and depression, *Psychological Medicine*, 27, pp. 21–33.

Burbidge, J. (Ed.). (1997) *Beyond Prince and Merchant: Citizen Participation and the Rise of Civil Society* (New York: Pact Publications).

Callon, M. (1985) Some elements of a sociology of translation: domestication of the scallops and the fishermen of St. Brieuc Bay, in: J. Law (Ed.) *Power, Action, Belief: A New Sociology of Knowledge?*, pp. 196–233 (London: Routledge & Kegan Paul).

Campbell, N. A. and Reece, J. B. (2005) *Biology* (Upper Saddle River, NJ: Benjamin Cummings). **Q1**

Caspi, A., McClay, J., Moffitt, T. E., Mill, J., Martin, J., Craig, I. W., Taylor, A. and Poulton, R. (2002) Role of genotype in the cycle of violence in maltreated children, *Science*, 297(5582), pp. 851–854.

Centro de Estudos Sociais (2005) *Identifying Trends in European Medical Space: Contribution of European Social and Human Sciences* (Coimbra, Portugal: Centro de Estudos Sociais).

Clarke, A. and Fujimura, J. (1992) What tools? Which jobs? Why right? in: A. Clarke and J. Fujimura (Eds) *The Right Tools for the Job: At Work in Twentieth-century Life Sciences*, pp. 3–44 (Princeton, NJ: Princeton University Press).

Collins, H. M. (1981) Stages in the empirical programme of relativism, *Social Studies of Science*, 11, pp. 3–10.

Cronon, W. (1991) *Nature's Metropolis: Chicago and the Great West* (New York: Norton).

Davey-Smith, G. and Ebrahim, S. (2007) Mendelian randomization: genetic variants as instruments for strengthening causal influences in observational studies, in: M. Weinstein, J. W. Vaupel and K. W. Wachter (Eds) *Biosocial Surveys*, pp. 336–366 (Washington, DC: National Academies Press).

Dickens, W. T. and Flynn, J. R. (2001) Heritability estimates versus large environmental effects: the IQ paradox resolved, *Psychological Review*, 108(2), pp. 346–369.

Eley, G. (2007) Historicizing the global, politicizing capital: giving the present a name, *History Workshop Journal*, 63(1), pp. 154–188.

Epstein, S. (2008) Patient groups and health movements, in: E. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman (Eds) *The Handbook of Science and Technology Studies*, pp. 499–540 (Cambridge, MA: MIT Press).

Flynn, J. R. (1994) IQ gains over time, in: R. J. Sternberg (Ed.) *Encyclopedia of Human Intelligence*, pp. 617–623 (New York: Macmillan).

Flynn, J. R. (2000) *How to Defend Humane Ideals: Substitutes for Objectivity* (Lincoln, NE: University of Nebraska Press).

Flynn, J. R. (2007) *What is Intelligence?* (Cambridge: Cambridge University Press).

Frank, J. (2005) A tale of (more than?) two cohorts—from Canada, in: *3rd International Conference on Developmental Origins of Health and Disease*.

Fryer, R. and Levitt, S. (2004) Understanding the black–white test score gap in the first two years of school, *The Review of Economics and Statistics*, 86(2), pp. 447–464.

Galton, F. (1865) Hereditary talent and character, *Macmillan's Magazine*, 12, pp. 157–166, 318–327.

Galton, F. (1875) The history of twins, as a criterion of the relative powers of nature and nurture, *Fraser's Magazine*, 12, pp. 566–576.

Galton, F. (1978) *Hereditary Genius* (New York: St. Martin's Press).

Gessen, M. (2008) *Blood Matters: From Inherited Illness to Designer Babies, How the World and I Found Ourselves in the Future of the Gene* (Orlando, FL: Harcourt).

Haddow, S. H. (2003) Gripped by uncertainty: Sturgeon Falls springs into action following the closure of its primary employer, *Northern Ontario Business*, 1 January.

Hardin, J. (2008a), Available at: http://worms.zoology.wisc.edu/frogs/gastxen/wholegas.mov (accessed 26 June 2008).

Hardin, J. (2008b), Available at: http://worms.zoology.wisc.edu/frogs/gastxen/gastxen_sagview.html (accessed 26 June 2008).

Harris, T. (Ed.). (2000) *Where Inner and Outer Worlds Meet* (London: Routledge).

Harvey, D. (1995) Militant particularism and global ambition: the conceptual politics of place, space, and environment in the work of Raymond Williams, *Social Text*, 42, pp. 69–98.

Hirschman, C., Alba, R. and Farley, R. (2000) The meaning and measurement of race in the US census: glimpses into the future, *Demography*, 37(3), pp. 381–393.

Hutchins, E. (1995) *Cognition in the Wild* (Cambridge, MA: MIT Press).

Inskip, H. M., Godfrey, K. M., Robinson, S. M., Law, C. M., Barker, D. J. and Cooper, C. SWS Study Group. (2006) Cohort profile: the Southampton Women's Survey, *International Journal of Epidemiology*, 35(1), pp. 42–48.

Klein, N. (2007) *The Shock Doctrine: The Rise of Disaster Capitalism* (New York: Metropolitan Books).

Latour, B. (1987) *Science in Action: How to Follow Scientists and Engineers through Society* (Milton Keynes: Open University Press).

Law, J. (1987) Technology and heterogeneous engineering: the case of Portuguese expansion, in: W. E. Bijker, T. P. Hughes and T. J. Pinch (Eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, pp. 111–134 (Cambridge, MA: MIT Press).

Massoglia, M. P. (2003) Genomics and 'the promise of tomorrow', *Visions (Wake Forest University School of Medicine),* Winter/Spring.

Miele, F. (2002) *Intelligence, Race, and Genetics: Conversations with Arthur Jensen* (Boulder, CO: Westview Press).

Neisser, U., Boodoo, G., Bouchard, T. J., Boykin, A. W., Brody, N., Ceci, S. J., Halpern, D. F., Loehlin, J. C., Perloff, R., Sternberg, R. J. and Urbina, S. (1996) Intelligence: knowns and unknowns, *American Psychologist*, 51, pp. 77–101.

NewSSC (2008) *New England Workshop on Science and Social Change*. Available at: http://www.stv.umb.edu/newssc.html (accessed 1 May 2008).

Nisbett, R. E. (1998) Race, genetics, and IQ, in: C. Jencks and M. Phillips (Eds) *The Black–White Test Score Gap*, pp. 86–102 (Washington, DC: Brookings Institution Press).

Paul, D. (1998) The history of newborn phenylketonuria screening in the US, in: N. A. Holtzman and M. S. Watson (Eds) *Promoting Safe and Effective Genetic Testing in the United States*, pp. 137–160 (Baltimore: Johns Hopkins University Press).

Public Broadcasting Network (2006) Family That Walks on All Fours. Available at: http://www.pbs.org/wgbh/nova/transcripts/3317_allfours.html or http://www.youtube.com/watch?v=0gNKNo55jdE (accessed 20 June 2008).

Robinson, S. (1984) The art of the possible, *Radical Science Journal*, 15, pp. 122–148.

Sewell, W. H. (1992) A theory of structure: duality, agency and transformation, *American Journal of Sociology*, 98, pp. 1–29.

Shook, D. (2004) *Xenopus laevis Vegetal View of Gastrulation & Neurulation*. Available at: http://www.gastrulation.org/Movie13_1.mov (accessed 26 June 2008).

Simpson, J. (2007) *Burning to Read: English Fundamentalism and its Reformation Opponents* (Cambridge, MA: Harvard University Press).

Stanfield, R. B. (2002) *The Workshop Book: From Individual Creativity to Group Action* (Toronto: Canadian Institute of Cultural Affairs).

Taylor, P. J. (1993) What's (not) in the mind of scientific agents? Implicit psychological models and social theory in the social studies of science. Available at: http://www.faculty.umb.edu/pjt/4s93.html (accessed 8 January 2000).

Taylor, P. J. (1995) Building on construction: an exploration of heterogeneous constructionism, using an analogy from psychology and a sketch from socio-economic modeling, *Perspectives on Science*, 3(1), pp. 66–98.

Taylor, P. J. (2002) We know more than we are, at first, prepared to acknowledge: journeying to develop critical thinking. Available at: http://www.faculty.umb.edu/pjt/journey.html (accessed 1 November 2003).

Taylor, P. J. (2005) *Unruly Complexity: Ecology, Interpretation, Engagement* (Chicago, IL: University of Chicago Press).

Taylor, P. J. (2006a) Heritability and heterogeneity: on the irrelevance of heritability in explaining differences between means for different human groups or generations, *Biological Theory: Integrating Development, Evolution and Cognition*, 1(4), pp. 392–401.

Taylor, P. J. (2006b) Heritability and heterogeneity: on the limited relevance of heritability in investigating genetic and environmental factors, *Biological Theory: Integrating Development, Evolution and Cognition*, 1(2), pp. 150–164.

Taylor, P. J. (2006c) Exploring themes about social agency through interpretation of diagrams of nature and society, in: Y. Haila and C. Dyke (Eds) *How Nature Speaks: The Dynamics of the Human Ecological Condition*, pp. 235–260 (Durham, NC: Duke University Press).

Taylor, P. J. (2007) The unreliability of high human heritability estimates and small shared effects of growing up in the same family, *Biological Theory: Integrating Development, Evolution and Cognition*, 2(4), pp. 387–397.

Venter, C. and Dawkins, R. (2008) Life: a gene-centric view—a conversation in Munich, *Edge*, p. 235.

West Nipissing Economic Development Corporation (1993) *Vision 20/20: Shaping our Futures Together, Executive Summary*, April.

West Nipissing Economic Development Corporation (1999) *Vision 2000 Plus, Executive Summary*, June.

Williams, R. (1980) Ideas of nature, in: *Problems in Materialism and Culture: Selected Essays*, pp. 67–85 (London: Verso).

Williams, R. (1985) *Loyalties* (London: Chatto & Windus).

Williams, R. (1990) *People of the Black Mountains: The Beginning* (London: Palladin).

Williams, R. (1992) *People of the Black Mountains: The Eggs of the Eagle* (London: Palladin).

Wolf, E. (1982) *Europe and the People without History* (Berkeley, CA: University of California Press).