

"Infrastructure and Scaffolding: Themes and Questions to Support Diverse Engagements with
the Sciences of Changing Life"

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Version 5/1/08. Not for circulation at this time beyond the Gulbenkian and CES workshops.

Comments welcome.

#1

The wind got up in
the night and took our plans away.

Chinese proverb

All plans? Whose plans? And where does that wind come from?

#2

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 forty years of his life elaborating his interpretation of historical and ongoing social transformations.

An English contemporary of Marx, Francis Galton, sought to promote social progress by interpreting patterns in data drawn from human relatives. As Galton proclaimed early in the forty years of research he conducted:

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, 165-6).

Fast forward to 2008. Genomics entrepreneur, 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 and Dawkins 2008).

#3

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, less grand in scope, concerns the relationship in social studies of science and technology (STS) between interpreting the projects in the life sciences and influencing their direction. On this second level my starting point is the tension between, on one hand, accounts built around simple themes that are readily conveyed and digested by a wide audience and, on the other hand, 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. I will return to the simple

side shortly. On the complexity side, the social studies of science has since the 1980s 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 (Latour 1987; Law 1987; Clarke and Fujimura 1992, 4-5; Taylor 2005, 93ff). My personal experience pursuing applied scientific research matches this picture. This has led me to explore the idea that anyone wanting to influence developments in some area of science would benefit having some kind of "map" of the complexity of resources or practical commitments involved in knowledge construction in that area. Such maps point to multiple places at which concrete alternative resources could be mobilized, which allows a range of researchers, taking into account their own background and interests, to identify specific changes that they could effect (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. We can hardly provide maps of the complexity in a range of cases that span the interests of our intended audiences, but we might aim to guide or inform the choices that students and readers go on to make as they shape their paths into that complexity. In that spirit, one pedagogical/ expository approach I employ is to use cases or scenarios to motivate themes of a certain kind: they 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 is to employ what I call "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. This essay pursues a variant of these two approaches in an experiment whose character will emerge in due course.

* * *

#4

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)

If the case of phenylketonuria (PKU) is any guide to our imagination of this world, significant complexities should be expected to arise once neonatal diagnosis and advice about protective measures becomes 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 shows, the certainty of severe retardation has been replaced by a chronic disease with a new set of problems. Although screening of newborns became routine quite rapidly during the 1960s and 70s, there remains an ongoing struggle to secure health insurance coverage for the special diet and to enlist family and peers to support PKU individuals staying on that diet. 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. 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.

Debate can be anticipated 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 so-called "maternal PKU." Scientists or interpreters of science who want to contribute to improving the lives of people affected by PKU 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 counseling, paid family leave, or...? 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.

#5

"Family That Walks on All Fours" is a popular science documentary on the United States Public Broadcasting Network (<http://www.youtube.com/watch?v=0gNKNo55jdE>; see transcript; http://www.pbs.org/wgbh/nova/transcripts/3317_allfours.html). 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 3 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—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?

#6

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 anti-social behavior in adults in relation to the activity of monoamine oxidase typeA (MAOA) and childhood maltreatment (Caspi et al. 2002). They summarized their results 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.

Caspi and Moffitt conclude that their results "could inform the development of future pharmacological treatments" (Caspi et al. 2002, 853). In the context of research on childhood experiences and adult behavior, the implication of their conclusion is that, if low MAOA children could be identified, prophylactic drug treatment could reduce their propensity to anti-social 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 sideeffects, and some of these may not emerge till 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 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?

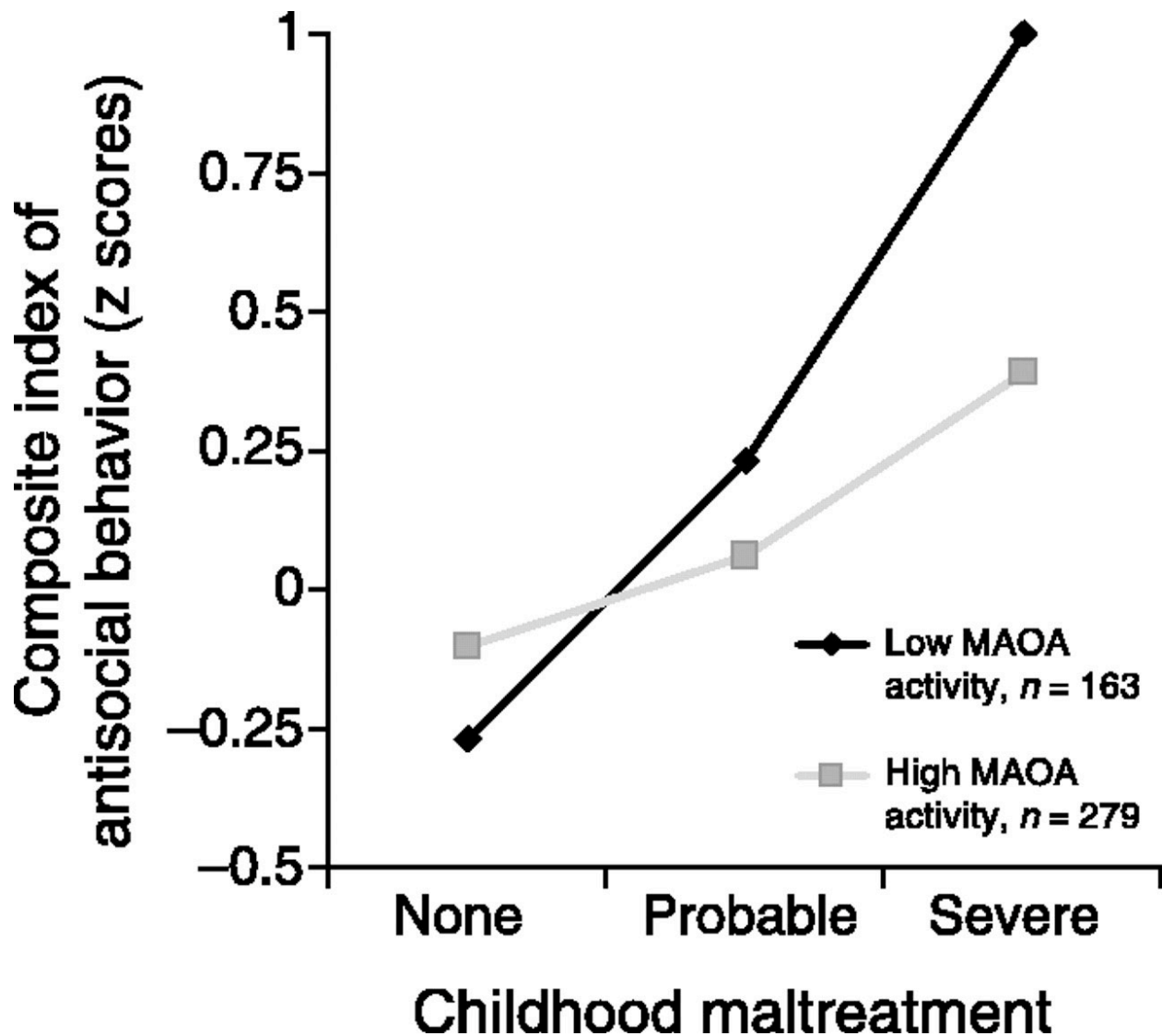


Figure 1. Average adult composite anti-social behavior score in relation to levels of MonoAmineOxidaseA and Level of Childhood Maltreatment for a sample from Dunedin, New Zealand (from Caspi et al. 2002, 852).

With the issue of social infrastructure 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 2 are the averages for the respective categories of people. Within each category people show a range of anti-social 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 anti-social behavior scores than some of the low MAOA individuals. The potential for misclassifying people into those who may end up

antisocial is not eliminated by adjusting what counts as antisocial. If we count 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 as antisocial. If we lower the cutoff score, many high MAOA individuals end up with behavior classified as antisocial (Figure 2). Whatever the cutoff score, the best that can be achieved with Caspi and Moffitt'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 antisocial and high MAOA ending up not).

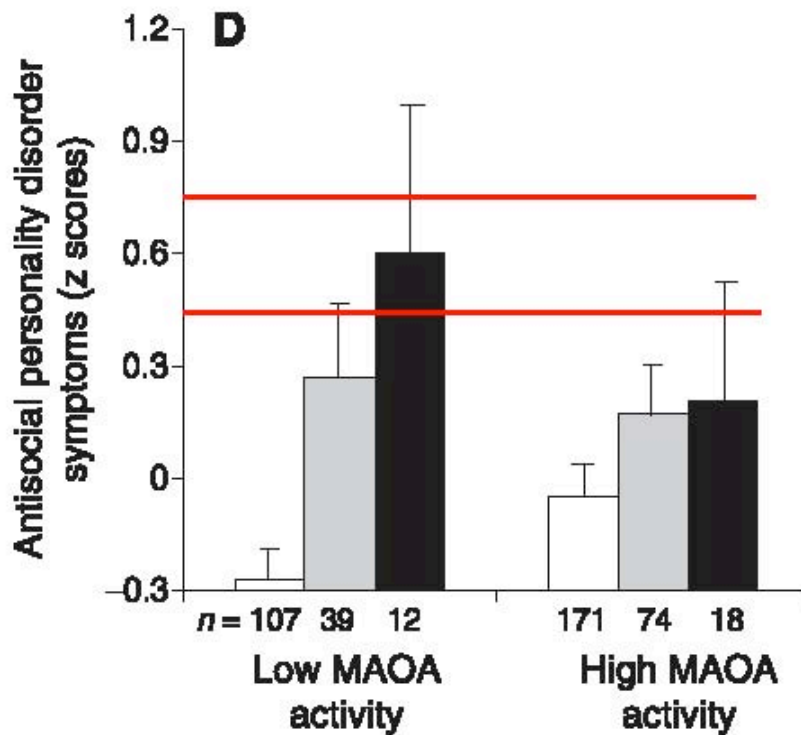


Figure 2. Average and standard deviation for adult anti-social personality disorder score in relation to levels of Monoamine Oxidase A and Level of Childhood Maltreatment for a sample from Dunedin, New Zealand (from Caspi et al. 2002, 852). Horizontal lines added to indicate the misclassification effect of a low and high cutoff for labeling a person as anti-social (see text for discussion).

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 them (and perhaps help predict who among the high MAOA children is 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 is contingent on the presence or absence of social infrastructure; the positive benefits depend on extensive social reconstruction.

#7

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 post-natal 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.) By analogy with the MAOA case, 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 or markers, 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.

Now, the promise of personalized medicine is that people can be informed 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. The risk is that this may not be a passing phase. What conditions—what social infrastructure—can ensure that the information and resources needed to move beyond it are forthcoming?

#8

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 and 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? Once it is out of the picture, how can large differences between generations (or racial groups) in this highly heritable trait be explained in terms of environmental factors? 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, which 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). Once this is accepted, the two-part argument about average group or generational differences dissolves into symmetrical position: no environmental factor is associated strongly with the group or generational average differences, and no genetic factor is either (Nisbett 1998, 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, or even 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 methods to collect and analyze the data so as to discriminate among possible models. Yet, statistical analysis at its very foundations depends on comparing differences between averages in

relation to the noise or "error" of variation around those averages. How can it be an aid, not an obstacle, in addressing such a challenge?

#9

The possibility that heterogeneous pathways underlie the variation in any given human trait leads, in turn, to a puzzle for socially engaged researchers (Taylor 2006; 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; 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 for African-Americans. Yet, exposing the best way to ameliorate the effects of racial group membership for any individual may depend on having 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 (environmental) benefits and costs. Conversely, can researchers continue to track 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 genuine paradox that applies to the use of IQ test scores in U.S. society seems to be that researchers and policy-makers who want to move beyond explanations and policies based on racial group membership cannot escape taking into account the disadvantages and benefits individuals experience because of their group membership.

The situation for research is even more sticky once we move from models to analysis of data 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, Alba, and Farley 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 U.S. 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.

#10

The data that researchers collect shapes 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, 566). However, especially for the traits that concerned him, namely, “superior faculties” or abilities that were “exceptionally high” (1892 [1978], viii), Galton concluded at an early stage of his inquiries that “nature prevails enormously over nurture” (1875, 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 may be less than convincing to us—at one point he begs the question by defining the traits he was measuring as those that “exclude the effects of education” (1892 [1978], viii). What is 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 needs to be collected over the life course of individuals so that researchers in say, thirty 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 almost has to emphasize the effects of genetic factors (but see Davey-Smith and Ebrahim 2007).

#11

A line of research from England, initiated by the sociologists Brown and Harris in the late 1960s, investigates 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 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 effect, the Life Events and Difficulties methodology integrates "the quantitative analyses of epidemiology and the [in] depth understanding of the case history approach" (Brown and Harris 1989a, 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 eleven (Brown and Harris 1978; 1989b). A reconstruction of Brown and Harris' work 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).

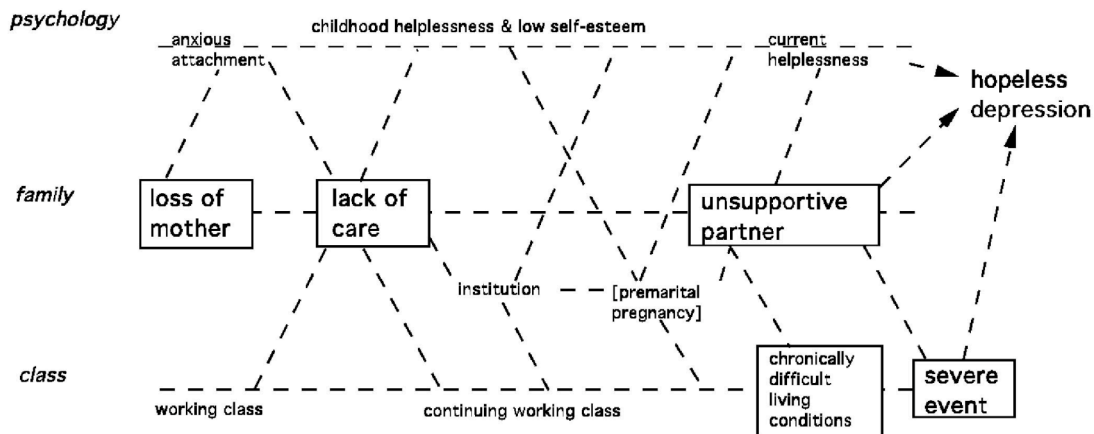


Figure 3. Life development pathways to severe depression identified in Brown and Harris's study of working class women and reconstructed by Bowlby. The dashed lines indicate that each strand tends to build on what has happened earlier in the different strands. See text for discussion and sources.

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 and 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.

* * *

#12

Early in this essay 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 detailed examination of concepts and methods or analysis of social context. Many searching questions about the concepts, methods, and social context have been raised, but what can I expect readers or listeners to do with such questions? That question cannot be answered with any definiteness or specificity—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 to a second set of vignettes.

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, heuristics (rules of thumb), 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 through which

readers crystallize for their own particular circumstances an impetus to mobilize different resources or organize them in new directions. In other words, the themes and questions from this essay's vignettes might provide pieces of scaffolding that help readers contribute to construction and reconstruction of social infrastructure.

#13

The essay could have ended at this point, 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 have left critical questioning of research serving as the motor of STS attempts to influence on the life sciences. More attention needs to be given to the society side of STS. Of course, impressive work is already being done (e.g., Centro de Estudos Sociais 2005; Epstein 2008). I will not attempt to duplicate or review that work. Instead, let me speak to one area that calls for more development, namely, the conceptualisation of the structure or *structuredness* of the social context of scientific and technological developments and human agency in the ongoing restructuring of that context.

Consider two influential schools of STS work: Collins' "empirical program of relativism" (EPOR) and Latour and Callon's actor-network theory (ANT). Collins describes the first two stages of EPOR as exposing the interpretative flexibility of experimental data and showing some of the "mechanisms through which the potentially endless debate about interpretation is limited" (Collins 1981, 7). The third stage would be to relate the constraining mechanisms to the wider social and political structure. Neither Collins nor the other authors he reviews 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 a program of 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 structuredness. Pursuing this interpretation, we might ask how human agents' actions generate, maintain, and undermine that structuredness. Indeed, the agents themselves might consciously identify at least some of these regularities or structure/dness. The issue of social determination of the production of knowledge that ANT seemed to banish 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. This is the impetus behind the vignettes to follow.

#14

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 multistranded 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 intervention or 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.

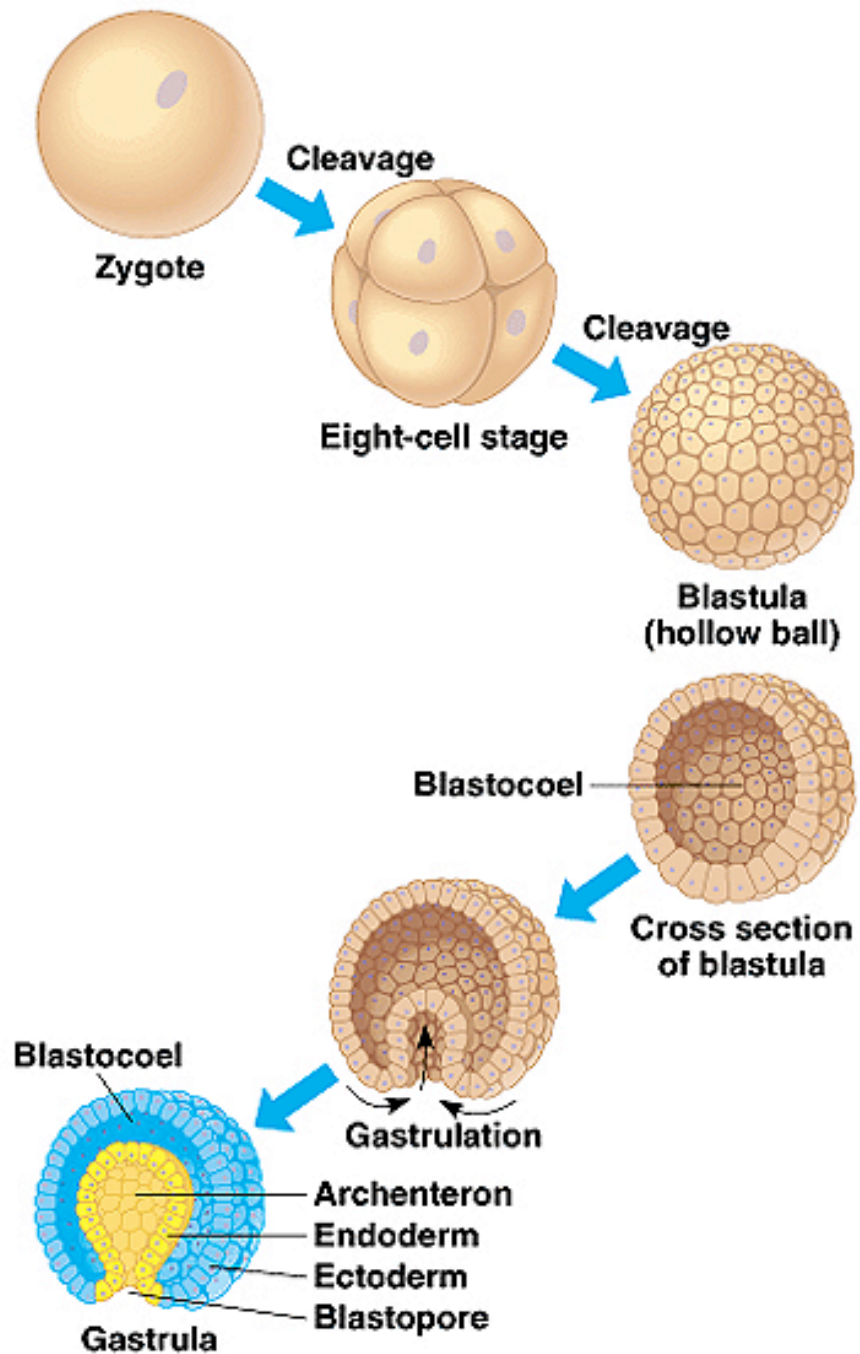
In discussing depression among working class women, rather than in other groups, I could be seen as perpetuating a male, professional-class perspective. However, the politics of the case can be viewed quite differently. Although depressed working class women are the focus, the intersecting processes 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 counsellors, 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 such exchange among the 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. The intersecting processes picture supports diverse engagements with the sciences of changing life.

#15

There has been a long history in social theory of discussion of how to relate social structure and human agency (Sewell 1992). In Taylor (2005, 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, through which the original ball of cells 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 its 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.



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Figure 4. A generalized depiction of early embryogenesis and gastrulation resulting in two cell layers, ectoderm and endoderm. (For more dynamic views, see see also http://www.gastrulation.org/Movie13_1.mov, <http://worms.zoology.wisc.edu/frogs/gastxen/wholegas.mov>, http://worms.zoology.wisc.edu/frogs/gastxen/gastxen_sagview.html.)

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 of the geographer, David Harvey, "Militant Particularism and Global Ambition" (Harvey 1995), which analyzes these works and earlier novels of Williams 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, 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 trans-local 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' 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, 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 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, 357-8). 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" (161). People have to align their work and lives within the prevailing social infrastructure, but should expect that infrastructure to change around them.

#17

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. Their work anticipated and now exemplifies the post-Cold War emphasis on a vigorous civil society, that is, of institutions between the individual and, on one hand, the state and, on the other hand, the large corporation (Burbidge 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 goal of ICA workshops is 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. As well as desiring specific plans, the EDC 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 they could not simply 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). The detailed scientific analysis of an agricultural region was conducted 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 2 or 3 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, such as the start 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, their analysis of changes that arise beyond the local region or at a larger scale than the local? For example, even if I had moved to the agricultural region we studied and participated directly in shaping its future, I would still have known 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. What would it mean, then, to take seriously the creativity and capacity-building that seems to follow from well-facilitated participation but not to conclude that researchers should "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 they 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? 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).

#18

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 summer road-trip). 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—trans-local contrast. The translocal side can encompass resources as well as perspectives or knowledge 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.

Weyerhauser'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 (Cronon 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 the title of anthropologist Eric Wolf's (Wolf 1982) book Europe and the People Without History implies (and the content of the book shows), there are always groups hidden, but dynamically present, in dominant historical narratives. This is spelled out by historian Geoff Eley (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 any "layer" of a globalized political economy emerges in relatedness.

#20

Second order effects complicate the militant particularism—trans-local contrast. Attention needs to be given to the unevenness of militant particularist loyalties or solidarities. There will always be "locals" who are prepared to support people with trans-local 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 "ocal" scales up to the level of a nation, the translocal often corresponds to international financial or military knowledge and resources. Naomi Klein's (Klein 2007) case studies in "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, drastic cuts in government spending, and 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 to prepare and implement economic "shock therapy" in Bolivia in the mid-1980s, to the economic agreements made by the A.N.C. in South Africa as they focused on avoiding a civil war and negotiating the political path to a post-apartheid democracy.

#21

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 (2007, 19).

The connection between neo-liberalism and fundamentalism is amplified in 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, 2). As such, the Protestant reformation is seen as leading to 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 and (idealized) true Church history over those of others.

To observe that interpretation arises within a historically located community is not to apologise 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 questioning the dominant developments in science and technology must lead to marginal and schismatic

positionings, that it is better to be subservient to the dominant, received understandings of the meaning of biological knowledge. 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. 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. We can suspect the same of Venter and Dawkins' fantasy of genetic information serving, with a minimum of interpretation or social infrastructure, to reshape life and solve social problems. The wind that takes our plans away is fanned by the plans themselves.

* * *

#22

Heterogeneous components and pathways; multiple partial joint engagements within intersecting processes; militant particularism versus contributing or withdrawing translocal knowledge and resources; differentials and uneven development; meaning-in-relatedness and second-order effects; flexible engagement—these themes and questions that accompanied them are pieces of scaffolding you may or may not assemble to help conceptualize the structuredness of the social context of scientific and technological developments and the nature of human agency in the ongoing restructuring of that context. Each of us needs to play as well as work with our concepts and interpretations so as to support our diverse engagements with the sciences of changing life. Composing this essay has been an experiment in playful, yet serious work. I invite you to further the experiment.

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