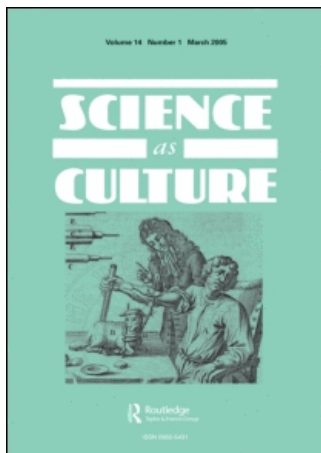


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GENOMIC CAPITAL: Public Cultures and Market Logics of Corporate Biotechnology

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GENOMIC CAPITAL: Public Cultures and Market Logics of Corporate Biotechnology

KAUSHIK SUNDER RAJAN

This essay is about the cultural transformations—institutional and conceptual—that biocapitalism is creating in the materiality and exchangeability of what we call ‘life’. These transformations are created through shifting and variable use of market commodification versus public commons or public goods formation, both of which are disciplined by new forms of capitalist logic, conforming neither to those of industrial capitalism nor those of so-called postmodern information capitalism. Hence ‘biocapitalism’, which basically asks the question of how ‘life’ gets redefined through the contradictory processes of commodification.

Specifically, this essay is about the enterprise of genomics as a window on contemporary capitalism.¹ It is a window that affords a particularly important view into the latter’s workings as the confluence today of the information and life sciences redefines not just biology but society and its perspectival vantage points writ large. Paul Rabinow coined the term biosociality to describe social relations organized and coordinated on the basis of shared biological identifications (Rabinow, 1992). If capitalism could be understood in the nineteenth century through an understanding of the industrial revolution, which itself was powered by the dynamics of circulation of money and commodities, then the twenty-first century could be said to be an era of biotechnical capitalism, in which the sciences of life construct and articulate new historical modes of capitalism.

BIOTECHNICAL CAPITALISM

The argument that the life sciences are increasingly assuming a definitive importance in illuminating capitalist dynamics in the twenty-first century may be a contentious one. Nevertheless there is

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no doubt that biotechnical capitalism (or biocapitalism) can be used as an explanatory framework for contemporary capitalism. This features emergent and shifting topological manifestations and conundrums of value generation and market logic that come out of the bio-informatic (disciplinary and corporate) mergers of the genome sequencing revolution.

The salient features of biocapitalism, as I explore them in this paper in sequential sections, are as follows: (1) a breathless rhetoric of speed, implying seamless flows of information, tempered by speed bumps in the form of ownerships through patent protection; (2) mobile and unpredictable strategic terrains of conflict and co-operation between different companies and types of companies as well as between companies and public-funded scientists and institutions; (3) the establishment of new forms of contractual alliance such as consortia that destabilize the commodity status of information while instantiating the gift regime as a logical, strategic and ethical mode of corporate functioning; (4) the emergence of forms of symbolic capital through confluences of advertising excess and ethical embodiment; and (5) the emergence of new biosocialities and subjectivities that are always-already embedded in the logic of the market—a logic which is itself very much at stake in the strategic articulations of biocapitalism.

In trying to understand biocapitalism, therefore, I am interested in asking, firstly, where value resides as biology becomes an information science (and some kinds of information become biological), and secondly, what work and (whose) agencies are required to create these values. Answering these questions involves understanding the circulation of information and the changing forms of corporate activity. My attempt is to theorize the dynamics of information flow and corporate action around the fact that information is something that can be and is now owned. This essay, therefore, will offer an analysis of the dynamics of information ownership, and its effects on both institutions and on information itself. Specifically, it focuses on the relationship between information flows and the ‘speed bumps’ created by private ownership, in order to trace its implications for understanding the operation of biocapitalist market logics.

It is, however, very important to emphasize that biocapitalism is not just an understanding of an information system. Indeed, genomics itself, while marked most notably by its material representation of

life as information, is precisely information *about life*, that both epistemically and materially ties into the creation of tangible knowledges and products. In other words, 'genomics' is both an information science and not just an information science. It is aimed towards the production of particular kinds of things, such as pharmaceuticals and crops. It is important to keep in mind that what is at stake is an understanding of how the various elements, practices and objects—informational and 'thingly'—of genomics articulate. It is in the particular modes of articulation—of information and materiality, rhetoric and practice—that genomics distinguishes itself from other information systems such as the Internet economy or finance.

This essay looks at corporate genomics today. All three of these words need to be explained right at the beginning. By genomics, I mean an ensemble of events, technologies, discourses and institutions that spring up around the sequencing of genomes.² The 'today' is important: there is a tendency to conflate genomics with its best known institutional manifestation, the Human Genome Project (henceforth referred to as HGP). The HGP, however, is very much just a fragment, albeit a central one, of genomics today. Firstly, a primarily state-sponsored venture, the HGP occupies a particular political space vis-à-vis genomics writ large, as an endeavour which has used and continues to use public money to generate gene sequence information—and I will talk more about this particular political space later in the essay.

Secondly, the sequencing of the human genome, a project that just a few years ago seemed so dauntingly far away (if not temporally, then at least in sheer volume of effort) as to be an end in itself, is today very much conceived of as just the end of the beginning, at a moment when a working draft sequence of the human genome is already complete. Genomics today therefore is largely what might have been called 'post-genomics' even a year ago. And by 'corporate' I refer not just to the enormous number of what are called genomics corporations that have sprung up in the last 5 years, but to the entire nature and agenda of genomics writ large.

There is a specific, busy and under-studied intersection that is marked by genomics. Firstly, there is a general (public and academic) absence of understanding of biotech and its specific forms of value. The approach of theorists of the information economy [such as, for instance, David Harvey (1990) with his sector economy

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approach] misses the points where science and industry intersect Life as opposed to Work.³ I am starting from within biotech to understand its form of life (Fischer, 1999). My emphasis on information is not to project genomics as an 'information system' (in the way that 'systems' have been theoretically propounded in such literature), but to show the specific roles that information comes to play. These include ways in which information:

- affects the entire dynamics of the drug development industry;
- intersects with public culture. Particularly important in this regard are debates over ownership and privacy that adopt tricky shapes which mask the capitalist dynamics of even those modes of strategic action that present themselves as somehow altruistic or external to the market; and
- relates to the emerging notions of value specific to biotech as research, capital and life force— notions that require close ethnographic attention in order to be adequately understood.

In other words, the locus of analysis for understanding emergent drug development dynamics writ large is not information but the biological—which implies that an analysis of biocapital is not just a derivative of other analyses of information or late capitalism. Moreover, what is considered constitutive of 'genomic' information has itself been changing. In 1999–2000, for instance, genomics was about the selling of databases. Since the completion of the working draft sequence of the human genome in June 2000, however, a lot of information is in the public domain, and a lot of the best commercial sequence databases have already been sold or licensed. Therefore, in the 'post'-genomic era that we are now in the midst of, there is a push even within the industry towards focusing on diagnostics and drug development, and 'genomic' companies are being forced to reinvent themselves in various ways to contend with that. In other words, genomics is not about information as much as it is about the relationship between information and that downstream, material 'something else' that is a consequence of its availability and use. In this relationship, information itself acquires materialities and types of value that are constantly morphing.

The larger project of understanding biocapital then is less about understanding the flow of information and more about understanding the circulation of various forms of biologicals, information being

a particular type of biological that creates and operates in particular circumstances through particular modes of action. This isn't just about understanding a particular type of information economy in which information happens to deal with 'life', but is rather about trying to understand the various inaugural moments in the process of life sciences constructing and articulating different forms of meaning and value, in the realm of political economy and otherwise.

Secondly, it is not possible to do justice to understanding biocapital without, firstly, understanding the commodity status of human biologicals, and secondly, inserting that understanding not just into a political economic understanding but into understandings of how new subjectivities get created—value in all the senses of the word have to be understood, as do the modes of abstraction that are peculiar to the inaugural moments that biocapital marks.⁴

This essay is organized into five sections. In the first, I set out my argument regarding the ways in which speed operates as a material-rhetorical fulcrum to structure biocapitalist terrains as they pertain to the commodification or making public of genomic information, where speed is seen as both essential to the operation of market logic and brings with it inherent speed bumps that can equally be justified by taking recourse to market logic. In the second, I proceed to explore these terrains thus structured, specifically the relationship between the public Human Genome Project and private companies, and between upstream and downstream life science corporations. In the third, I describe some of the modes of articulation that constitute these terrains, specifically looking at emergent forms of contractual alliances such as consortia that question the naturalized commodification of genomic information. In the fourth, I speculate upon the resultant emergence of and deployment of new forms of value and symbolic capital by genomics and pharmaceutical companies. And in the fifth, I ponder the question of market logic and argue that it is the very definition of what constitutes market logic that is often most at stake in the strategic articulations of biocapitalism. I conclude by suggesting that understanding the adaptive mechanisms of capitalism, using biocapitalism as a lens through which to study them, involves paying close attention to the strategic and contradictory articulations of the various involved actors, and noting the ways in which such contradictions, leading to frictioned terrains and processes of value generation, can in fact be incredibly productive of

new ways of doing science and business, and of new public and corporate cultures.

■ SPEED AND SPEED BUMPS

In this section, I introduce the argument that a breathless rhetoric of speed is constitutive of biocapitalism. This is a rhetoric that implies seamless flows of information, and yet this seamlessness is constantly interrupted by speed bumps in the form of ownerships through patent protection.

One of the features of sequence information flow in genomics is the remarkable speed at which DNA sequences are being generated, a consequence of considerable automation and investment in technological hardware in the form of new DNA sequencing machines. The pervasive rhetoric surrounding such rapid information generation is, not surprisingly, one of speed. The sense conveyed is of being overwhelmed with a huge amount of (presumably) valuable data that is virtually impossible to keep up with. As I will try to show, this isn't merely rhetoric (though it's all rhetorical), because it is true that there is a huge amount of data being generated, and while nobody quite knows the biological significance of even a fraction of it, any piece of information in this haystack could turn out to be extremely valuable, therapeutically and commercially.

Speed is also of direct material value, since a delay in the production and marketing of what turns out to be a blockbuster drug could well cost a drug company in excess of a million dollars per *day*. Speed manifests itself in two distinct ways: both as massively compressed research and production time, and as a number of emerging segments that contribute to or feed off speediness. In other words, 'speed' in genomics is not just important because change is fast, but because 'speed' is a material-rhetorical fulcrum used to lever first the government, and then the public and other companies, into responding to 'hype' and thus further entangling themselves in biotech.

In order to stake a claim to the potential value of genomic information, there is a desire (amongst private genomicists, for sure) to own it. Ownership, however, puts fetters on the seamless flow of information, which is the desired condition in order to enable information to be transformed into that valuable 'something else', which is often a pharmaceutical or agricultural product. I will unpack

this dynamic in greater detail as the essay proceeds, but this is the central theoretical problematic that I'm trying to contend with: the breathlessness manifested through a speed surrounding information flow, tempered by the speed bumps installed as a necessary consequence of an institutional regime that allows information to be owned. This leads to a frictioned process. I use the notion of friction rather than that of noise (which has commonly been used in information theory to denote obstructions to information that, if overcome, can lead to a seamless flow of information),⁵ because such obstructions are not externalities waiting to be subsumed in a seamless flow, but are, rather, internal to the dynamics of the flow itself. Friction is both the product of things rubbing against each other and suggestive of conflict; it is not just obstructive, but productive. Speed, speed bumps and friction, therefore, are all inherent to the circulation of genomic information in contemporary capitalism.

■ CONFLICT AND CO-OPERATION

In this section, I map the mobile and unpredictable strategic terrains of conflict and co-operation between different companies and types of companies as well as between companies and public-funded scientists and institutions.

The US National Institutes of Health (NIH)-funded Human Genome Project (HGP) started at the end of the 1980s as a public-funded effort by five nations to sequence the human genome, coordinated by the National Human Genome Research Institute (NHGRI) of the NIH. The current head of the NHGRI is Francis Collins. The major sequencing centres of the HGP are located at the Whitehead Institute in Cambridge, MA, Washington University, Baylor College of Medicine, the Joint Genome Institute of the US Department of Energy and the Sanger Centre located near Cambridge, England. In addition to the Rockville, MD based Celera Genomics, which is Craig Venter's company and a daughter company of Perkin-Elmer, some of the other major genome companies include Incyte Genomics (based in Palo Alto and Cambridge, England), Millennium Pharmaceuticals (Cambridge, MA) and Human Genome Sciences (Rockville, MD). Incyte is a major rival to Celera as well as to the public-funded project. HGS was initially co-founded

by Craig Venter after he left the NIH, along with William Haseltine. Venter left HGS after serious differences with Haseltine, who now continues to head it. Millennium, which is also involved in drug development in addition to DNA sequencing and functional genomics work, is by contrast rather more friendly with the public-funded project, as one of its co-founders is Eric Lander, who is the head of the Whitehead Genome Center and thereby a major player in the HGP.

The original plan was to sequence the genome starting from one end and working towards the other, with a very stringent error frequency of not more than one every 10,000 base pairs (10X). The HGP, in its initial years, was indeed a rather languid affair.

In May 1998, however, the HGP was thrown into turmoil by an announcement by J. Craig Venter that his company, Celera Genomics, was going to sequence the human genome through a more rapid method that involved shredding the genome into pieces, sequencing the pieces and putting them back together again, with somewhat less concern for error, through his private sector labs and using his new extra-quick automated sequencing machines. The major reason for the turmoil was the well-known fact that Venter (and other private sector genomicists who were entering the sequencing fray in a big way at this time) would patent the DNA sequences they generated, thereby keeping them out of the public domain.

‘Craig Venter’, says *Time* magazine in an issue devoted to the Future of Medicine (11 January 1999) ‘is a man in a hurry, and now all the genome mappers are operating on Venter time’. This one sentence encapsulates the multiple embodiments of hastened temporality in the contemporary world of Big Biology, where fast technologies are mirrored by fast CEOs. Venter’s announcement turned the genome programme into a competitive race, in which the HGP researchers were forced to redraft their plans (Collins *et al.*, 1998), in the process changing the maximum error allowed from 1 in 10,000 base pairs (referred to as 10X frequency) to 1 in 5,000 base pairs (5X).

Time continued to articulate the speeded up genomics enterprise in terms of Venter’s own characteristics, as it proceeded: ‘Driven, impatient, demanding, irritating, Craig Venter has a knack for making the rest of the world run at Venter speed’ (Thompson, 1999).⁶ This is not an unusual description for the contemporary maverick of

Big Biology: indeed, *Time's* character history of Venter is uncannily similar to the popular character sketch of that other maverick-genius who has revolutionized biology in the last decade, Kary Mullis.⁷ In the same article, Venter's wife and fellow genomicist Claire Fraser is quoted as saying: 'Vietnam changed him. It impressed on him the idea that time is precious, that you have to make every single minute of every single day count'. Even two decades after the war?

Perhaps Big Biology isn't just a race though. Perhaps it *is* a war.

Venter's history is controversial. He was at the NIH in the early years of the HGP, and was involved in an NIH attempt to patent DNA fragments from brain tissue in 1991 (Cook-Deegan, 1994, pp. 311–325). The NIH burnt its fingers in the process and Venter left the NIH. Not surprising then that much of the ire of the HGP scientists towards Venter today is (at least on the face of it) not just a fear of being upstaged, but the knowledge that Venter will patent the DNA sequences that he generates. If the genomics enterprise is a race, then it isn't just a race for credit, it is one for ownership as well.

The attempt to trace large-scale political economic processes has been an emergent challenge in the latest 'experimental' moment in anthropology (see Marcus and Fischer, 1986). The tension between the speedy trajectories of genomics and specific locales in which genomics in various forms is practised (produced, circulated, consumed) is of utmost importance. Genomics is practised in particular labs, universities and corporations, and these particularities are of consequence. This makes an exercise in mapping genomic worlds equally of importance. The sociological or ethnographic mapping of technoscientific processes in the work of the early STS mappers such as Latour (1987) and Knorr-Cetina (1981) or schools such as the Social Construction of Technology (SCOT), were primarily concerned with the construction of scientific knowledge and technological artefacts. We also need to map the cultural transformations that accompany and co-produce the redefinition of 'life itself'.

Such mappings need to be dynamic: commodification of 'science itself' can lead to a very quick internalization and acceptance of these processes as natural. This commodification takes recourse to an inherent 'market logic' to innovation and scientific knowledge. However, the main argument of this paper is precisely that 'market logic'

is *not* natural, but rather a strategic–rhetorical invocation that allows the (re)structuring and negotiation of biocapitalist terrains. In other words, the *apparent* naturalization of complete commodification as the condition for scientific innovation masks the fact that commodification is selected and contested, subject to conflicting interests and ethical representations. Therefore, I argue that the strategic deployments of speed versus speed bumps, and commodification versus commons, show that such naturalization can be dramatically denaturalized at break points in the shifts of forces and competitions in the political economies involved.

Finally, the global integration of this work requires an attention not just to the co-production of science, politics and culture, but to such co-productions across multiple relational locales, adding a further level of complexity to the analysis. Put simply, the object of bioscience, the practice of bioscience and the locations of bioscience have all changed. These changes call for an STS/anthropology of science approach that combines political economic, business and bioscience analysis and ethnography. Some recent pioneering works in STS (Cambrosio and Keating, 1995; Franklin, 1997; Fujimura, 1997; Haraway, 1997; M. Fortun, 1999a,b; Kelty, 1999; Fischer, 2000; Helmreich, 2000; K. Fortun, 2001; Dumit, forthcoming) and in the related field of medical anthropology (Farmer, 1993; Rabinow, 1997, 1999; Petryna, 1999; Cohen, 2000; Biehl *et al.*, 2001) have begun to chart such a terrain. Also of relevance are models of other ethnographic work sensitive to the relationship between global political economic processes and local practices, knowledges and value systems provided by authors such as Taussig (1980, 1987), Scott (1987, 1998), Strathern (1992, 1999), Appadurai (1996), Maurer (1997) and Gupta (1998). In the case of genomics, the tension between the ideological, rhetorical and material commitment to ever-accelerating speed—and the nature of the practices and its multiple locales—need to be analysed.

In 1999, the Human Genome Project was clearly haunted by the spectre of Venter. Much as the HGP researchers insisted that the media overplayed the Venter story, he was referenced everywhere, in often thinly veiled taunts ('combative entrepreneur' and 'worm genome detractor' being amongst the more colourful ones). So it is perhaps worthwhile to narrow in on the dynamics of the HGP v. Venter race for a while, to see just how high the stakes indeed were

for the former, and how irrational their involvement post-Venter might seem to be.

I would like to mention here that much of the following perspective was obtained from talking to students and post-docs, who feel less compelled to quote the Party Line that their more illustrious seniors espouse. A general consensus amongst younger public scientists at sites in 1999 seemed to be that the winner in the race, irrespective of who sequenced the genome first, was always going to be Venter.⁸ He was perceived to be in a win-win situation simply because he always had the NIH project's sequences to draw upon as soon as they were done (since they get immediately released into the public domain), while he didn't need to divulge his sequence to the Project. So effectively, the millions of dollars of taxpayers' money going into the Project has all gone into the Venter project as well, without his having to lift a finger; and there's nothing anyone could have done about it. Also, there really is a differential concern about quality between a project that is essentially scientific, and one that is a means towards a primarily commercial end.

The people who have undertaken all the risk are the NIH people. They've already spent too much public money to pull out, and need to spend much more to win the race;⁹ and the more they spend, the higher the stakes become.

■ COMMODIFICATION AND CONSORTIA

In this section, I trace the establishment of new forms of contractual alliance such as consortia that destabilize the commodity status of information while instantiating the gift regime as a logical, strategic and ethical mode of corporate functioning.

I now want to spend some time telling a story about the interactions between 'public' and 'private' genome worlds that will hopefully complicate the opposition between the two that I have just set up, while simultaneously unravelling the 'private' genomics enterprise as something infinitely more complicated and heterogenous.

Signals magazine, an online magazine that analyses biotechnology for executives, has the following quote:

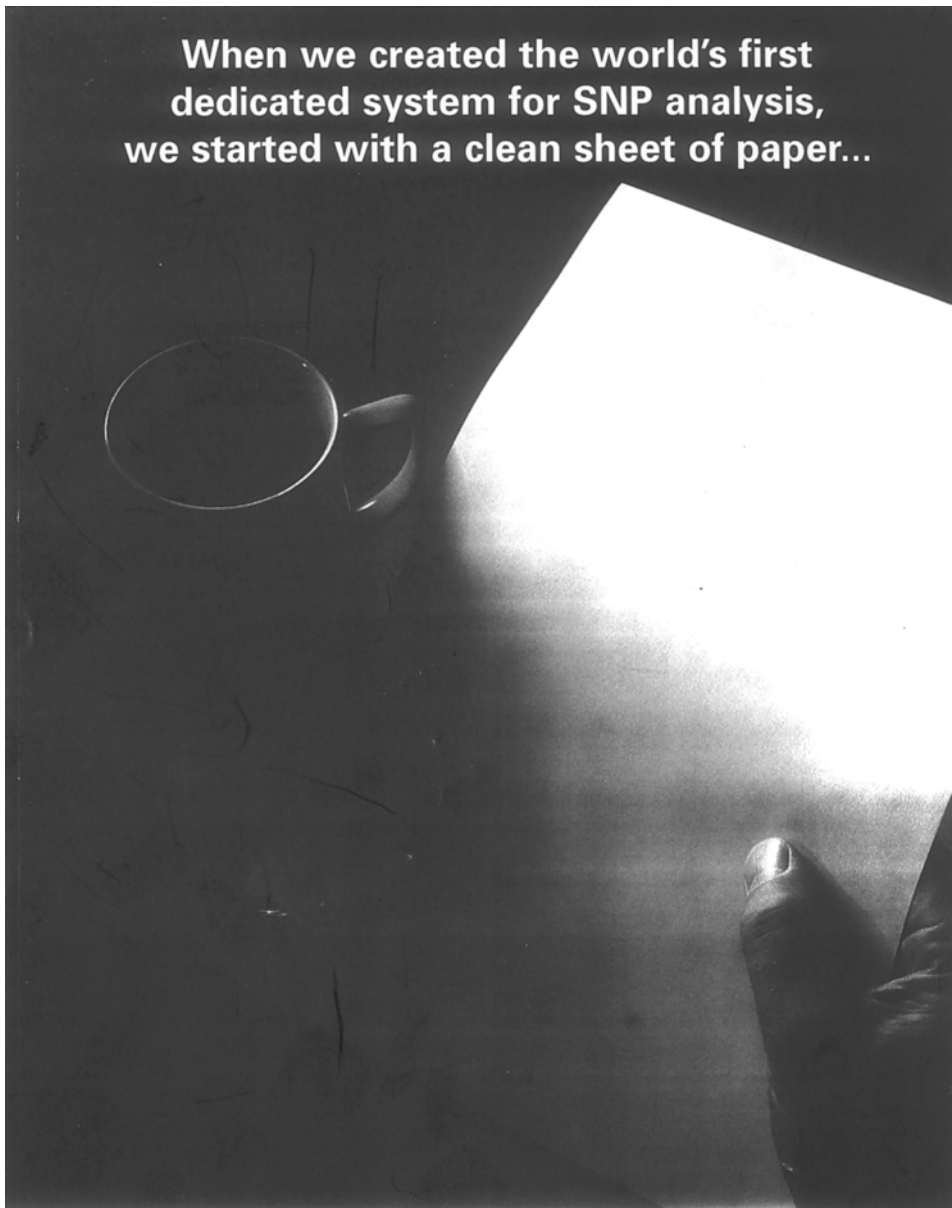
Coming soon: A global genomic map of single-nucleotide polymorphisms (SNPs), the tiny differences between two people's DNA that largely determine everything from who's

the natural athlete to who's the klutz to who's likely to get lung cancer from smoking and who's not. In the not-so-distant future, scientists will also be able to tell who's at risk for cardiovascular disease, whatever their lifestyle, as well as who will respond, or not, to this drug or that. But the techniques now used for discovering or mapping SNPs are costly, tedious and Ph.D.-intensive. The real mark of a SNP-detection assay scale-up will be its downward mobility: for characterizing huge numbers of SNPs among large populations, cheap, fast and easy is the way to go.¹⁰

Genomics is not just about the Human Genome Project, even though the Venter challenge that turned genomics into a major media event was about sequencing the human genome more rapidly. The HGP, however, will not yield any information about genetic *variability* between individuals and populations, which has become an area of increased interest for scientists and the biotechnology industry. The ultimate pharmaceutical aim of studying human genetic variation is to generate individualized therapy. Determining human genetic variation is a much more daunting task than sequencing the human genome, both because the sample of humans required to be sequenced is much larger, and because a truly meaningful correlation of genetic sequence and disease trait would involve identifying the person from whom the sample came, which raises ethical concerns about genetic privacy and informed consent. As the HGP has progressed, however, an increasing amount of interest has been paid to informational and technological tools that may help study human genetic variation, and conflicts and alliances have begun to arise around these tools.

The major informational artefacts in this emergent battlefield are called single-nucleotide polymorphisms or SNPs (pronounced 'snips'). SNPs are single base variations in the genetic code that occur about once every 1,000 bases along the 3 billion base human genome. Knowing the locations of these closely spaced DNA landmarks both eases the sequencing of the human genome and aids in the discovery of genes variably linked to different traits. A map of all the SNPs in the human species would provide the basic database to perform association studies, which compare the prevalence of particular genetic markers in individuals that possess a certain trait

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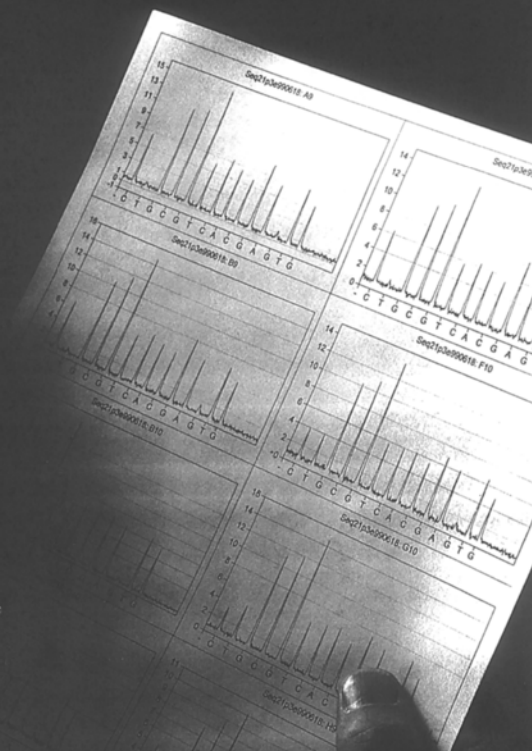
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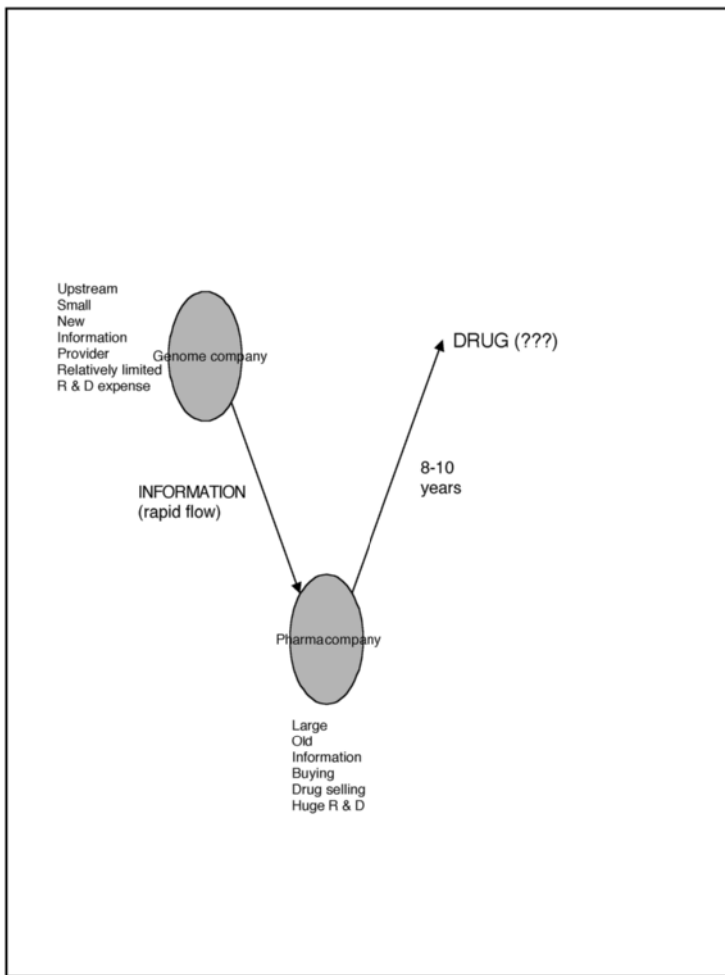
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analyses in your hand.**



(which may be a disease trait, a predisposition to a disease, or side effects to certain drugs) to those who don't. Association studies are a potential goldmine through the insights they might provide in unearthing obscure disease-related genes or in helping preventive diagnosis. SNPs, therefore, have a potential value as tools leading to therapy, in a more pinpointed and versatile way than a random DNA sequence. Pharmaceutical companies, not surprisingly, are extremely interested in SNPs.

A brief taxonomy of some involved 'types' of drug discovery and development companies may be useful at this stage. A crude distinction may be made between a 'genomics' company, whose business is to sell genetic information, and a pharmaceutical company, whose business is to sell drugs. This is, of course, a simplistic distinction. Nevertheless, a broad distinction can be made between the relatively small, new, information-selling genomics companies and the relatively larger, older, information-buying and drug-selling companies. Certainly, a common mode of operation for genomics companies is to license their information to big pharma, which is often more convenient for the pharmaceutical company than setting up an extensive genomics facility (see the figure below).

In the autumn of 1998, the NIH allocated \$30 million to the National Human Genome Research Institute (NHGRI) to enter the race to identify SNPs. This itself was a more than slightly breathless undertaking (or as Francis Collins, head of the NHGRI put it, an undertaking of 'some urgency'). The basic strategy that was decided upon in December 1997 involved the collection of at least 100,000 SNPs from DNA donated by 100–500 people in four major population categories: African, Asian, European and Native American (Marshall, 1997b). Collins first started promoting this project in September 1997, in response to the danger that SNP information would get patented and 'locked up' by genomics companies (Marshall, 1997a). In November 1997, Collins co-authored a Policy Forum piece in *Science* with Mark Guyer and Aravinda Chakravarti that argued that SNP data will get locked away in 'private collections' if it doesn't get public support (Collins *et al.*, 1997). Chakravarti has also argued for coordinated data gathering with public support not just for reasons of unfettered access, but for reasons of *ordered* access, saying that 'we will lose information if we don't combine it all in one place' (Marshall, 1997b).



Upstream—Downstream Terrain of Drug Development.

In other words, researchers like Collins and Chakravarti have been well aware since before the Venter challenge that owning DNA sequence information slows down information flow. What is interesting in the SNP story is the strategy that the public researchers have devised to get around this, and the speed with which the strategy was employed. This is a speed that potentially sacrifices some of the scientific quality of the data, an accusation that has ironically been levelled by the public-funded scientists themselves against Craig Venter's sequencing *modus operandi*.

In April 1999, the NIH strategy grew into a \$45-million consor-

tium funded by the British non-profit Wellcome Trust and ten of the major multinational pharmaceutical companies. The objective of the consortium was to generate a full-length SNP map within 2 years of starting and to place the results into a free public database. The members of the consortium read like a Who's Who of big pharma combined with the major players of the HGP.¹¹ The objective is that the public databases will be filled with enough SNP data to get around anybody's patent. According to SNP Consortium chairman Arthur Holden, 'Everybody will be able to do this sort of work without being held hostage to commercial databases'.¹²

While The SNP Consortium database is not a commercial *database* (in that it isn't being established as a commodity in itself), its establishment is undoubtedly a commercial enterprise. As Elliot Sigal of Bristol-Myers Squibb said at a major genome meeting, 'This isn't altruism, but win-win'. The move for a SNP consortium, in terms of connections and networks, has to be seen as a hegemonic move. Firstly, it recognizes and aims to remove the inherent contradictions in the commoditized/regulated circulation of information that I have analysed above. Secondly, it ensures that, by immediate release of information into the public domain, the major pharmaceutical companies do not have to go through tedious or expensive licensing procedures with smaller genomics companies. And finally, it gives an aura of legitimacy to the big pharmaceutical firms, both in the eyes of public-funded scientists (especially when compared to institutionalized enemies like Venter) and in the eyes of the 'public' at large—while Sigal is honest enough to admit that it wasn't altruism that drove the major pharmaceutical companies into sharing information, it can certainly be profitably projected that consortium members have foregone patent rights on SNP information in order to facilitate cheap, fast and easy public access to it. A wonderful example of, to use Edward Grefe and Martin Linsky's term, new corporate activism (Grefe and Linsky, 1995).

The SNP Consortium is not the only corporate collaboration out to hunt SNPs, and it is by no means the first. In 1997, Abbott Laboratories seeded the French genomics company Genset to the tune of \$42.5 million in order to construct a SNP map.¹³ This is considered to be the first 'strategic alliance' (as Genset calls it)¹⁴ in pharmacogenomics. Like many other genomics-pharma alliances, and unlike The SNP Consortium, this is an *exclusive* alliance, and

the division of labour in this alliance is quite typical: while Genset's job is to develop a proprietary map of the human genome with relevant markers and genes associated with responses to particular pharmaceutical compounds, Abbott's job is to 'develop, produce and market diagnostic systems derived from these genes and markers to clinically test patient response to specific drugs'.¹⁵ The SNP Consortium therefore replaces the direct contractual agreement of the Genset–Abbott type with something that is more 'communal' in nature, and at first sight counter-intuitive to 'market logic'. What is evident however is that The SNP Consortium is less an attempt to negate market logic as much as it is to redefine the terrain in such a way that 'market logic' is dictated by the strategic interests of the consortium members (whose aims are by no means identical or even co-terminous).

A major figure in The SNP Consortium (officially referred to as TSC) is Alan Williamson, former vice-president of research strategy at Merck. It was he who called the April 1999 meeting. According to him, 'Some companies have a very positive attitude towards the idea of supporting a public database'.¹⁶ What statements like this *imply*, in the rhetoric of New Corporate Activism, is that some companies are inherently open to sharing of information, while others are nasty little spoilers who want to own it all themselves; what it hides is an element of corporate subjectivity that shows all the nuances of social subjectivity, except that the playing field is unquestionably of billions.¹⁷ And this is where the genomics/pharma distinction comes to the fore again—even major genomics companies that might fancy themselves as pharmaceutical companies, at least in the future, do not have the history of pharmaceutical R&D and regulatory infrastructure that the big multinational pharmaceuticals have, and drugs are neither their primary nor an assured product. For TSC members, however, any possible profit they might make on a SNP patent is small compared to the profit they can make on a drug, and it is in their interests to remove the necessity of sharing that profit with a genomics licensee. As Williamson says, 'I don't think a SNP patent per se is going to be worth much. It's the clinical significance that really counts. Each SNP has to be evaluated epidemiologically or pharmacologically'.¹⁸

Therefore, while The SNP Consortium is purportedly against the ownership of DNA sequence information, it is very much in support

of owning biologicals *per se*—while speedy and free access of information to a large number of researchers will undoubtedly be an outcome of the TSC database, at another level it increases the monopoly of the big pharmaceutical partners in the consortium on any therapy that might accrue, at a lower cost to the companies involved. In other words, it isn't ownership itself, but the *modes* of ownership, that constitutes the terrain for hegemonic struggle in genomics.

Speed bumps are not removed the instant information reverts to being a pure use value, because there is commodification and consequent friction all the way through in Big Biology. For instance, genomicists have been looking for alternatives that speed up and ease SNP detection, and the DNA (SNP) chip promises to be one such technology.¹⁹ The market logic of Big Biology, however, dictates that the incentive to create new technology resides in the possibility of owning that technology, which means that while one speed bump might be removed, its replacement is, by virtue of itself being a commodity, another. Such has been the case with the DNA chip.

Patent disputes around DNA chip/microarray technology are bewilderingly numerous as well as complex, because it is very difficult to determine exactly what a particular patent covers, and what specific licensing agreements have covered. Patents are taken out not just on the DNA chip, but on the hardware and software associated with the chip, the applications of the chip for different research, therapeutic or diagnostic purposes, the fundamental principles on which the chip operates, and so on. Patent disputes over research tools can span different 'components' of the tool (underlying principle versus method of manufacture versus specific application), previous licensing agreements and different national legal regimes, and are further complicated by the fact that the companies involved themselves often postdate the initial fundamental patents that get argued about.

These disputes again highlight issues of corporate subjectivity. While unobstructed access and speedy progress of research remain the stated goals of all parties concerned, clearly for each party research progresses 'speedily' only when *they* have unobstructed access, combined with the right, whenever they feel appropriate, to slow down and charge everybody else—the inherent logic of *owner-*

ship, after all, is that the owner can decide what to do with the object owned.

Big pharmaceuticals have indeed been complaining for years about what are called ‘stacking royalties’, which are the fees that they have to pay out to various other upstream providers that stake a claim on the downstream drug product. Indeed, something like a SNP consortium is precisely a way out of having to deal with upstream information sellers who own information. Pharmaceutical companies have for a long time used ‘anti-stacking language’.²⁰ An article in *Signals* magazine titled ‘Is the alliance deck becoming “anti-stacked” against innovators?’ describes the Big Pharma argument for anti-stacking language as follows: ‘If Big Pharma licenses a lead compound from Biotech and that compound is later blocked by another party’s patent, it is Biotech who should bear the responsibility for that occurrence and shoulder the burden of crediting Big Pharma for the amount due the third party’.²¹ In the 1980s, Biotech companies themselves incorporated anti-stacking provisions in their dealings with universities. Since the late 1980s, however, Biotech companies have increasingly gone upstream, providing a range of utilities and services to now downstream pharmaceutical companies, and thereby have increasingly found themselves subject to similar anti-stacking agreements drawn up by pharmaceuticals. The justification for anti-stacking is further increased as the number and range of upstream providers increases.

■ VALUE AND SYMBOLIC CAPITAL

In this section, I show how forms of symbolic capital emerge through confluences of advertising excess and ethical embodiment.

Two questions are central to the analysis of value in genomics: first, the question of where value resides, in the various ‘informations’ and for the various actors, and second, what agencies are required to create and maintain the values and their directionalities.

Let us start by looking again at the actors involved in the contestation. There is, broadly speaking, the ‘NIH’, an umbrella term for an institution of the state that has sequencing under it various generally academic research institutes; there are upstream companies, which may be genome companies that sell information (either by simply sequencing, or after annotating the information), or

tool companies like Affymetrix; and there are downstream companies, of which pharmaceuticals (and invariably big multi-national pharmaceuticals) are the most downstream. Tied into the differentiation of upstream and downstream companies is the upstream–downstream relationship of information itself to its ‘ultimate’ product, the pharmaceutical (which of course need never actually be realized, but its existence as a future goal is vital to the operation of the entire dynamics of the present).

Now the NIH doesn’t want information to be owned because it has a commitment, as an institution of the state generating information with public money, to release the information into the public domain.²² In other words, for the state as represented by the NIH, information has the status not of commodity but of public good.²³ The downstream companies do not want information to be owned because their locus of surplus value generation is in selling the drug, and the less they have to dish out to upstream companies on the way the better for them. However, by framing this rather narrow self-interest in terms of a ‘relinquishing’ of patent rights on DNA sequences in order to enter into a ‘partnership’ with the HGP to allow ‘free and rapid’ flow of information, the New Corporate Activism of the pharmaceutical companies shifts the nature of information from the realm of commodity into the realm of gift.

The idea that information is a gift on the part of big pharmaceutical companies is well in keeping with the tenets of New Corporate Activism. As Marcel Mauss (1990 [1954]) has shown, the gift has attached to it cultural obligations both to receive and to reciprocate. The field of gifting/reception/reciprocation is much less clearly delineated in genomics than in the ‘archaic societies’ of Mauss, and encompasses that extremely diffuse and undefined and constantly recruited arena of the ‘public domain’. As Jacques Godbout and Alain Caille have argued, the gift economy is central to the dynamics of the market and the state, with the market absolutely dependent on the existence of gift exchange (Godbout and Caille, 1998).

There is, therefore, a tension between a linear race towards commodification and the changing status of information from commodity to gift. In other words, the linear race towards commodification has instabilities inherent to it, instabilities that push actors to take recourse to mechanisms outside the sphere of commodification, mechanisms that in turn facilitate the ‘linear’ (now

purposefully in quotes) race towards commodification. This is an instability that is a consequence of the particular structures of biocapitalist knowledge production, especially its upstream–downstream terrain, that are particularly well demarcated in the US context. Here, academic research is at least discursively (and sometimes in actual fact) designated as contributing to the ‘public domain’.²⁴ But also, public research is naturalized as being the *enabler* of private research, but a silent one. In other words, the mantra that innovation comes from the private sector hides one of the fundamental conditions of possibility that makes private innovation possible, which is the role of public institutions in enabling private research.²⁵

Now let us look at where else and in what other forms the value of information might reside. Clearly, information has some use value, in being the ‘raw material’, if you like, that provides the knowledge and therefore the conditions of possibility to create a drug. But the reason why any information needs so much work in order to be turned into a commodity is not just because there are conflicting interests among the various institutional actors involved, but because by its nature, the exchange value of information is entirely dependent on the context and framing of particular transactions.

As soon as information is released into the public domain, it falls out of the system of commodity circulation and its ‘ownership’ is of no further value. In order to stay within the sphere of commodity circulation, information needs to be circulated through specific transactions of exchange between the seller and buyer. Even in these transactions, any exchange value for an information seller like Venter’s Celera is only obtainable, for each transaction, at the moment of first sale. Once the information gets bought, it reverts to being a pure use value for that particular buyer–seller pair, and cannot be recommoditized.²⁶ Information can only retain exchange value if the ownership rights on information are tied to downstream ownership rights on any product that might accrue. Which is why for an upstream company, it is vital to patent information and tie that patent into downstream royalties.

Information, however, has a third form of value, a ‘moral’ value that operates in the realm of symbolic capital. This comes from two sources. First, as a primary good that the state distributes or as a could-have-been commodity that the (downstream) company relin-

quishes as gift, information acquires a decommoditized status through a mechanism of rhetorical abdication that suggests that its *natural* state is as commodity, and the *decommoditization* is an act of virtue. In the process, the (downstream) company gets portrayed as a willing partner to the state in maintaining the unfettered flow of information, and therefore of science. A second, more direct manner in which genomic information is virtuous, is through its extensive linkage, rhetorical and real, to therapy—a linkage indeed that is made real by the rhetoric. There was this wonderful moment, for instance, at the very end of a 1999 industrial genome conference, when Randy Scott, Chairman and CSO of Incyte, raised a toast, to ‘the genomic community. Because they aren’t in genomics for themselves, they are in it for Life’. Mirroring, indeed, Incyte’s own logo, which is Genomics for Life™.

It is very evident that the production of value in genomics is to a large extent a discursive act, whether it be through advertising, the selling of futures or the rhetorical creation of a genomic community committed to Health, or of many competing companies relinquishing property rights for the common good. Indeed, the creation of this single genomic community has as internal to its logic, the existence of multiple competing actors all of whom try to propagate their particular informational value at the expense of their competitors’.

What is evident is that information has to perform active work, work that may be variously material, discursive and performative, in the process of which the genomic community is created as a homogeneous entity, but one that is simultaneously an *ethical* entity, an entity represented (and encompassed) by the Incyte logo, Genomics for Life™. It isn’t just the subject within the genomics profession who gets in-formed at this moment; equally in-formed is the subject (as in discipline/endeavour/venture) of genomics and the corporate subject such as Incyte, as ethical subjects that are in the business of saving lives.

■ MARKET LOGIC

In this section, I hint at the emergence of new biosocialities and subjectivities that are always-already embedded in the logic of the market, while arguing that it is this logic which is itself what is at stake in the strategic articulations of biocapitalism.

In this essay, I have tried to show how genomics provides a window into contemporary capitalism. Doing this analytically involves going beyond reading texts, doing data analysis and reacting to pre-existing theorizations of the information economy with fresh data. It involves, simultaneously, figuring out where the access points are and analysing ethnographic data in a scene that is changing rapidly even over the course of particular research projects. It is easy to become confused about whether genomics is simply a puzzling, fast changing and really important set of objects and practices in the world, or a system whose understanding will contribute to general debates about capitalism, which does not anymore depend on land, labour and capital in the classic sense. To the extent that this essay attempts the latter, it does so through the route of the former. In concluding, I will review the arguments that I have made, namely:

- (a) Genomics can provide a window into contemporary capitalism, which itself is different from earlier industrial capitalism.
- (b) The contradictions of producing genomic knowledge are creating new legal and economic structures, which are transforming not only the way knowledge is produced and money is made, but also the way the medicine will approach therapeutics and society will interpellate individuals as bundles of genetic variations that can be targeted, tested, monitored and changed in new ways. These contradictions, that arise around the contested commodity status of information, include business models that must be followed; the ordering procedures (and strategies) for demarcating what is in the public domain from what is available for proprietary ownership, and the re-ordering procedures of re-accessing previously proprietary information.

‘Good genomics’ is judged not by truth and falsity as much as by efficiency or its lack, an efficiency that is manifested through speed.²⁷ What makes speed–efficiency not just legitimate but desirable is the element of virtue that is associated with a seamless downstream flow of information towards a drug product, and the actual material value at stake.

What is important here is to see how in genomics the ‘classical’ scientific binaries of truth and falsity are *articulated* with those

of efficiency and inefficiency, justice and injustice—articulations of non-economic forms of socio-moral values that the sociology of science in its earlier Mertonian guise regarded as separate.

In order to understand what is unique about genomics, it is not sufficient to analyse it merely as a set of knowledge producing practices. These practices need to be positioned in a particular framework of contemporary capitalism.

Genomics can be simply defined as an informational science, but of a particular sort, where information is one of many biologicals, and indeed a precursor to other biological objects of commodified circulation such as drugs. Many of its attributes, therefore, can be studied by studying the social lives of the various forms of information—raw DNA sequence data, function of a gene, SNP, protein information, information as database, and so on. I started this essay by analysing the friction inherent to the flow of information in a regime in which private ownership in general is considered the natural state of society, while *its own* ownership is extremely contentious.

A fundamental question both of politics and of method, that has haunted at least dialectic analyses of political economy since Marx, is: what implications does the unearthing of contradiction have for understanding social practice, in the case of genomics the creation and inhabiting of certain strategic terrains that inscribe a particular political topography onto a system that economically can still be described away as ‘capitalist’? The question for this essay then becomes: how do the contradictions that are inherent to genomic circulations of information create new forms of knowledge politics, and what do these contradictions imply for the stability of the (capitalist) system that institutionalizes and sustains such contradictory flows? The uniqueness cannot manifest itself merely in the analysis of information as an object (of knowledge or currency), but in the articulation of the social life of information with the social lives who in-form and get in-formed by it. In this essay, I have looked at the social lives of the scientific–corporate actors of genomics. Understanding genomics as both a system of knowledge and as a window to contemporary capitalism involves looking at how contradictions inherent to information are articulated to specific modes of strategic response—modes of response that, I shall argue, redefine some of the parameters of ‘capitalism’ itself.

This essay, then, is about flows, of information and of capital, the former flowing 'downstream' from raw DNA sequence information through annotated and more 'meaningful' forms of information into the in-formed drug. The flows are constrained and enabled by legal regimes and technological advances, but, intuitively at least, by that most nebulous and over-arching of entities, 'market logic'. Market logic plays a similarly obstructive role to the analysis of capitalism that scientific method plays in the analysis of science. Both are terms that are at once the ultimate signifiers of the boundaries of actions which the market and science respectively can allow in order to be the market and science, and yet precisely because of that they assume an almost transcendental position, impervious to analysis themselves. I have not analysed market logic as a single entity, but have tried, through an analysis of information, scientific–corporate actors, conferences as sites of the production of information and the confluence of these actors and of value, to tease out elements of market logic as it gets played out.

In the process, I have tried to argue, firstly, that information can mean many different things in genomics, but is never at any point without meaning, even if it is raw 'meaningless' information. Secondly, information is not a finite mathematically representable entity, but is, on the contrary, overwhelming. This overwhelming nature of information is not just a consequence of its quantity, but results from the speed with which it is generated. The speed with which it is generated is indeed consequent to technological development, but is equally an intuitive outcome of 'market logic', whereby the speedy progress of science is commercially beneficial. That it is therapeutically beneficial lends speed further legitimacy.

This much is apparent and intuitive. What is hidden from the process is that the very same 'market logic' (which in this case is the possibility of private ownership of information for its producer) has inherent speed bumps to the circulation of information; and this dialectic is not unique to information, but to any intellectual property in biotechnology. Various institutional strategies get devised either to perpetuate or to get around this impediment.

The crucial point is that both the perpetuation of ownership and its obstruction can be argued as being 'sound market logic': in the former case, ownership is the reward that functions as incentive to innovation, whereas in the latter the regulation of ownership (or its

strategic elimination, as in the case of The SNP Consortium) allows maximally efficient and rapid circulation (which itself can be an incentive). Clearly, therefore, the contestation here is not between market logic and 'something else', but is over the very definition of what constitutes market logic, the outcome of which has considerable implications for the overall terrain of co-operation, conflict and value generation. Neither one nor the other alone *can* represent an uncontradictory market logic.

Furthermore, sound market logic goes much beyond a quantitative generation of maximal surplus value. It also needs to generate other forms of symbolic capital, that in the case of biotechnology already exists in the rhetorical and real construction of the biotechnology industry as an industry that is in the business of Food, Health and Hope (to borrow this time from Monsanto's logo). Meanwhile, there is the NIH, an organ of the state, that has its own interests and constraints as a consequence of being an institution that is funded by the public, and that thereby needs to have a commitment to the public domain. This is a commitment that again gets justified through 'market logic' at a contemporary historical moment when market logic is perceived to greatly exceed the bounds of the market. Such a formulation of market logic as exceeding its boundaries however implies that it simply takes over the new terrain it encroaches upon (such as that of the state or the university) while itself remaining immutable.

'Market logic', however, often (indeed necessarily) draws upon strategies that are external to the process of commodity exchange, the gift regime being a major one. The SNP Consortium, a wonderful example of such a gift regime, therefore manages simultaneously to espouse 'sound market logic' (by allowing 'cheap, fast and easy' circulation of information, leading ostensibly to cheaper, faster and easier drug production) while gaining symbolic capital as a consequence of the abdication of property rights on information, that can be projected as a self-sacrificial *abdication* of market logic in the public cause. In the process, by the simultaneous holding up of 'market logic' while it is being negated, market logic as a terrain of hegemonic contestation gets redefined. While the strategies of the various actors redefine the terrain of contestation, they simultaneously redefine their own value as actors, as well as the value of the information they produce.

■ CONCLUSION: GENOMIC CAPITAL AS MULTIPLE LOGICS

This analysis tries to provide an insight into capitalism's adaptive mechanisms, which can destabilize the fundamental mechanisms of capitalism themselves while at the same time upholding them. As Slavoj Žižek says:

The 'normal' state of capitalism is the permanent revolutionizing of its own conditions of existence: from the very beginning capitalism 'putrefies', it is branded by a crippling contradiction, discord, by an immanent want of balance: this is exactly why it changes, develops incessantly—inconstant development is the only way for it to resolve again and again, come to terms with, its own fundamental, constitutive imbalance, 'contradiction' (Žižek, 1994, p. 330).

This incessant development is brought about not because of the superiority of the indices—efficient production, competition, market logic, surplus value generation and so on—but because of its willingness to constantly abandon, redefine and mutate many of its own fundamental conditions of existence in ways that are contested, unpredictable, but most importantly still the fundamental conditions of its existence.

It would be hasty to conflate the specific logics of the enterprise of genomics with *the* logic of capitalism. Indeed, here I attempt to challenge the notion that capitalism has such a singular logic, and further, to show that the absence of such singular logic is a major source of its sustenance. These multiple logics get highlighted through the strategic and contradictory articulations of the various involved actors, and therefore need attentiveness to the public and political cultures that these create and inhabit in order to be mapped.

Thus, it is possible to show up the explanatory categories through which contemporary capitalism is understood as complicated and mutable. In particular, I have shown how the boundaries of commodification and commons (or gift) can shift according to the logics of upstream–downstream profit calculations. Moreover, this analysis can use the idea of capitalism as a risky enterprise of Deep Play (see Geertz, 1973) that is deeply embraced by a performative rhetoric of ethics in the present and therapeutics in the future; this also helps to

understand other forms of speculation that underpin contemporary capitalism.

The notion of biocapitalism, further, draws explicitly upon theorizations of biopolitics, and argues that such biopolitics must be understood as already positioned in the multiple frameworks and logics of capitalism. These multiplicities need to be further explored and theorized.

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□ NOTES

1. While not specifically explored in ethnographic detail here, this paper draws upon ethnographic research conducted over the last 3 years in labs and companies in Northern California, Massachusetts and India, as well as a number of genome researcher and investor conferences in the US.
2. In this paper, I focus largely on genomics and its politics in an Anglo-American context. But it bears keeping in mind that the enterprise of genomics, both as represented by the Human (and other public) Genome Projects and by various private genome enterprises and collaborations, is global in scale and effect, and the particularities of the different places in which genomics 'happens' in all its myriad ways is of extreme consequence. My larger project looks at genomics and 'post'-genomic drug development in the US and India in comparative context. See also Rabinow (1999) for the way in which 'French DNA' was constructed as a material-semiotic object of contestation that eventually led to the breakdown of an

attempted collaboration between the French public lab Centre d'Etude Polymorphisme Humain (CEPH) and the Cambridge, MA based company Millennium Pharmaceuticals.

3. Meanwhile, literature in science and technology studies (STS) has not often enough engaged the question of political economy (science as corporate), though this is clearly an emerging field of emphasis within the discipline.

4. This is of course beyond the scope of this essay. See however Dumit (1997) and Sunder Rajan (2000) for elaborations on this theme. Indeed, one cannot make claims about biocapital without bringing in the work that epistemology is doing. It's not just life sciences being done in *corporations* (and hence the legitimate question—why is that different from finance, or the Internet industry?), but *life* sciences being done in corporations that we need to understand.

5. For the essay that 'fathered' information theory, see Shannon (1948).

6. See also M. Fortun (1999a) for an analysis of speed in genomics.

7. Through his development of Polymerase Chain Reaction (PCR). See Rabinow (1997).

8. As it happens, both the HGP and Celera have generated a working draft of the sequence at roughly the same time, though Celera insists it got there first.

9. The 'race' of course gets constantly redefined; now that the working draft sequence of the human genome has been completed, the 'competition' between the NIH and the private sector shifts to other types of information, such as annotated sequence information or information about genetic variability. This competition, after all, isn't just about finishing first and getting the credit for it—who generates information first has huge implications for whether that information goes automatically into the public domain or becomes the property of particular companies. As I will try to show later in the essay, however, this opposition between the public and private sector is expectedly more complicated than it seems at first sight, from the 'race' to generate the working draft sequence.

10. From *Signals* magazine, an online magazine that analyses biotechnology for executives. www.signalsmag.com/signalsmag.nsf/0/DEC74B56C34589DC882567D1006C676E. The genetic determinism in this quote is particularly striking: while not directly relevant to this essay, it is interesting to see how it is precisely such deterministic language that is shed in, for instance, the promotion of cloning. It is also striking to note how SNPs simultaneously seem to represent information about individuals, populations and the 'globe'.

11. The academic centres involved are the Whitehead Institute for Biomedical Research, Washington University School of Medicine, the Wellcome Trust's Sanger Center, the Stanford Human Genome Centre and Cold Spring Harbor Laboratory. The list of pharmaceutical members of the consortium is even more impressive, and comprises AstraZeneca, Bayer, Bristol-Myers Squibb, Hoffman-la Roche, Glaxo Wellcome, Hoechst Marion Roussel, Novartis, Pfizer, G. D. Searle and SmithKline Beecham.

12. Quoted in www.signalsmag.com/signalsmag.nsf/0/DEC74B56C34589DC882567D1006C676E.

13. <http://www.signalsmag.com/signalsmag.nsf/0/799C47CDCD7A924788256609004E0503>.
14. http://www.genxy.com/About/abt_history.html.
15. <http://www.genxy.com/News/Releases/abbott.html>.
16. <http://www.signalsmag.com/signalsmag.nsf/0/799C47CDCD7A924788256609004E0503>.
17. As Pierre Bourdieu insightfully remarks: '[W]e need to be able to recognize as such the strategies which, in universes in which people have an interest in being disinterested, tend to disguise strategies' (Bourdieu, 1999 [1975], p. 35).
18. <http://www.signalsmag.com/signalsmag.nsf/0/799C47CDCD7A924788256609004E0503>.
19. The SNP chip (GeneChip™) was first developed by the Santa Clara, CA-based company Affymetrix, and consists of what are called microarrays, precisely ordered arrays of oligonucleotides built up nucleotide by nucleotide on a glass-wafer substrate. Arrays are basically templates upon which large-scale hybridizations can be performed, and are useful for comparisons of any two samples to detect differential DNA sequence or expression.
20. This term and much of this analysis draws upon an excellent article in the online magazine for biotechnology analysis, *Signals*, and is available at <http://www.signalsmag.com/signalsmag.nsf/657b06742b5748e888256570005cba01/ffd2cf3f7f7ea56f8825661200697ce3?OpenDocument&Highlight=2,anti-stacking>.
21. *Ibid.* 'Biotech' here refers to an upstream service provider for Big Pharma, which in the context of DNA chip technology, for instance, could be a genomics company or a tool company. I shall use 'Biotech' in the same context for the rest of this argument.
22. 'Public', of course, is as vexed a term as information or commodity, but this essay isn't the place to go into that.
23. Of course, while the state, *as represented by the NIH*, and *in the case of DNA sequence patents*, defends genomic information as part of a commons for the public good, it is also the state that constructs the boundaries between public and private goods in ways that, especially in the US, favour the appropriation of the commons by private companies through intellectual property protection.
24. Academic research labs often aggressively pursue intellectual property protection. It is just that, in the context of DNA sequence debates, they have generally avoided doing so, thereby framing themselves as committed to the 'public domain'.
25. For three seminal studies that highlight the necessary role of public research in 'private' innovation in drug development, see Comroe and Dripps (1976), Maxwell and Eckhardt (1990) and Stallings *et al.* (2001).
26. Though it can be encumbered, through contractual and legal devices such as non-disclosure agreements.
27. Indeed that this 'efficiency' is often at odds with the quality of the data produced, and is likely to swamp scientists with a deluge of 'useless' information, is evidenced both by the criticism of many public-funded researchers of Venter's *modus operandi* as well as by the scepticism of some towards the public-funded SNP project's urgency.

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