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Bioinformation Worlds and Futures

Introduction

Bioinformation refers to information that is derived from biological organisms or that describes biological processes and lives (Parry and Greenhough 2018). Its emergence as a concept across academic disciplines and domains of practice marks transitions from body to data, biological substance to information, and archives to datasets. Linking life and information in the digital age, bioinformation has become newly entwined in social relations. As unprecedented amounts of data relating to biological processes and lives are collected, aggregated, traded and exchanged, infrastructural systems and machine learners produce real consequences as they turn indeterminate data into actionable decisions for states, companies, scientific researchers and consumers. The uptake of ancestry DNA and direct-to-consumer genetic testing, for example, has risen exponentially in the past five years as individuals seek to explicate their own genealogies of historical and contemporary relatedness. This rise can be explained by three factors that center multiple values and changing of bioinformation. Firstly, populations undergoing direct testing have increased across the world; second, the aggregation of genetic data produced by the corporate consolidation of DNA testing provision; and the increased interoperability of formerly discreet platforms are creating new, and much more tightly intertwined landscapes of bioinformational exchange. In 2019, the DNA of over 26 million people was accessioned to the world's leading testing companies, whose user numbers in 2019 outstripped all previous years combined (Regalado 2019). There is also much more traffic of information between providers as individuals transfer raw DNA samples and derivative bioinformation is uploaded to one platform, such as Ancestry.Com to others in search of answers to health, paternity or other questions.

As big data and algorithmic processes learn to predict every aspect of social life with ever more granularity, anthropology must turn to framing the entangled histories and temporalities which bioinformation connects and actualizes. The global COVID-19 pandemic has made visible how bioinformation is transforming biological citizenship (Rose and Novas 2004, Petryna 2004) at a time when governments and public health bodies seek to ease lockdown restrictions and return to safe levels of social interaction. As genetic and antibody information becomes essential to understand the pandemic origins and track transmission and immunity in human populations (Forster et al 2020, Ferretti et al 2020), bioinformation becomes an

essential interface that reconfigures relations between citizens, governments, and institutions. As testing and other forms of intervention evince (Marres and Stark 2020), bioinformation is constitutive of – and not external to – forms of governance and sovereignty, but its analysis in public health contexts can have detrimental consequences for differently gendered, sexualised and racialised subjects and populations, who are further differentiated on the grounds of genetic, illness, HIV- and citizenship status. Bioinformation analysis, as practice and figuration, is therefore also enmeshed in routinized forms of structural violence, modes of precarious existence, illness and premature death that are linked to deprivation and gendered and racialized inequalities.

In this context, new questions are emerging about the shaping and social impact of bioinformation extraction, storage, and circulation. The aggregation of multiple sources of genetic data similarly generates significant challenges in forensics, producing unprecedented tensions between national and supranational criminal justice systems and enforcement cultures as they vie for control of identifying information. For example, the aggregation of DNA in global genetic databases that can be cross-matched with private company data significantly increases the probability of discovering potentially life-changing information about kinship and ethnicity. Genomic mapping companies promise to transform outcomes following a life- changing diagnosis, but unregulated availability of analytic services has also led to data breaches, misguided decisions, and unwanted harm. In the current context, and as contributors to this volume show, the readability, transparency and legibility of bioinformation are collectively transformed by historically unprecedented levels of interoperability between public and private actors across the Global North and South. In the age of global infrastructures, bioinformation is routinely donated, exchanged, traded or extracted under diverse arrangements and transactional forms that involve persons, institutions and biotechnologies. Indeed, the global reach of bioinformation infrastructures make bioinformation a ‘global social fact’ – a form of relationality that links multiple localities, infrastructures, scientific cultures and interests. While access to personal bioinformation analysis is facilitated by the availability of genetic sequencing, the unlicensed exchange of genetic bioinformation between commercial, research and clinical environments emerges as a fundamental challenge as donors remain largely unaware of the consequences of global bioinformation traffic, marketisation and aggregation. As differences in the type, quality and integration of existing services widens, bioinformation demands new conceptual

approaches, intensive transnational empirical investigation, and the institution of global conversations between diverse stakeholders.

Anthropological studies of biomedicine and bioethics have offered incisive accounts of how some of these transitions map onto the attribution or disavowal of personhood in medical contexts or how different epistemic communities might figure relations and belonging through these new technologies (Tamarkin 2014). They show how cultures of expertise bridge expert and lay divides, as the ‘new genetics’ (Pálsson 2007, 2008) offer new visual and mapping imaginaries for figuring relatedness, property and value. New ‘biosocialities’ (Rose 2007) also emerge, as bioinformation in its genetic iteration becomes an area of concern for publics as diverse as Indigenous communities and geneticists (TallBear 2013), patient groups (Shaw 2009), and sheep (Franklin 2007) and horse breeders (Cassidy 2002). Through new conceptual and ethnographic analyses of the purchase, ethics and politics of bioinformation, this volume will unpack questions of access and interpretation, taxonomic and individual identification, appropriation and reproduction. With Gregory Bateson, we propose to understand bioinformation as a ‘pattern that connects’. Through bioinformation, individuals become enmeshed in unexpected relations as they acquire knowledge that rewrites previous understandings of their identity, kinship ties, ancestry, health status, and even prospective criminality. Taking bioinformation as an object of ethnographic analysis also makes perceptible the multiple values and disvalues that bioinformation accrues as it travels from bodies to data in particular databases, archives and infrastructures. Moving from analysing systems, infrastructures and ecologies to understanding the cultures, practices and contexts that shape their development, this volume aims to answer a central question: How do cultural elements shape public understandings of life and death through bioinformation? In this context, we look at how well bioinformation travels across fields and domains of practice, drawing the significance of their social lives and afterlives for the public domain of science. We are particularly concerned with science as a practice of truth-making in the pursuit of wellbeing and justice, and the establishment, maintenance and transmission of ‘cultures of evidence’ across multiple domains of expertise. Ethnographic research in forensic archives, museums, biorepositories tied to cohort studies, medical technologies prototype manufacturing, e-waste management and airport biosecurity surveillance forensic research centre, biorepository and biobank, we focus on shifts in data materialities and the making of connections and disconnections between epistemic

communities and publics. These relations, we argue, are constitutive of bioinformation throughout the life cycle, as biological specimen and resources are progressively disembodied and re-contextualized across multiple infrastructures from before birth to after death.

Life, Death, Data

Life and death are at the heart of contemporary debates in social theory. The proximity and interconnections between processes of living and dying, the uneven and unequal distributions of life chances, and the proliferation of precarious forms of existence in the context of social exclusion, dispossession, violence and crisis have generated considerable debate and critical reflection. Foucault's theorisations of biopower and biopolitics in particular have offered a theoretical register to grapple with relations between institutions, forms of knowledge and expertise, and practices of 'letting live' and 'making die' (Foucault 1981, 2001, 2003). This field has progressively highlighted the ways in which forms of vulnerability, exposure and expendability are constitutive of – and not external to – forms of governance and sovereignty, with deadly consequences for differently gendered, sexualised, racialised, and HIV serostatus marked subjects and populations (Agamben, 1998; Comaroff 2007; Povinelli 2011). Whilst Foucault focused on biopower as 'a power to foster life or disallow it to the point of death', a sustained emphasis on sovereign power as fundamentally concerned with death-making has emerged. This scholarship has highlighted progressive, routinized forms of structural violence and how 'letting die' connects to modes of precarious existence and the normalisation of extreme suffering. In this context, illness and premature death are linked to deprivation and gendered and racialized forms of marginalisation (Biehl 2001; Farmer 1996). In the midst of a data revolution transforming every aspect of social worlds, data infrastructures and analytics are fast transforming what it means to live and die. Infrastructures have brought forward new ways of doing and believing in evidence, as simulation techniques make themselves 'easy to love and difficult to doubt' (Turkle, 2009, p.7, see also Kennedy 2016) by scientists and general publics.

Predictive analytics and machine learning based on a ubiquitous process of datafication, have foreseen 'the end of theory' (Anderson 2008), replacing 'traditional' classification practices and methods in the sciences with process sensitive, 'real-time' data-driven analytics (Mayer-Schönberger and Cukier, 2013). In this context, data infrastructures – tools for storing,

processing and analysing data – are becoming ever more central to the functioning of social worlds. Data infrastructures not only include data registers and technologies, but processes and organisational principles that detail how data can be accessed and processed, as well as the principles that govern human-technology interactions. In this context, changing notions of public and private, individual and collective, information and evidence accelerated by data-driven science are of significant consequence for the lives and deaths of individuals (Nisa 2016). However, the relation between the promise of these technologies and how they can make a difference in research, policy and service delivery is still far from settled.

This volume argues that living and dying are underpinned by geographies and infrastructures of connectivity, prosperity and wellbeing, and of risk, toxicity and exposure, which are generative of new tensions and frictions in the body politic (Harvey and Knox 2015; Harvey, Jensen and Morita 2017; Mittman, Murphy and Sellers 2004). Infrastructure studies place emphasis on the ‘socio-material’ status of infrastructures, and the consequent instability, dynamism and differential impact of the infrastructures and computational architectures that subtend life and death. Building infrastructures and design of analytic interactions can further economic inequalities through practices of targeting, prediction and ranking. Infrastructures extend life- and death-making practices into emergent domains of social practice which, whilst offering opportunities for connectivity, sociality and identification, also entail differential burdens of risk and vulnerability. The chapters collected in this volume analyse a range of archives, biorepositories, archives, museums, forensic laboratories and biobanks to consider how, in the digital age, infrastructures raise urgent questions about how computational designs and architectures, and digital cultures may be reorganising life and how governments, regulators and constituencies may respond to the increasingly central role of new technologies in the everyday, as data oscillate between the corporeal and the informational.

Biosocialities (Rabinow 1996), anthropology of the ‘new genetics’, and the cultures and publics of scientific infrastructures rearticulate the relation between the biological and the social in theory and social practice, biosocialities exemplify how social understandings of genetic information may give rise to novel configurations of subjectivity and belonging, generating new social identities as individuals grapple with the implications and possibilities inherent in biological data and genetic analytics. Bioinformation – derived from the analysis of physical or biological characteristics of a person – is now redefining

approaches to security, surveillance and governmentality informing the development of new logics and techniques of managing economic, social and political relations. For example, health researchers have stressed how taxonomies of health and illness and related diagnostic categories underpin the emergence of genetic identities, advocacy and activism (Gibbon and Novas 2008; Taussig 2009) They have also charted the inequalities and exclusions that map onto genetic and health determinants. The anthropology of ‘the new genetics’ has been increasingly concerned with highlighting the pitfalls of objectifying and commodifying users, foregrounding instead the biosocial relations that sustain genomic services and the establishment and maintenance of biobanks, in the context of the emergence of personalised medicine and the economic exploitation of bioinformation (Ventura-Santos and Wade, 20014; TallBear 2013; Prainsack et al 2014). More fundamentally, the new genetics entails grappling with the inherent partiality of genetic knowledge – e.g. DNA information – and a sustained engagement with the articulations of social meanings which are elicited by the incompleteness of scientific information (Franklin 2003).

We suggest moving beyond the framework of socialities of diagnosis and sociologies of expectation, and propose that analyses of bioinformation worlds ought to encompass multi-scale investigations of the infrastructures, cultures of evidence, and scientific practices that emerge as corporeal information is turned into data. The volume takes as forensic archives, research and innovation centres, the biorepositories, museums and biobanks as ethnographic field sites to examine the making of life and death through data, and as key locales where bioinformation can be tied to data publics – constituencies seeking access and participation in the making and interpretation of bio- and genetic information. Through a focus on how data is handled, processed and interpreted by different communities – e.g. scientists, archivists, technical staff, software experts, anthropologists, and user groups – the essays collected in this volume draws on these established perspectives to ask new questions expand the debate in novel directions, looking to transform the understanding of the practices, value and values underlying decisions by data.

Patterns and Relations

Bioinformation derived from the analysis of physical or biological characteristics of a person – is now redefining approaches to security, surveillance and governmentality informing the development of new logics and techniques of managing economic, social and political

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Bioinformation research takes the forensic archive, the forensic research centre, the biorepository and the biobank as ethnographic field sites to examine the making of life and death through data, and as key locales where bioinformation can be tied to data publics – constituencies seeking access and participation in the making and interpretation of bio- and genetic information. We suggest moving beyond the framework of socialities of diagnosis and sociologies of expectation, and propose that biosocialities of health and illness, and life and death, ought to encompass multi-scale empirical investigations of the infrastructures, cultures of evidence, and publics that turn corporeal information into data. Through a focus on how data is interpreted by different communities – e.g. scientists, archivists, technical staff, software experts, and user groups – in specific research sites, the ethnographically grounded bioinformation research presented in this volume draws on these established perspectives in anthropology to ask new questions and expand the debate in novel directions. Through a contextual, empirical, multi-method understanding of interactions between users, technologies, and health systems, the chapters in the collection transform our understanding of the practices, value and values underlying decisions by data.

Debates on genomic archives and ‘post-archival genomics’ shed light on the shifting constitutions of bioinformation that move from biology to ‘logistics’, a shift enabled by the availability and accessibility of genomic sequencing technologies. Through modelling, visualizations and infrastructure maps, computational architectures are shown to be tied to how these complex tensions between presence and absence may persist in digital archives.

An anthropology of bioinformation focuses on understanding data structures and architectures, processes of set up and operation of local networks, infrastructures and cloud technologies, as well as the operations of algorithms used in data processing. This approach builds on philosophies of computation based on combining qualitative and quantitative approaches, to answer targeted (explanation oriented) and meta questions, to map how infrastructures operate and think, and how they help us make sense of data, understand and explain them. Cloud geographies currently pose significant stakes for governments, corporate health providers and health publics, as their management, use and access has become a critical asset of health systems. Ethnographic methods can probe whether and how infrastructures are invested with new powers to scale interventions and reduce uncertainty, for example, or consolidate taxonomic orders through which species boundaries are devised, regulated and governed – as Chapter 1, by Tahani Nadin, shows.

Anthropological accounts of bioinformation mobilise formative debates in anthropological theory which have foregrounded how categories and relations emerge at the intersections of knowledge and social practice. The interplay between scientific or expert knowledge and situated experience is central to the study of bioinformation, as individuals and communities actively engage in the making and remaking of ‘the politics of life itself’ (Rabinow and Rose 2006, Rose 2001). In turn, domains of expert knowledge have been shown to be rooted in malleable milieus, where lay discourse often shapes research questions and practices. The history of the gendering of the X and Y chromosomes (Richardson 2013) can serve as a notable example of this dynamic. Medical anthropology has extensively documented these dynamics, notably with reference to people’s understandings and interactions with specific medical technologies, diagnostic categories, and expert theories and models (Lock DATE, Thompson DATE). Ethnographic approaches to the study of biosocialities are instructive here. Re-articulating the relation between the biological and the social in theory and social practice, biosocialities exemplify how social understandings of genetic information, for example, may give rise to novel configurations of subjectivity and belonging, generating new social identities as individuals grapple with the implications and possibilities inherent in derivative analyses of biological data.

Anthropological perspectives extend this discussion beyond an account of the connection and interplay between expert and lay domains, knowledge and social practice, science and culture. They re-centre notions of ‘patterns’ alongside ‘relations’ to address the urgent

questions posed by the contemporary (re)emergence of bioinformation as a research object and site of social and cultural anxieties. A rapprochement with anthropological theory concerned with systems and patterns, from the work of Gregory Bateson to Levi-Strauss, through to Strathern's (2020) latest re-conceptualisation of the notion of 'relation', may be an apt starting point for anthropologies of bioinformation. In *Mind and Nature* (1977), Bateson offers an expansive discussion of the relationship between epistemology, or *knowing*, in Bateson's own terms, and the world. Bateson invokes a 'wider knowing which is the glue holding together the starfishes and sea anemones and redwood forests and human committees' (1977: 5), suggesting that a broad set of terms might be needed to imagine and understand what enables the coalescence of human and non-human figures. Bateson recasts longstanding debates about the status of the distinction between the categories of the 'human' and the 'non-human', '*creatura* (the living) and *pleroma* (the nonliving)' (1977:7), and the contours and boundaries of 'life' and proposes 'the pattern that connects' as a way to think through some of these questions and problems:

'The pattern which connects...What pattern connects the crab to the lobster and the orchid to the primrose and all the four of them to me? And me to you? And all the six of us to the amoeba in one direction and to the back-ward schizophrenic in another?' (1979:8).

The pattern which connects is, for Bateson, dynamic and always already in context, that is, 'a pattern through time' (Bateson 1979: 14) and across scales of relation and abstraction through which 'the living world' can be figured. It is our contention that bringing Bateson's pattern which connects to bear on the analysis of bioinformation is particularly apt, given Bateson's own interest in the convergence of life and information. Bateson's arguments in *Mind and Nature* prefigure many of the questions that emerge in contemporary research on bioinformation, as patterns of interconnectedness come into renewed focus and raise urgent questions about how exactly we are to think about the reframing of persons, relatedness, and community through bioinformational relations in which the entanglement of chemical and informational processes defined the process of living.

Indeed, the idea that biological fragments such as the gene contained information had found resonance with cybernetic theories of communication. Von Neumann's definition of a self-producing machine in his path breaking paper 'General and Logical Theory of Automata',

presented in Pasadena, California, on September 20, 1948, in which he famously equated DNA and software. Von Neumann, an outsider in the field of genetics, ventured in this paper to offer a mathematical theory of artificial autonomy applied to ‘natural organisms’ - a task nested under a broader aim to compare complex living organisms with artificially generated automata, a problem that von Neumann related to the making of units and fragments which functioned individually, within a broader understanding of how these fragments are organised into wholes, the function of which was revealed and expressed in the individual elements. Von Neumann hypothesised that axiomatising the behaviour of the elements might lead to understanding the functional characteristics of systems, defined through how unambiguously they responded to stimuli. By deploying analogic thinking in linking ‘natural’ and artificial life. To von Neumann, artificial automata had similarities with the central nervous system, and, as such, they are needed when the complexity of a task involves functionality beyond elementary operations¹. Von Neumann understood living organisms to have elements of both digital and analogue systems, defined demonstration purposes as digital automata: not only were they composed by elementary units whose functions mirrored those of automated elements, but the system responded to stimuli which directed the flow of energy from the element in question to the source (McMullin 2000). With this description, von Neumann opened up a new grammar to understand the molecular differences upon which organisms are built, interpreting biology through digital parameters based on yes-no responses to information.

For Bateson, the ‘pattern that connects’ enabled the establishment of links between, for example, chemical pathways and structures, parts and wholes, ‘ethological’ and biological process (see Bateson 1939). Likewise, an important dimension of bioinformation as a conceptual device is the totalising vista it produces and enables. The pattern that connect is an idiom that speaks to claims often attached to bioinformation as enabling what Haraway (1988) termed the ‘god trick’ of a view from nowhere and totalising vistas which often fit governmental rationales and exigencies. Bioinformation holds the promise of total connectivity and totalising knowledge which Bateson aptly expressed with reference to the pattern that connects, as follows:

‘How do ideas, information, steps of logical or pragmatic consistency, and the like fit together? How is logic, the classical procedure for making chains ideas,

related to an outside world of things and creatures, parts and wholes? ... What has to be investigated and described is a vast network matrix of interlocking message material and abstract tautologies, premises, and exemplifications' (Bateson 1979:19-20).

Patterns that connect often stand for infinity, their heuristic qualities appearing as objects, figures or interactions in the social world that are returned to us, recursively, and 'seen twice', or an infinite number of times (Riles 1998). An anthropological approach may ask 'whose patterns are these?' (Riles 1998: 394). This question draws attention to the importance of understanding context and location, but also extends the discussion to a consideration of how information may become property and transaction (Hirsh and Strathern 2004). Bioinformation is assembled through social, political and technical material-semiotic entanglements. The historical emergence of bioinformation worlds as objects of analysis can be traced in reference to a number of scientific developments, such as the rise and marketisation of genomic science, but also practices of making sense tied to state apparatuses (Koopman. Indeed, Susan Oyama (2000) laid out the significance of information beyond the genetic prefiguration, placing information beyond hylomorphic distinctions that sustained definitions of life and death. Information, as a becoming phenomenon, 'dependent on its actual functioning' (Oyama 2000, p. 3.) This process has yielded new vernacular ideas about life and the politics of living. the notion of 'emergence' has taken new ground in explanations of organisms as collectives, describing how processes and properties emerge from informational interactions between parts, between parts and wholes, and between systems and environments.

We are specifically interested in global perspectives on technoscientific practices, and particularly the global utopian visions that underpin large scale technological projects. As bioinformation storage, analysis informs policy shifts in this changing field, technologies of bioinformation extraction and interpretation are newly linked to individual and collective bodies by enacting long cultural histories. For example, M'Charek (2020) shows that bioinformation not only identifies individuals, but rather are develop as 'tentacular' mechanisms of racialisation employed first and foremost in the making and management of populations. Medina's (2011) account of the rise and fall of Project Cybersyn, the nation-wide technological system that spanned across public and private sector and which would

offer a real-time picture of economic production to inform economic policy and management in Allende's Chile, is instructive.

While the turn to bioinformation led communication theorists to reflect the textual fabrics of life (Kay 2000; Oyama 2000) for anthropologists and other social scientists it also reveals the social fabrics that underpinned the rise of bioinformation as a key commodity at the core of definitions of life and its futures. Bronwyn Parry's (2004) global ethnography illustrates how the global circulation of bioinformation relies on complex ethical, political and economic implications and entanglements. Bioinformation has become a commodity in a rapidly evolving technoscientific landscape to changing relations between humans and natural worlds. Following bioinformation as it turned into a highly prized commodity in an informational economy, Parry tracked increasing difficulties in keeping track of bioinformation as less material forms, including the development of new markets and forms of exchange (see also Hoeyer 2013), and how the slippery nature of shifting bioinformation and their value forms for different stakeholders made any effective market regulation challenging. At the same time, the biotech industry grew exponentially by seeking lower production costs and labor in developing countries, while a shift in the biosciences towards data-centric approaches (Leonelli 2016) drive the development of ever more complex data architectures and infrastructures.

Bioinformation worlds and their futures

In Chapter 2, 'All the Data Creatures', Tahani Nadim focuses on an analysis of DNA sequences as empirical sites where the concept of species is dynamically articulated. The DNA sequence of a West African dwarf crocodile provides a concrete and yet abstract example of the analytical work DNA sequencing entails, notably in the form of the genetic barcode - a standardized short sequence of DNA. Genetic barcodes are shown to be devices geared towards species identification orchestrated by contemporary fantasies of the total (genetic) archive of natural history. These fantasies have a long history in the knowledge formations and practices of pillaging and capture of Empire. The chapter considerably advances research on bioinformation, by identifying processes and artifacts – and their infrastructural and rhetorical organisation – notably, 'bioinformation pipelines' and 'data moments', two important analytical contributions to the study of bioinformation and 'data-

centric biology (Leonelli 2016). Three ‘data moments’, or case studies illustrate how the project of circumscribing ‘species’ is in fact continuously undermined by the capacity of database records to multiply relations in and through ‘an elsewhere’ that always displace ‘the original referent’. Nadim examines the book of accession of specimens in one department of the Museum, the digitalisation of records and use of Excel sheets and how marginalia are excised in the digital conversion – a point that resonates with the analysis of cohort studies records offered by Cruz, Tinkler and Fenton in Chapter 4. The barcode it tied to claims about the efficiency, accuracy and speed in species identification which illustrate the data practices and processes in play in, notably sieving, layering, smoothing and the production of more data through manual and automated operations. Data moments therefore show how barcodes produce, rather than represent, species distinctions and how bioinformation pipelines are punctuated by

In Chapter 3, ‘Capturing Genomes: The Friction and Flow of Bioinformation at the Smithsonian’, Adrian Van Allen offers a compelling ethnographic account of how samples are added to the genomic collection in the Smithsonian Institution Biorepository. Van Allen explores the processes of remaking, re-inscribing and removing boundaries between nature and culture in the everyday handling of biomaterials, as animals become specimen in a collection geared towards biodiversity conservation against the horizon of ecological crisis. The tissue samples and the bioinformational objects that derive from them hold the promise of reproducing the future, a potentiality that is not realised or brought to term in the biorepository, but which shapes the social practices and data practices which unfold in and through the biomaterials. Genomic collecting relies on material practices which create specimen that are made to stand for animals such as the crab and the fish whose tissue samples Van Allen follows through the genomic museum. The creation of the genomic archive illustrates ethnographically what Fortun has called ‘care of the data’ (Fortun 2019), that is, the range of sensory and scientific procedures that are often overlooked but that are key to the fashioning of biodiversity conservation in the museum repository. It is Van Allen’s contention that these are also practices through which power operates and varied forms of capture (Parreñas 2018) are actualised. Friction and flow characterise the bioinformation processes in genomic collecting, as worlds are captured, frozen and preserved for uncertain futures.

Chapter 4 focuses on an analysis of how bioinformation is entangled in the figuring of kinship in the context of large cohort studies, which underpinned the development of totalising archive projects built around visions that centred person data in governance and policy. Cruz, Tinkler, and Fenton follow the 1946 cohort study to ascertain how different types of data gradually resulted in compiling population databases. A cohort birth study presents an opportunity to frame the importance of relations as these emerge and evolve in the way archives materials are assembled, and in the logics, voices and gaps preserved in the archive over time. Cruz, Tinkler and Fenton's chapter is a prime case study of state-led and funded bioinformation processing under research programmes designed to inform public health interventions and health policy at national level. The chapter thus makes an incisive intervention in debates that centre bioinformation in the present, by showing that the collection and analysis of bioinformation are part of longer histories of epidemiological and biomedical research that entangled bodies, information and governance (Koopman 2019; Foucault 1991). 'Salvaging' the archives through creative practices of recomposition and creative interpretation, the chapter follows bioinformation as it is interpreted first hand by the participants in the study, drawing out the significance of the bioinformation in figuring kinship relations and the significance of kinship in the generation and function of bioinformation, centering how of kinship, and more specifically parent-child relations, were essential to the constitution and storage of biodata, and how, conversely, databases were modelled around kinship transmissions. These are, then, also histories of institutions, as research bodies are established and then fold, when new priorities and technologies emerge to signal the future. The chapter shows that the bioinformation modelling within cohort studies is also underpinned by a need to make sense of biological data as a blueprint for social practice.

Writing a new role of bioinformation in personalised medical services, in Chapter 5, 'Bioinformation In Formation: Inventing Medical Devices in Contemporary India', Anisha Chadha offers a rich ethnographic exploration of the place of bioinformation in the making of medtech devices in Delhi. Chadha centers the processes that lead to the fashioning of these devices to capture the nuances, expectations and promises that link bioinformation to consumer medtech devices that make use of technical capacities of mass bioinformation extraction. Her account for bioinformation processing and circulation takes the vantage point of local entrepreneurs. Through ethnographic observation, Chadha opens the relationship between bioinformation, biomedical technologies and the professional identities and

innovation cultures populating a dynamic biotech sector in India. Chadha focuses on prototyping as a practice that stages real and imagined relations between human bodies, governmentality, promissory regimes and futures, as prototypes embody the rise of entrepreneurial citizenship with hopes to develop global development opportunities (Lindtner 2020, Irani 2019). As Indian medtech engineers employ prototyping models to conceptualise social dimensions of biomedicine, including the relation between humans and digital devices, bioinformation transfers and circulation defines the process of engineering problem space as a set of evolving relations between biological, heuristic and semiotic materials. These translations are not only consequential in how innovation cultures shape biomedical research and service industries, but pose crucial ethical challenges that frame the value and values of bioinformation.

The next set of chapters address state-led bioinformation processing in criminal justice and surveillance systems. Both McKelvie and Jabloner's contributions show that the field of forensics is often located at the intersections of criminal justice and medicine. McKelvie stresses the ways medical technologies deployed in the aftermath of sexual assaults in the UK often entail intrusive procedures of bioinformation recording. Jabloner, in turn, examines the other end of the forensic pipeline, namely datasets which result from bioinformation collection for the purposes of prosecutions where black and brown men are over-represented, given the widely documented racism in policing in the United States. Maguire and Murphy's chapter, on the other hand, is concerned with offering an ethnographic account of a key bioinformation processing site, the international airport. Forensic bioinformation gathering and processing at the airport illustrates the embeddedness of the medical/forensic interface in everyday life. It also draws attention to the interoperability of systems and the rhetorical and concrete force of analytics focussed on databases integration. The chapters illustrate the endpoints of what we call the situated forensic bioinformation complex, that is, multifaceted bioinformation ecologies situated within national jurisdictions, but also transnational in scope. The situated forensic bioinformation complex rhetorically invokes visions of totality, is often extractive, but is also in practice open, overflowing and made out of gaps, blanks and bioinformational hiatuses.

In Chapter 6, 'Top_to_toe.ods: Bioinformation and the politics of rape response', Sylvia McKelvie offers a compelling account of the vicissitudes of bioinformation collection in rape investigations in the United Kingdom. McKelvie shows how sexual assault survivors'

personal data is captured by systematically invasive procedures that straddle the domains of medicine and criminal justice. McKelvie's contribution builds on feminist technoscience studies that have documented the cultural-material practices of forensic science and rape response and shown how prototype kits are used to produce different types of knowledge and memories of assaults, to produce objective, neutral facts. However, a range of issues emerge as bodies are produced through these material-semiotic processes, throwing up quandaries for anti-rape movements. Here McKelvie deftly shows the limits of carceral feminisms (Bumiller 2008, Richie 2012) and their complicity with law and order agencies which are often gender blind and structurally racist, as they ground their quests for justice in the ability of bioinformation through a totalising bioinformation system. McKelvie argues that rather than an unproblematic route to justice in rape cases, the 'bodies as information' in sexual assault cases feed into national databases such as the United Kingdom NDNAD and becomes a resource for state security (see biometrics), rather than gender justice claims. This requires new conversations between feminist technoscience and bioinformation studies and McKelvie outlines a compelling agenda for feminist approaches to bioinformation. When read through technoscientific apparatuses, women are subject to new forms of control that emerge from rendering their bodies readable, claiming

In Chapter 7, 'American Bioinformation and U.S. Race Politics: The Values of Diverse Genetic Data', Anna Jabloner raises a range of compelling questions regarding how 'diversity' is figured across a range of bioinformation institutional and political imaginaries in the United States. Jabloner shows how 'diversity' is ascribed to data in different contexts, sustaining very different raciological (bio)political projects and biocapital calculations. The chapter illustrates how 'data that lack diversity' or 'super-diverse data' are not stable entities. Rather, over- and under-representation of some groups acquire differential meanings and value(s) across domains. Raciological orders are both reflected and constituted through the making of 'diversity' in bioinformation and Jabloner shows how 'diversity' is seen and unseen across forensic and health data ecologies in ways that do not align neatly. Diversity is invoked as a core value to underpin large research endeavours such as the All of Us Research Program, a venture which aims to capture diversity in terms of race, gender, sexuality and socio-economic status nationally. In forensic contexts such as the federal criminological genetic database CODIS, the over-representation of certain groups is not seen as a marker of diversity. Instead, here indexing is used to produce race neutrality, while at the same time obscure the racism of policing and law enforcement institutions which produce the database

in the first place. The over-representation of racially minoritized groups is offered as an argument for universal bioinformation gathering in biomedical research, target disproportionately black and brown men, arguably to redress the racism which results in ‘diversity deficits.’ It is in this way that the value of bioinformation data can be framed as universal. Jabloner contrasts these incommensurate claims about the value of bioinformation data on the grounds of diversity or universality, as articulated from situated, albeit unmarked, privileged vantage points. Building on Fortun’s elegant rendition of the contradictory stakes and claims in the genomic biotech industry in Iceland through the figure of the chiasmus (2008), Jabloner shows the frictions that emerge in genomics in the context of American race politics along the nexus of specificity/universality and individuality/collectivity. The value of bioinformation changes across domains and infrastructures, as it transverses legal, biomedical, and consumer data ecologies.

Transnational and global bioinformation dynamics are the focus of Chapter 8. In a study of bioinformation regimes through practices of extraction and e-waste management, Peter Little raises key questions about the changing biopolitics of extraction and bioaccumulation. Little’s analysis of e-waste management takes into account labour practices at facilities in China and Ghana, establishing a fruitful comparison between these cases to illuminate new how bioinformation underpins forms of global biopolitics which demand that we think apparently different and contrasting practices in relation. Focusing on derivative information relating to toxicities and genomic instabilities, China and Ghana offer contrasting of environmental health narratives that raise new questions about biopolitical critique, posing new questions about the politics of extraction, the value of aggregation and epidemiological metrics, and their connection with wider geographies of e-waste health management and expertise. Little follows environmental epidemiologists, e-waste workers, and shifting material forms of bioinformation to explore how local relations between labouring bodies and electronic discard policies expose patterns of e-waste toxicity connected to global bioinformation economies and the technoscientific systems that produce them., Little argues, following Lock (2017) that these wider historical and socio-political relations frame the significance of local bioinformation biologies in terms of a ‘technoecobiopolitics’ (Little 2012), a politics of life entangled in tecno-environmental disruption, toxicity and contamination that becomes an object of regulation and expertise in global technoscience. Indeed, Little shows that bioinformation itself entangles these wider informational

metanarratives in its constitution, management, and afterlives once it becomes part of particular research or policy assemblages.

In Chapter 9, 'Seeing like an airport: towards interoperability in contemporary security', Maguire and Murphy show, through a rich ethnographically grounded account, how the airport is a site of production of bioinformation in and through (bio)surveillance systems and infrastructures. The airport itself appears to be a multi-temporal site made out of modern bureaucratic practices that belong to the 19th and 20th centuries and that unfold alongside 21st century biometrics and bioinformation-centred systems which seem to be increasingly interoperable, or at least promise increased integration, interoperability and efficacy. Maguire and Murphy approach the airport as a space of multi-temporal heterogeneity where modern, biometrics and bioinformation surveillance systems unfold alongside each other, occasionally criss-crossing - and where remarkably stable social logics and taxonomies of population surveillance are reproduced. In this specific iteration, however, bioinformation at the airport is a material semiotic object which is in part matter, part rhetoric. Interoperability is at once a rhetorical device that sustains the project of 'seeing like an airport' and a range of socially situated practices of surveillance. The future-oriented vision of interoperability and integration – a version of the 'total system' similar to the 'total archive' (Lemov 2015, Daston 2017) – however, is shown to entail in practice notable blank spots in the systems, exemplified by the corridors and pathways where 'the airport cannot see' and where, beyond the surveillance gaze, flora and fauna thrive. Maguire and Murphy's incisive maps the blank spaces in the integrated systems model coded as the interoperable future. This has significant implications given that governments are currently investing heavily in operationalising automated predictive technologies which promise increased integration and interoperability. The UK strategy is the Home Office Biometric Strategy, for example, aims to combine fingerprints, DNA and facial images, in an integrative vision of post-archival data consolidation (Gonzalez-Polledo and Posocco, forthcoming). Open source expert systems promise to process ever-increasing volumes and types of data - biometrics, facial recognition, retina scans, and behavioural patterns alongside fingerprint capture, photo matching and a plethora of context-specific operations of data capture and processing. The analyses of bioinformation presented in the volume, however, considerably complicate the vision of totality, integration and optimised interpretation in expert and lay accounts.

In the final chapter, Kiheung Kim and Jongmi Kim focus on responses to the Covid-19 pandemic in South Korea in 2020. They show that the management of citizens' bioinformation was central to governmental strategies to contain the spread of the virus. However, they argue that to understand the readiness of South Koreans to adopt digital tracking methods such as tracing the movements of mobile phones and credit cards as well new technologies of testing in drive-thru and walk-thru methods, socio-historical factors should be considered. More specifically, the histories of bioinformation management in previous public health emergencies and histories of biocitizenship in the country are particularly salient. Kim and Kim relate the Covid-19 crisis to decades-long set of reforms that begun in earnest in the 1980s and which have progressively led to the construction and reframing of the disease controlling and preventing systems, through the responses to outbreaks of zoonotic infectious diseases including SARS, MERS, Foot-and-Mouth disease and African Swine Fever. The chapter, then, connects developments in bioinformation management and integration to new forms of governmentality increasingly concerned with transparency and direct democratic processes in the aftermath of anti-government movements, the so-called Candlelight Movement, which led to the impeachment of former president Park Geun-hye. Unpacking Orientalist framings of South Koreans as docile citizens unable or unwilling to contrast governmental intrusion into everyday life due to Confucian traditions and ethics, the chapter presents bioinformation in the age of Covid-19 as a postcolonial artefact which diffracts socially situated anxieties about the status of power and the parameters of agency at play in voluntary bioinformation relay and surrender. As Covid-19 recast yet again questions about bioinformation governance and infrastructures with new urgency and in a new light, the case of South Korea is an important reminder of the way bioinformation histories can at once sediment and emerge in the ordinariness of life in the pandemic.

10. Afterword / Noah Tamarkin

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