DIGITAL MEDIA ECOLOGIES

ENTANGLEMENTS OF CONTENT, CODE AND HARDWARE

SY TAFFEL

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Introduction:

Re-thinking media ecology

This book is about digital ecologies and entanglements. It asks how assemblages of code and carbon, blogs and brominated flame retardants, advertising and algorithms affect politics, communications and culture. While 'ecology' is a term commonly used as an alternative way of saying environment, of denoting the 'natural' or nonhuman systems which human beings inhabit, its etymology derives from the Greek term *oikos*, meaning household, suffixed by *-logy*, meaning 'study of'. Unlike biology – the study of life – ecology comprises the study of patterns of entanglement, connectivity, interaction and symbiosis between agents ranging in scale from individuals to ecosystems, exploring how different parts of the global household relate to one another. Whereas the term 'environment' evokes something outside of human systems, a 'natural' exterior,[1] ecology makes no such distinction between the human and nonhuman, living and nonliving elements of ecosystems. Ecology, therefore, becomes a productive way of

[1]Following this train of thought, ecological activists such as Rupert Read (2010) argue against using the term 'environment', contending it reinforces dualistic ontologies that situate humans outside of ecological contexts. Read suggests the terms 'ecology' or 'ecosystem' are always preferable due to their inherent connectivity. This proves problematic though, as removing the term environment loses a useful descriptor for distinguishing between primarily social issues such as labour rights or access to health care, and issues such as loss of biodiversity or ocean acidification which are at least equally focused upon nonhumans. While both scales involve entanglements of human and nonhuman actors, the balance of those relations is quite different. Consequently, despite the tendency towards dualism associated with the term, I will use environmental ecology and environmental justice as descriptors referring to conflicts that foreground nonhumans.

eliding the assumed oppositions between socially constructed human culture and the nonhuman domains of nature and technology.

Ecology emphasizes process, flow, dynamism and complexity. As Matthew Fuller (2005: 2) argues, the term ecology is 'one of the most expressive language currently has to indicate the massive and dynamic interrelation of processes and objects, beings and things, patterns and matter'. This is one of the two entangled connotations of the term which is central to the media ecology of this book, with the second being the sense of ecological crisis that is associated with climate change and the Anthropocene. While thinking about media and ecology often foregrounds dynamism and complexity, my argument here is that media ecology must also articulate how digital media are deeply politically, materially and culturally implicated in the production of contemporary ecological crises and are necessary components of collective mobilizations designed to substantively address them. My approach to media ecology therefore requires the formation of an ecopolitics that employs technologies to mobilize actions and produce structures characterized by equity, commons and mutualism, rather than the neoliberal logic of competitive individualism that largely dominates contemporary technology, culture and society.

Alongside ecology, a second key term for this book is 'entanglement'. My usage of this term derives from the works of the feminist philosopher of science Karen Barad and social anthropologist Tim Ingold, for whom the term refuses subject/object, nature/culture and representation/reality dualisms. Instead, entanglement posits a world of becoming which is not composed of isolatable, interconnected individuals, but of entities that are bound in continuous, evolutionary and non-teleological transformations of one another: 'To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair. Individuals do not pre-exist their interactions' (Barad 2007: ix). Entanglement presents a novel way of approaching the world in which the atomized individual components which are normatively conceived of as nodes within networks, or organisms within environments, are instead considered as meshworks of knotted lines which collectively compose ecological systems. As Ingold (2011: 71) emphasizes:

> Beings do not simply occupy the world, they *inhabit* it, and in so doing – in threading their own paths through the meshwork – they contribute to its ever-evolving weave. Thus we must cease regarding the world as an inert substratum, over which living things propel themselves about like counters on a board or actors on a stage, where artefacts and the landscape take the place, respectively, of properties and scenery.

As a social anthropologist, Ingold is primarily interested in exploring entanglement, movement and growth in living systems, whereas this book

is primarily concerned with ecologies of contemporary digital media. Such systems always include human and technological elements, and following the philosopher of technology Bernard Stiegler, this book will approach technological systems as being fundamentally constitutive of what it means to be human.

While humans design, alter, hack, modify and otherwise condition the state of technological evolution, those technological developments simultaneously alter the plastic structures of the human brain through what Stiegler terms 'epiphylogenesis', a mode of evolutionary change which occurs outside of genetics and is dependent upon the distributed cognitive apparatus of technology. Epiphylogenetic activity can be traced to the earliest human interactions with tools and the formation of what we understand to be culture. Thus understood, culture is always and has always been entangled with nonhuman technological systems. Consequently, this book uses the term 'technoculture' as shorthand which seeks to inscribe the nonhuman agencies of technology into the domain of culture, drawing attention towards the way that tropes such as culture and society, which are often presumed to relate to humans always involve entanglements of humans, other living beings and technologies.

Digital ecosystems and platforms

The terms 'media ecology' and 'media ecologies' are currently used in multiple ways in differing areas of media scholarship. Perhaps the most common application of the term 'ecology' to digital media refers to analysis that recognizes the commonality between digital technocultural systems and ecosystems insofar as both are dynamic, negentropic systems maintained at a point of balanced disequilibrium by flows of energy and matter, and which consequently exhibit non-teleological, complex behaviours. Whereas a savannah or jungle requires flows of sunlight, heat and water for its inhabitants to collectively constitute those systems, digital ecosystems require electrons, (human and nonhuman) attention and a plethora of materials for infrastructural production and maintenance.

Frequently, we hear of the Apple and Google mobile ecosystems, demarcating the ways that these two corporations have built integrated systems of hardware, such as the iPhone, iPad, iMac, Apple Watch, iCloud storage (and the Google/Android equivalents), software, such as the iOS operating system, iTunes, the Apple App Store, Safari web browser and content creation and sharing tools such as Final Cut Pro, iMovie, Aperture, Photos, Garageband and Logic Pro. The key to understanding the success of the iOS/Android systems is based not upon any particular part of this ecosystem, but upon the way that all of the constituent elements relate to one another and, critically, how they allow third parties to contribute

to this ecosystem, for example by populating the App Store. Similarly, Facebook and Twitter are examples of software platforms which are often referred to as providing an ecosystem due to the manner by which they provide publicly available Application Programming Interfaces (APIs) with which third-party software developers can develop various forms of software which interface with the core platform. Examples include social games such as Farmville and Mafia Wars, customized interfaces such as TweetDeck, and the Facebook Connect API, which allows third-party website users to log in using their Facebook account and to 'Like' pages, which provides Facebook with valuable data which would otherwise be outside of its domain (Morin 2008).

One of the key points this raises is that value is not predominantly generated by Facebook itself, but through the productive activity of both partner sites and users, which is understood as one of the hallmarks of an effective platform as ecosystem (Bodle 2011). Whereas in the mass media age value was primarily derived from creating mediated content, building a digital ecosystem means constructing a participatory community, which from a commercial perspective amounts to monetizing the activity of what was previously the audience or customer in addition to third-party developers. While understandings of media audiences as commodities, as eyeballs being sold to advertisers has long been one way of grasping the political economy of media (Smythe 1981), the degree of generative activity, in terms of creating content, communities, networked social relations and the data-driven modes of user surveillance and statistical behavioural prediction (Amoore 2013) has been substantively altered by networked digital media.

One prominent ecologically inflected trope we find employed alongside that of the technological ecosystem is that of the walled garden, a way of denoting concern surrounding how closed-source informational ecosystems erect boundaries around how hardware and software may be used. This produces a situation where it can be extremely difficult for alternative platforms to gain a critical mass of users and apps, and has been particularly prominent in the areas of mobile computation and social media. Whereas the web was designed with open protocols, enabling access which did not discriminate based upon the type of hardware being used, iOS and Android apps only work on those specific platforms and buying software on one platform does not entail continuing access if users subsequently change platform. Consequently, consumers find themselves being placed behind barriers which inhibit movement but are exceptionally successful in keeping users 'loyal' to corporate ecosystems.

Historically, the horticultural variety of walled garden was not designed to keep intruding humans or animals out, but to create spaces that were warmer than their surroundings, affording walled gardens in temperate climates, such as in England and Ireland the ability to grow grapes, peaches and other plants which normally require a Mediterranean climate. The enclosing walls

of brick or stone would shelter plants from wind and absorb heat from sunlight during the day, which would slowly radiate out overnight, creating a warmer microclimate (Campbell 2006). The analogy of creating enclosed digital spaces as a means of protecting fragile users from nefarious hackers, pornographic content and other online hazards is undoubtedly one which platform providers would identify with, but in practice walled gardens have been criticized for locking customers in to technological systems (Netanel 2007) and allowing corporate entities to function as gatekeepers who are free to censor, ban and otherwise foreclose material which challenges their worldview (Gillula 2015).

While such accounts of digital ecosystems and walled gardens employ ecological and horticultural tropes as a metaphor, they often remain somewhat adrift from engagements with the materiality which underpins digital technocultural forms. Consequently, the notion that there is a separate, digital space which exists alongside the meatspace of embodied interactions is promulgated, which follows the tradition of approaching networked media through a series of old/new, analogue/digital, passive/(inter)active and present/absent binary oppositions. The ecological framework proposed by Paul Virilio exemplifies this dualistic logic, arguing that alongside the green ecology of 'nature', we find a 'grey ecology' of industrial culture. While Virilio's exposition of 'dromocracy', the speeds borne from contemporary industrial technoculture is useful in grasping aspects of the contemporary technocultural context, striating ecology into green and grey ecosystems effectively reinstitutes the nature/culture dualism that ecology undermines.

The dualistic model of green and grey ecologies resembles another deployment of the term media ecology, which is associated with the works of Marshall McLuhan and Neil Postman. This version of media ecology is primarily concerned with human engagements with the symbolic or cultural environment of media, and the moral ramifications of these interactions. While there is overlap with this book vis-à-vis concerns pertaining to effects of technologies on social structures and a focus on the pace, scale and patterns associated with particular technological ensembles, this approach to media ecology diverges sharply from this text insofar as it is concerned with making:

> People more conscious of the fact that human beings live in two different kinds of environments. One is the natural environment and consists of things like air, trees, rivers, and caterpillars. The other is the media environment, which consists of language, numbers, images, holograms, and all of the other symbols, techniques, and machinery that make us what we are. (Postman 2000: 11)

Whereas ecology is used here to elide binary oppositions between nature and culture, instead highlighting the flows of energy and matter throughout

a series of entangled scalar ecosystems, the approach favoured by Postman and McLuhan reinforces dualisms through the study of a symbolic or cultural environment which is posited as distinct from its natural counterpart. Consequently, McLuhan and Postman's version of media ecology does not address the materiality of media networks: the environmental and labour issues that are associated with the extraction, manufacturing, energy, transportation and waste industries that are absolutely fundamental to the production of the material infrastructures that are necessary for there to be digital media, as these issues do not fall within the 'media environment' that Postman articulates as existing alongside the natural environment.

The conceptual divergence between the McLuhan/Postman tradition of media ecology and that employed here and within recent materialist appropriations of the term (Fuller 2005; Parikka 2007, 2010, 2011) derives from the onto-epistemological frameworks within which the respective modes operate. Postman's version of media ecology 'emphasises a humanistic approach to understanding media, communication, and technology' (Grossweiler 2002). Humanism, the dominant philosophical tradition within Western culture, emphasizes humanity's separation from nature, casting humans as rational animals which uniquely possess free will, differentiating them from the determinate automatons which comprise other living and nonliving systems. Consequently, Postman has been criticized for proposing a form of media ecology which is based on a dualistic ontology (Stephens 2014). Eco-materialist thought opposes this dualistic onto-epistemology, instead following thinkers such as Gilles Deleuze, Felix Guattari, Gregory Bateson and Donna Haraway in positing humans as one species entangled with others. While humans may form particularly dense knots of entanglement within ecosystems, they are not ontologically distinct entities.

Anthropocenic ecologies

I have two primary motivations for exploring digital media through the lens of ecology; firstly, I am interested in the potential utility of analysing media as dynamic adaptive ecosystems, and secondly, I want to explore the political implications of adopting this approach. Ecology as a way of studying interconnection and interaction in complex dynamical systems seems apt as a method of exploring rapidly evolving contemporary systems of digital media production, distribution and consumption, especially when media is increasingly collaboratively created, consumed, shared and remixed. While formal homologies between complex, dynamical systems and digital media have long been explored by texts such as Kevin Kelly's *Out of Control* (1996), this book differentiates itself from this tradition through a sustained engagement with an ecologically informed politics, that profoundly diverges from formal homologies between ecology and digital technologies that are pursued within the context of what Kelly describes as

the benevolent corporate super-organism of neoliberal capitalism. Indeed, we frequently find the language of ecology applied to technocultural and business-led systems as a way of naturalizing these constructed entities, a discursive sleight of hand which designates them as ideologically neutral, 'natural' processes rather than politically contestable strategies.

Rather than exploring ecological metaphors and digital media, or ways that ecology might provide productive insights for increased efficiency and systemic exploitation, this text considers what the application of an ecosophical ethic and politics to digital media may involve. My argument here is that an ecological approach may prove productive in reconsidering particular dimensions of mediated practices with regard to social and environmental justice in the Anthropocene,[2] a geological epoch where human activities are said to play a defining role in altering the planet's climate and biodiversity in ways that will be quantifiably detectable in the planet's geological strata. Key markers of this new epoch include anthropogenic climate change, alterations to the planetary nitrogen and phosphorus cycles, the production of vast quantities of biologically persistent 'technofossils' such as plastic and a massive reduction in biodiversity with the current species extinction rate only equalled within the handful of terrestrial mass-extinction events that have occurred in the past two billion years. Reorienting technocultural systems to avoid the dystopian future forecast by the Anthropocene – an Earth with dramatically reduced numbers of human beings and other species of life collectively struggling under an inhospitable climate – therefore becomes an urgent task for contemporary ecopolitics.

Terming the contemporary geological epoch the Anthropocene should, however, raise several conceptual questions. Does the foregrounding Anthropos – humanity (or more accurately, and problematically, man) – restate the misplaced emphasis on humans as autonomous agents who mobilize an inert and passive nature that has been substantively problematized by posthuman and new materialist discourses on agency (Bennett 2010; Haraway 2016)? Does the Anthropocene problematically posit a homogenized humanity, thereby forming a depoliticized technocratic discourse that neglects the roles of privileged elites and capitalist systems of overproduction and hyper-consumption in contemporary ecological crises (Moore 2015; Malm 2016; Boneuil and Fressoz 2017)? Does the Anthropocene mark the re-emergence of the overly-simplistic, universalist meta-narratives that were supposedly consigned to the dustbin of history by postmodernism, albeit with the positive Enlightenment metanarrative of progress replaced with the negative discourse of anthropogenic ecocide (Taffel 2016a)?

[2]In 2016, a working group established by the International Commission of Stratigraphy formally recommend that the Anthropocene be adopted as the geological epoch following the Holocene, for more details see Taffel 2016a.

While these questions highlight serious shortcomings with Anthropocenic discourse and terminology, its utility rests upon its potential to galvanize political actions to escape a future where humanity plays a major role in destabilizing the global climate and precipitating an enormous reduction in planetary biodiversity, alongside how the term re-connects human (technocultural) history with geological (natural) histories. The eco-ethical imperative then is to formulate technocultural systems designed to mitigate the current direction of the Anthropocene; an unprecedented speed of ecological alteration, within which assemblages of (certain groups of) humans, nonhuman life forms (such as cattle and corn) and nonhuman technical entities (such as computers and coal-burning power stations) are collectively imposing an acceleration of changes upon ecosystems which contain entities who lack the adaptive capacity to evolve at such speeds. Notwithstanding the widespread fantasies of technological salvation via geoengineering, nuclear fusion or carbon capture and storage, any species which quarrels with its own ecology is one which likely destroys its own future.

Ecology cuts across the traditional dualisms of nature and culture, human and nonhuman, living and nonliving systems presenting a method of tracing connections through entangled technocultural phenomena which have frequently been approached as distinct, divided and even oppositional. A pertinent example is the historical division between Marxist social justice advocates and their environmental justice counterparts, whereby Marxists criticized environmentalism as 'a defensive movement in which the middle classes and capitalist entrepreneurs are attempting to protect their interests, which are increasingly threatened by the internal contradictions of capitalism' (Pepper 1984: 173). While such accounts do not dispute the reality of environmental degradation, they contend that such phenomena were not novel developments; the environmental ramifications of the coal pits and factories that fuelled the industrial revolution had always caused immiseration and detrimental health impacts to humans,[3] but this suffering was borne primarily by the working classes: 'The ecological movement has

[3]Nonhuman concerns having been largely absent from the majority of Marxist–humanist accounts. It is, however, important to note that according to Marx (1967: 505–6): 'Capitalist production … disturbs the metabolic interaction between man and the earth, i.e. prevents the return to the soil of its constituent elements consumed by man in the form of food and clothing; it therefore violates the conditions necessary to lasting fertility of the soil … all progress in capitalist agriculture is a progress in the art, not only of robbing the worker, but of robbing the soil; all progress in increasing the fertility of the soil for a given time is a progress towards ruining the more long-lasting sources of that fertility. … Capitalist production, therefore, develops technology… only by sapping the original sources of all wealth – the soil and the worker.' This focus upon ecology and metabolic rifts within Marx's writings has become central to contemporary eco-Marxism (Bellamy-Foster 1999; Moore 2011).

only come into being since the districts which the bourgeoisie inhabit and their living conditions have been exposed to those environmental burdens that industrialization brings with it' (Enzensberger 1974: 10).

Whereas Enzensberger contends that environmental protests are merely manifestations of the bourgeoisie feeling the effects of the internal contradictions of capitalism, the adverse effects of Anthropocenic ecological crises will be primarily borne by people lacking the economic capacity for adaptation, or who are directly reliant on local environmental resources for their income. In other words, while there are geographically disparate effects expected to arise from ecological crises such as climate change, they tend to affect social groups proportionally to their economic status, with the poorest groups, whose labour is often directly tied to the land or oceans, and who lack the economic capacity for adaptive measures, hit the hardest. Consequently, within the globalized context of the Anthropocene, social justice issues cannot be understood as distinct from environmental justice issues.

This entanglement of the domains previously understood as nature and culture, humanity and technology, or (human) history and (natural) geology, calls for an ecological ethic and political mobilization addressing the dire predictions of a planetary mass-extinction event predicated by industrial anthropogenic activity, while also questioning the anthropocentrism present in such claims. There currently exist several ecological ethics which contrast with conservationist approaches that seek the preservation of romanticized notions of a pre-industrial or pre-colonial nature and thereby depart from ecological approaches that are concerned with complex dynamical systems. Two prominent positions here are social and deep ecology. Social ecology maintains an anthropocentric perspective, centring on human societies and understanding 'nature' as a series of resources to be utilized for human benefit, while contending that the concept of humans dominating nature arises from the social context of humans dominating other humans. Murray Bookchin (1982: 11) surmises the ethical approach espoused by social ecology as an ecology of freedom, which expresses 'the reconciliation of nature and human society in a new ecological sensibility and a new ecological society – a re-harmonization of nature and humanity through a re-harmonization of human with human'. While social ecology goes beyond current understandings of value as primarily derived from economic wealth, critics such as Arne Naess (1973, 1989) and Jonathan Porritt (1984) argue that it maintains that nonhuman life is valued primarily in terms of utility to human societies and that while this exceeds economic usage, encompassing aesthetic and spiritual dimensions, the anthropocentric focus on 'natural resources' requires challenging.

The deep ecology perspective instead contends that nonhumans have intrinsic value: 'the value of nonhuman life is independent of the usefulness

these may have for narrow human purposes' (Naess 1989: 29). It proposes a biocentric ethic whereby humans are accorded no special ontological status and are compelled to act in a manner which will not reduce biological diversity, regardless of the impacts upon human society. Indeed, one of Naess's principles of deep ecology contends that for human and nonhuman life to flourish a substantial decrease in the human population is required, from a current global population of over seven billion to less than a hundred million. While Naess posits no methods to achieve this gargantuan population reduction, this argument has been criticized as misanthropic, neo-imperialist and racist (Bookchin 1982; Hardt and Negri 2005: 165–7), as a privileged, white, European man calls for a massive reduction in the global population.

While questions of population are politically difficult, they must be understood in relation to what sort of existence is being posited. A future society which expects to use coal, shale oil and tar sands to power intercontinental travel, digital technologies and industrialized animal agriculture could sustainably support a miniscule population when compared to one using local renewable energy sources, eating a plant-based diet and rarely travelling by air (at least if using contemporary forms of fossil-fuel-based transportation). Indeed, while the controversial but influential IPAT equation (Impact = Population x Affluence x Technology) used to model human impacts upon ecological systems has been widely criticized for including technology as an unquantifiable weighting variable alongside population and affluence (which is measured by GDP per capita), it does at least foreground that the ecological impact of human populations can only be understood in combination with their technologies. We must, however, bear in mind that the richest 10 per cent of the global population is responsible for half of anthropogenic carbon dioxide emissions (Oxfam 2015: 4). Consequently, we see that it is vital to consider questions of social inequality and the differential ecological impacts of different ways of living into any discussion of optimal or sustainable global populations – a dimension which is entirely absent from IPAT – rather than homogenizing humanity into a singular force whose ecological impacts can be understood through the number of living individuals.[4]

While infinite population growth on a finite planet is clearly unsustainable, there are two major concerns with the discourse of overpopulation. First, the reductive disavowal of difference and inequality which provides a homogenized humanity and, secondly, the fact that this argument propagates

[4]This has also been a major critique of the Anthropocene, which in some cases argues that an undifferentiated humanity is the cause of contemporary ecological crises (see Moore 2015; Bonneuil and Fressoz 2016).

an apathetic stance whereby political urgency is disarmed by a sense that ecological problems are ultimately a result of there being too many people on the planet, rather than phenomena which can be addressed through collective actions aimed at curtailing the obscene levels of consumption associated with a relatively small percentage of humans and redistributing wealth more equitably. Furthermore, the pragmatic strategies that have historically proven successful at curbing population growth – decreasing child mortality rates, providing higher levels of education for women and access to contraceptives – are all socially desirable. Focusing upon improving lives by implementing these three things is likely to curb population growth without an explicit focus on reducing populations.

Rather than adopting either social or deep ecological positions, my approach to media ecology implements an ecological ethic based on the positions of Gilles Deleuze, Felix Guattari and Gregory Bateson which cut across a social/deep ecology dualism, positing a form of perspectivism that argues for multiple ecologics, not a single ecology (Chisholm 2007; Herzogenrath 2008). This approach questions the notions of harmony and stability common to social and deep ecological constructions of nature, instead positing a multitude of ecosystems which exist balanced at points far from equilibrium. This approach questions the usefulness of adopting a single standpoint which purports to centre upon either humanity or all life, instead drawing upon Guattari and Deleuze's logic of the AND, a methodological pluralism which emphasizes pragmatic embodied praxis over abstract universals and either/or binary choices. This logic advances through assembling, bringing together disparate elements to build coalitions capable of producing systemic change that escape the individualist and commodified tendencies that currently dominate digital cultures.

Scale and digital technoculture

One of the key concepts which media ecology mobilizes to address this logic of the AND is scale. Thinking in terms of entangled scalar ecologies allows us to move between phenomena encompassing the micro-temporal and micro-spatial registers of voltages, photons and algorithms, through to the global infrastructures of international standards organizations, undersea cables, satellites, server farms, cellular towers and social media platforms. Indeed, as Jussi Parikka (2015b: 220) has recently stated, 'to be interested in the multiple scales on which reality is built, co-constructed, is not a luxury, but a necessity for critical theory nowadays'. The concept of scale is applied in varying ways across a broad spectrum of academic disciplines, and outlining these debates surrounding scale is useful in clarifying how the term is deployed here.

Perhaps the most commonly encountered application of scale derives from cartography, whereby the term refers to the reduction of space by a numerical factor, enabling vast areas to be graphically represented upon maps; one centimetre represents a specific distance, denoting that within cartography scale indicates a direct and quantifiable relationship which exists between map and territory. This is also the sense of scale as size that is employed in the notion of scalability or scaling up, whereby tech start-ups seek to dramatically increase their size without effecting wider structural changes, a concept that is usefully critiqued by Anna Tsing (2015) as originating in the abstract world of mathematics but which applies poorly to the complex and specific ecological world.

Contrastingly, we find relational approaches to scale, such as its employment within the geologic time scale (GTS), which divides the earth's history into nested chronological units that are not based upon equal temporal durations but indicate alterations to geological strata corresponding to significant geological or palaeontological events (Gradstein et al. 2012). For example, the boundary between the Permian and Triassic periods is the Permian–Triassic extinction event, the most severe mass-extinction event found within the geological record, which denotes an abrupt change in the fossil record. What is important to grasp about the GTS, then, is that scale does not demarcate a linear series of measurements but particular relational aspects between neighbouring periods. A related application of scale as defining relations between entities can be found within music. The difference between a major and minor scale may only be a single note, but this relatively small alteration between the set of notes being played is heard and understood as comprising a significant shift in qualities of the acoustic arrangement. Scale in this case is not about quantitative change but refers to the configuration of relationships between actors within sets, and grasping this difference between scale as quantitatively measurable size and scale as relational configuration is key to grasping the way which scale is used here to explore digital media.

Scale has been heavily discussed within cultural geography, a discipline in which the cartographic connotations of scale as size have for a considerable time existed in tension alongside relational variants closer to the application of scale in the GTS. There has, however, been considerable debate over the precise meaning of scale within cultural geography, ranging from Richard Howitt's (1998, 2002) suggestion that scale is a foundational disciplinary concept alongside space, place and culture, through to claims that scale presents a highly problematic concept which should be eliminated from geographical discourse (Marston, Jones and Woodward 2005). Marston and colleagues apply theoretical insights from Deleuze and Bruno Latour surrounding a flat ontology to argue that scale presents ontological divisions, which, while adding nuance to a global/local distinction through the addition of intermediaries such as the national, are ultimately founded

upon verticalism and hierarchy, thus inhibiting network-led approaches to micropolitics. Consequently, they contend that 'scale is a classic case of form determining content, whereby objects, events and processes come pre-sorted, ready to be inserted into the scalar apparatus at hand' (Marston, Jones and Woodward 2005: 423). This approach to scale, however, concentrates on scale as size, whereas scale as relation is entirely absent.

Additionally, this critique presupposes that scale addresses ontological rather than epistemological phenomena, whereas various alternative perspectives within cultural geography emphasize scale as an epistemological tool rather than a series of ontological divisions (Hoefle 2006; Moore 2008). Instead of representing rigid striations between hierarchically nested layers of reality, 'scale itself is a representational trope, a way of framing political spatiality that in turn has material effects' (Jones 1998). There seems to be no reason why an ontological framework whereby existence is comprised of a single plane of immanence is incompatible with an epistemology which explores phenomena across a range of relational scales, presenting numerous overlapping apertures with which to comprehend entangled phenomena. Indeed, Guattari's framework of the three ecologies, derived from the environmental/cybernetic epistemology of Gregory Bateson, exemplifies such an approach whereby scale is understood as a relational quality between elements of ecological systems occurring within a single ontological register. Consequently, Guattari (2000: 42) argues that despite the apparent separation of these relational scales, it is 'quite wrong to make a distinction between action on the psyche, the socius and the environment'. Here, scalar ecologies are applied to provide overlapping modes of inquiry into entangled phenomena, rather than hierarchically determined ontological divisions.

Homologous to the three entangled ecologies of mind, society and environment proposed by Bateson and Guattari, the digital entanglements explored in this book focuses upon three relational scales of content, software and hardware. While ultimately, digital content and software both exist as magnetized regions or transistor states, and certain types of digital content such as computer games are only operationalized as executable code, the difference I draw between these entangled scales revolves around the way they are encountered, hence the emphasis on their existence as epistemological rather than ontological differences. Content is a scale at which end users encounter digital media, it is the part of the media assemblage that is most visible because it is designed to be experienced by humans. Code is a scale at which there are encounters between humans and machines. As we shall see, there are many levels of code, some of which (such as binary) are not human-readable, but a key characteristic here is the way that machines can be programmed to execute algorithms – step-by-step instructions – that allow the automation of decision-making processes based upon rules. While humans are today in almost constant contact with various forms of code, this process is often invisible and unfelt. Finally, hardware is

the scale that addresses the material assemblages of silicon, copper, plastic and countless other substances that afford the construction of code and content. While digital infrastructures such as transoceanic fibre-optic cables, satellite networks and data centres are often vast in size, the proliferation of miniaturized thin client devices such as smartphones means that they are rarely perceived and poorly understood.

This is not to suggest that these are the only scales at which media systems operate; we could, for example, equally think about media existing through the scales of spectrum (Wi-Fi, WiMAX, Satellites, GPS, cellular networks), earths (undersea and underground cables, mining metals and minerals and fossil fuels) and users (user interfaces, screens, haptic devices, cyborgs), or the layers of earth, cloud, cities, address, platform, interface and users, proposed in Benjamin Bratton's *The Stack* (2015). My selection of scales of content, code and hardware is partially designed to address recent calls in post-Marxist critical theory for open digital infrastructures at the levels of information, software and hardware (Hardt and Negri 2009). As with Bateson and Guattari's three ecologies, these scales are not distinct and separable layers, but entangled meshworks that cannot be functionally isolated from one another. The utility in exploring them as scales lies in grasping the differing types of relation highlighted by each aperture. While it would be wholly wrong to ascribe particular qualities in a singular fashion to each scale, such as claiming that meaning derives solely from content and materiality entirely relates to hardware, there are important differences in the way that particular relations manifest within different scales. As we shall see, there are different materialities, agencies, meanings and power relations that exist within images and sounds, algorithms and codecs, CPU architectures and fibre-optic cables, and grasping how these differences operate across and between entangled relational scales is an important task for a political ecology of digital media.

Digital infrastructures and inequalities

Politically and ethically orientated approaches to media and technology are by no means new. My argument, however, is that the contemporary situation requires a reappraisal of how we approach technocultural systems from ethical and political perspectives. The demarcation that has traditionally been drawn between ethics and politics is largely one of individual and collective action, with ethics referring to a system for understanding positive and negative behaviours, whereas politics denotes the collective actions taken to enact ethical action. As we shall see, this is somewhat complicated by an ecological approach to agency which blurs the boundaries between individual and collective practices, decentring the traditional notion of the unified subject into an evolving assemblage which is always composed of

multiple forms of organic and nonorganic life which escape the boundaries of the skin, but which is still concerned with purposive collaborative action and large-scale social and environmental change. Consequently, the line between ethics and politics dissolves into thinking about how to enact collective behaviours with ecologically beneficial impacts.

The technocultural context for the book is composed of both the backdrop of the Anthropocene and the ongoing changes to information and communications technologies. The massive increase in volume, speed and interconnection of information and communications technologies have arguably formed a new stage of capitalist development, variously described as informational capitalism, empire, cognitive capitalism, integrated world capitalism, globalization, late capitalism, platform capitalism and the network society. Although these concepts do not precisely describe a homogeneous system of relations and structures, they present a series of overlapping frameworks which examine differing aspects of contemporary society.

During this period, the cost of processing information using transistor-based computers, fell from over US$18 billion for one Gigaflop (one billion floating point operations per second) in 1961 to 3 cents by 2017, the internet has grown from a handful of nodes to having several billion users, global internet traffic has grown from 0.01 petabytes per year in 1990 to 160,000,000 petabytes per year in 2016 (Press 2016), and mobile phone usage has risen from a handful of corporate executives to the majority of the global population. Spanish sociologist Manuel Castells argues that in this context

> electronic media have become the privileged space of politics. Not that all politics can be reduced to images, sounds, or symbolic manipulation. But, without it, there is no chance of winning or exercising power. … Because of the convergent effects of the crisis of traditional political systems and of the dramatically increased pervasiveness of the new media, political communication and information are essentially captured in the space of media. Outside the media sphere there is only marginality. (Castells 1997: 311/312)

These claims are supported by empirical evidence delineating the frequency of media usage, such as Ofcom (2015: 28) finding that between 2005 and 2015, sixteen- to twenty-four-year-olds have on average gone from spending ten to twenty-eight hours a week online.

It is important, however, to recognize that it is not merely the frequency of our engagements with media that has changed over this period. As mobile, locative and pervasive computing has been increasingly ubiquitous, our lives have become increasingly bound up with the process of digital mediation. From movements through space that are recorded via GPS and feed into

recommendation algorithm systems such as Google Now and governmental surveillance systems such as the NSA's Co-Traveller, to our heart rates and quantities of sleep that are now measured and recorded by wearable devices such as the Apple Watch and Fitbit bands, our lives have increasingly become mediated.

Rhetorics of the quantified self, smart home and smart city illustrate that this mediatization of life permeates personal, domestic and social scales, that this increased level of digitization and quantification cuts across diverse domains (Greenfield 2017). Following David Berry (2013), we can understand that (post)human existence has become increasingly enmediated; that whereas twenty years ago media predominantly happened in particular places and at specific times, our lives are now fundamentally bound up with media. In this hegemonic technocultural space, approaching the political ecology of digital culture becomes an important task for those interested in processes of social change precisely because of the centrality of mediation to the biopolitics of the twenty-first century.

Understanding entanglements of technology, culture and mediation requires ethical and political analyses that go beyond focusing upon the content of mediated communications, additionally examining the infrastructures of software and hardware upon which digital communications are predicated. Most existing approaches to media ethics (e.g. Ess 2009) focus upon issues such as pornography, propaganda and representations of violence – all of which are serious issues, but ones that primarily relate to the content of media, its final communicational outputs. A political ecology of media must additionally consider the relations that are embedded within and propagated by the infrastructures which support the production of content – the code, algorithms and programs which exist at the scale of software, and the components, computers, cabling, cell towers and other entities which comprise the scale of hardware. As Susan Leigh-Star (1999: 379) explains, 'Study an information system and neglect its standards, wires, and settings and you miss essential aspects of aesthetics, justice and change.' As such, this mode of inquiry takes up the challenge posited by McKenzie Wark (2015: 220), who contends that in the face of the increasingly algorithmic and digital modes of social and ecological precarity, 'the whole question of what now constitutes an infrastructure must be revisited'.

Built into the systems of software and hardware are a multiplicity of affects, ethics and values which are frequently rendered invisible by discourses surrounding virtuality, informationalization and immaterial labour which surround ICTs. One of the aims of this text is to present examples of how and where these ecological impacts arise in order to render them visible and de-naturalized, while considering techniques and strategies which present eco-ethical alternatives. As such, this book has affinities with recent important recent works surrounding the materiality of hardware (Gabrys 2011; Maxwell and Miller 2012; Parikka 2015a; Starosielski

2015; Cubitt 2016; Rossiter 2016), while arguing that hardware should be approached systemically alongside software and content. Rather than presenting a materialist account of media as an alternative to discursive approaches, media ecology is interested in the ways that discourse and materiality are themselves entangled rather than oppositional. As we shall see, infrastructures affect discourses which in turn feed back into technological architectures. Whereas for German media theorist Friedrich Kittler (1998) there is no such thing as software (or for that matter digital content), as ultimately all code exists as voltage differences, media ecology contends that there are divergent affective and political consequences which result from examining media systems across differing scales.

We must also bear in mind that outside the preferentially connected nodes of the network society, the consumer-led media society which is often taken to be universal is still far from pervasive or homogenous. In 2018, global internet users exceeded four billion, meaning that over half of humanity had internet access, but the forty-something per cent with no access who are now, for the first time, a global minority should not be forgotten. While there has been continuing growth in internet usage, particularly among users of mobile broadband since 2008, this must be understood within a context of enduring social and economic divisions. According to the International Telecommunications Union (2017), while over 80 per cent of individuals in the developed world have internet access, this falls to around 35 per cent in developing nations, and just 10 per cent in the least developed nations. While these figures present a stark reminder that we must resist the cyber-utopian ideology of digital telecommunications as affording a globalized and universal realm, we should also be wary of addressing the digital divide as a binary opposition between the connected and disconnected, insofar as such accounts problematically assume that all modalities of access are equal, reducing a series of complex sociotechnical issues to a simple on/off dualism (Cisler 2000; Warschauer 2004: 8). In developing nations, where cellular connectivity is fast outstripping the growth of fixed-line broadband, the type of connectivity afforded by mobile phones is far removed from the professional digital creation and consumption tools provided by some other contemporary computing technologies. Equally, bandwidth is hugely variable between and within nations, and this determines the types of engagement that are possible.

Digital divisions can only be understood within wider social contexts; alongside digital divisions between rich and poor across and within nation-states, there are corresponding health care divisions, education divisions, human rights divisions and labour rights divisions, all of which require attention if social justice is to be addressed. Consequently, the approach to digital technoculture outlined here not only explores ways that media systems affect those who are preferentially connected within the network society but also considers how this technocultural system affects either

those disconnected from the communicational outputs of the information revolution or those who have only minimal modes of connectivity. This connects media ecology to key insights that arise from the political economy of digital culture surrounding inequality and exploitation (Fuchs 2014). What emerges is a range of forms of exploitation, which often either echo or update the dynamics of colonialism.

Chapter outlines

This book is organized into two parts. 'Part 1: Theorising Media Ecologies' is composed of two chapters that provide the conceptual background for my reimagined approach to media ecology. Chapter 2 begins by exploring debates surrounding technology, media and agency. The central questions addressed here are who and what can act, and how do these agential capacities play out within digitally mediated systems. These questions are explored through the example of algorithmic financial trading and the Flash Crash of 2010, which becomes a point of departure for considering how concepts derived from cybernetics, complexity theory, self-organization and ecology provide a conception of agency based upon assemblages rather than individuals. The chapter concludes by following Sean Cubitt's suggestion that we reconsider our conceptualization of cybernetic organisms, viewing corporations and financial systems as cyborgian assemblages that situate human nodes within inhuman and destructive networks whose logic is centred upon short-term economic profitability.

Whereas Chapter 1 focuses upon questions of how agency manifests throughout technocultural systems, Chapter 2 explores the values associated with an ecological ethic and how this system may be mobilized as an ecological politics. Such an ethic departs from the anthropocentrism of deontology and consequentialism – the two major branches of Western ethics – instead foregrounding ethics as something which is enacted rather than merely theorized. A key part of the ethical model outlined here is derived from the works of Gregory Bateson and Felix Guattari surrounding the three entangled ecologies of mind, society and environment. The chapter also explores several concepts generated through Guattari's collaborations with Gilles Deleuze and contemporary works these concepts have inspired which explore commons-based production in peer-to-peer systems and ecological approaches to value.

The theoretical focus upon the logic of the AND, assemblages, scale and entanglement found in Part 1 informs the structure of Part 2, 'Ecologies of Content Code and Hardware', which is comprised of three chapters that in turn consider content, software and hardware as entangled sites of conflict within digital ecologies. Each of these chapters does not use the aperture afforded by a single, unifying case study, instead they construct assemblages

which employ numerous examples that work across scales. Doing so is designed to apply a logic of the AND that allows multiple converging and diverging lines of conflict, hierarchy and resistance to be drawn out and examined using the conceptual tools that are outlined within Part 1.

Chapter 3 examines flows of attention and information within the scale of content. This is approached by examining phenomena ranging from the attention economy and big data, through to particular responses on climate blogs to the Climategate scandal. What emerges from this material are questions surrounding how, why and if change occurs in response to activist endeavour within the framework of what Jodi Dean has termed 'communicative capitalism'. Critical insights taken from this chapter include ways that the reception of networked media departs from rational–critical approaches such as those associated with the public sphere, with meaning instead often deriving from a combination of affect, technicity, cognitive frames and economies of attention. The latter term is of particular pertinence in mapping some of the novel forms of hierarchy which come into being through the formations of networked digital media, which are of central importance in considering what types of activist intervention are likely to draw lines of flight towards other systemic configurations.

Chapter 4 focuses upon the ecology of software, exploring the discourses and approaches associated with software studies and free and open source software, before exploring a range of agential, ethical and political conflicts which arise through practices ranging from jailbreaking Apple's iOS devices and firmware hacking Canon EOS digital cameras, to digital rights management software, and the personalization algorithms used by search engines and social media. The two key themes which recur across these examples pertain to questions of control, openness and surveillance on the one hand, and on the other foreground elements of nonhuman agency within software, as evidenced by unplanned actions surrounding the behaviours of search engine crawlers and security issues surrounding bugs and exploits used to compromise, hack or otherwise alter computational systems.

In Chapter 5, I examine a range of issues surrounding the life cycle of digital hardware. The cases explored include the procurement of conflict minerals for microelectronics, the manufacture of devices in Chinese sweatshops, the carbon footprint of creating and powering the ever-expanding array of digital media hardware, and their end-of-life as highly toxic e-waste which is often manually treated by impoverished workers who unwittingly poison themselves and local ecosystems. At every juncture within this process, the chapter explores how various practices – which often involve the usage of the offending microelectronics devices themselves – are being applied to reduce the current impacts of these technologies. The chapter concludes by considering how cradle-to-cradle production and open source hardware may suggest radically different models for how we produce and consume hardware, alongside how these models are being reterritorialized.

Chapter 6 provides initially presents two cases which traverse the entangled scales of content, software and hardware, the mobile game *Phone Story* and the Open Source Ecology project, that draw together some of the key insights from the previous chapters. This is followed by some conclusions that addresses the novel forms of hierarchy and reterritorialization that have seen digital culture become synonymous with a handful of multibillion-dollar corporations, alongside how we may enact ecological praxis and a biopolitics of media in the Anthropocene.

Re-thinking media ecology in an increasingly pervasive, digital culture is important because it foregrounds the entanglements between two of the core challenges that technocultures face in the twenty-first century: the politics of technology and Anthropocenic ecological crises. Without concerted efforts, the near future will see catastrophic climate change accompanied by a vast reduction in biodiversity faced by a technoculture which erects walls and boundaries around economic elites while perpetuating systems of colonial, racial and economic privilege. Reformulating media ecology is a way of trying to think through these challenges, of finding ways of building commonwealth and democratically accountable public infrastructure rather than commodities, of addressing the toxic drive towards short-term profitability rather than ecological sustainability and resilience, and dramatically reducing inequalities and hierarchies rather than strengthening them.

PART ONE

Theorizing digital ecologies

1

Technology, complexity and agency

On 6 May 2010, the US equity market experienced an extreme and novel form of turbulence. Commonly known as the 'Flash Crash', around US$800 billion was wiped off the value of stocks between 2:32 and 2:45 p.m., with the vast majority of the fall taking place between 2:41 and 2:45. After trading in Standard and Poor (S&P) E-Mini futures was paused for 5 seconds, the market began to recover, with over two-thirds of losses being recovered by the close of the day. In the wake of this event, media coverage focused on speculation surrounding the role that computer-based trading played in the Flash Crash, how this new class of digital actor had demonstrated the ability to impact financial systems in unpredictable ways that could lead to catastrophic economic consequences.

In this chapter, I will use the events of the Flash Crash as a way of examining a range of questions surrounding technology, agency and complexity. The concept of agency addresses who and what can and does act, how these actions impact upon other entities, and how these agencies are distributed between individuals and collectives, humans and nonhumans. While agency has traditionally been invoked as a purely human and individual affair, it is approached here as a distributed capacity that can never solely be attributed to a single, isolated entity. Instead, agencies are understood as unstable, relational and multiple rather than as the expression of an individual's will. In order to formulate an ecological model of mediation and political action, addressing questions of how agency is distributed between human, organic and technical systems is a necessary pre-requisite; conceptualizing how to mobilize and enact change in response to ecological crises requires us to first consider how agencies coalesce, cascade and erupt within complex, nonlinear systems.

The chapter begins by outlining the key actors involved in the Flash Crash, and how their collective interactions shaped this event. This then leads to a discussion of several concepts and genealogies that can help us to create a map of how agency functions within complex, dynamical technocultural systems. This begins by thinking through the multiple legacies of cybernetics, which includes the tropes of information theory, feedback and nonlinearity. I then move on to discuss several interrelated system theories that have been influenced by cybernetics: autopoiesis, complexity theory, and Deleuze and Guattari's concepts of assemblages and abstract machines, all of which assist in refining an ecological model of agency. Finally, I conclude the chapter by employing discourses of cyborgs and posthumanism to consider the inhuman agencies and politics of computer-based trading.

Algorithmic trading

To grasp what happened in the Flash Crash of 2010, we must first become familiar with the main entities that were involved in the event. This means exploring several types of computer-based trading systems, alongside structural changes that have occurred within financial markets which enable computer-based trading. In particular, this section will explore algorithmic trading (AT) and high-frequency trading (HFT) systems as two different types of digital agents whose actions were central to both the onset and the subsequent trajectory of the Flash Crash. Electronic trading is a relatively new phenomenon, which in certain contexts has largely replaced human-to-human transactions, to the point where now over half of all trades on financial markets are executed by algorithms. Whereas financial trading may still conjure up images resembling the human-led pit trading depicted in films such as *The Wolf of Wall Street*, by 2010 this was no longer the major form of exchange within digitized and globalized financial systems.

Pathways towards electronic trading have not been smooth and continuous. The evolution of automated trading systems is episodic and discontinuous, with technological changes surrounding software and hardware being accompanied by structural pressures arising from both transnational financial markets and the specific local politics that surround futures exchanges. While there clearly would be no automated trading systems without computers, connectivity and code, a range of human agencies also played key roles in these events. For example, the formation of the Globex trading system – which in 1992 became the first fully electronic trading system, when it was introduced as part of the Chicago Mercantile Exchange (commonly known as the Merc) – was largely a response to the perceived threat of futures markets in London and Hong Kong that were open while trading pits were closed in the United States. Donald Mackenzie (2015: 660) documents how 'electronic trading shifted from being an

unimportant adjunct to the pit to becoming a replacement for it', with the introduction of the S&P E-Mini stock market index futures contract in 1997.[1] Shortly after its introduction, the new E-Mini began to outsell the pit-traded 'big' S&P contract, in part because the near-instantaneous electronic Globex system meant that the inherent delays of embodied open outcry pit trading could be avoided.

Electronic trading does not have an unproblematic history. A prominent early example of the destabilizing impact of electronic trading surrounds the severity of the 1987 market crash commonly known as 'Black Monday'. This event was partially attributed to portfolio insurance, an early form of electronic trading that was 'designed to protect individual investors from losses, but when used by many investors simultaneously … helped make the fall in prices a systemic event with a feedback loop' (Carlson 2007: 15). While this high-profile, high-impact case where electronic trading played a prominent role in a stock market crash dampened the enthusiasm for computer-based trading in the late twentieth century, subsequent increases in computational processing power accompanied by the introduction of more algorithmically complex forms of electronic trading subsequently led to computer-based trading performing the majority of trades on global markets.

The final report of the Foresight project, which was commissioned by the UK government following the Flash Crash to explore the future of computer-based trading in financial markets, argues that there are two fundamental classes of computer-based trading system in operation today. The first is AT systems that perform trades that would have been undertaken by humans in the past, and the second is HFT systems 'doing jobs that no human could ever hope to attempt' (Beddington et al. 2012: 33). HFT systems execute trades at speeds grossly exceeding those which human traders are capable of. They execute huge volumes of these trades, with each individual transaction only designed to produce a fraction of a cent in profit. Over time, however, the massive quantities of miniscule amounts add up to a significant source of revenue, while vastly increasing the overall volume of exchanges in financial markets. This expedited pace of exchange can be grasped through the fact that whereas in 1945 US stocks were held for an average of four years, by 2011 this had decreased to a mere 22 seconds (Toscano 2013). HFTs are designed not to build any significant portfolios of stocks, so most assets are traded moments after they are acquired, and portfolios are not held overnight. While proponents claim that under most circumstances HFTs

[1]Each E-Mini contract is valued at 50 times that of the S&P 500 stock index, as opposed to the original S&P futures contract that was valued at 500 times the index. The 'big' S&P contract was subsequently reduced to 250 times the value of the index due to the popularity of the E-Mini.

add liquidity to markets due to the increased volume of transactions, as we will see, there are also situations in which they have contributed to sudden shortages of liquidity and thus to the formation of Flash Crashes.

While HFT has been a central figure in press coverage and popular debates surrounding the Flash Crash, the Securities and Exchange Commission (SEC) report into the Flash Crash identifies an AT program as the instigating factor for the event (SEC 2010). At 2:32 p.m., a large trader initiated an automated execution algorithm designed to sell a total of 75,000 E-Mini contracts, one of the three largest single-day sell programs executed on the E-Mini within a twelve-month period. AT programs can be instructed to take price, time and volume as variables into account when completing the order, but in this specific case, the AT program was set to sell orders at a rate of 9 per cent of the volume of trades occurring over the previous minute without specifying price or time as additional variables.

As the AT program began to sell large numbers of E-Mini contracts, many were initially bought by HFTs; however, as HFTs are designed not to hold large numbers of contracts at any time, as they began to accumulate contracts in a declining market, at 2:41 HFTs began aggressively selling contracts. The large AT sell program's response to this increased volume of trades was to increase the rate at which it sold contracts, as the only variable it was using to govern its activity was the volume of transactions, thereby adding further pressure to the market which had seen orders on the buy-side fall to less than 1 per cent of that morning's level (SEC 2010: 3). This caused a liquidity crisis, and consequently, AT systems that had been instructed to buy or sell particular stocks without price variables in some cases executed trades at irrational prices of either 1 cent or $100,000, 'stub quotes', or placeholders that are never intended to actually be traded. At 2:45:28 p.m., E-Mini trading was paused for 5 seconds by the Merc to prevent a further cascade of declining prices and irrational trades. This brief break in trading allowed the sell-side pressure to relieve, and when trading resumed prices stabilized and then recovered.

What does this event tell us about the relationships between technology, agency and complexity? On the one hand, the Flash Crash confronts us with the scope of particular forms of nonhuman agency within the ecology of partially automated, digital financial trading. The AT and HFT systems provide definite advantages in terms of speed when contrasted to human traders and that temporal advantage entails that in a competitive marketplace there is a strong rationale for replacing human traders with automated systems. Indeed, when it comes to HFT, we see strategies that would be impossible for humans to execute being highly profitable. However, these nonhuman decision-making entities also have the potential to behave in unpredictable ways that can amplify the impacts of crises and crashes, generating systemic instabilities which are highly undesirable. Furthermore, some of these behaviours, such as buying stub quotes at $100,000 each, the

highest price that can be listed, are forms of irrationality that would almost certainly not occur with human traders.

Within the internal logic of financial markets though, these unwanted impacts are insufficient for investment banks, hedge funds and other trading entities to consider jettisoning computer-based trading; this would leave these actors at a competitive disadvantage. The broader system therefore has a structural role in determining the agencies of individual trading entities, and while periodic instability may be unwelcome, the advantage of trading at the speeds of networked computational systems rather than those at which human bodies and communication acts function is perversely understood to outweigh these systemic risks. As Foresight conclude, a consequence of exchanges being conducted at speeds which outcompete human traders and prevent human oversight in real time from removing structural risk is that 'computer based (and therefore mechanical) trading is almost obligatory, with all of the system-wide uncertainties that this gives rise to' (Zigrand, Cliff and Hendershott 2011: 9).

Moving beyond this general understanding that computer-based trading has some form of agential capacity within contemporary financial markets, and that this both increases profitability and systemic risk, requires exploring how nonlinear systems function in some depth. We have seen that during the Flash Crash, HFTs created a feedback loop which amplified the risks and issues that emanated from the large AT sell program. In order to map these issues surrounding nonlinearity, technology and agency, I next turn to the history of understanding processes of control and feedback whose genealogy can be traced to the formation of the interdisciplinary field of cybernetics in the mid-twentieth century, before examining how processes of feedback and homeostasis that emerged in cybernetics have subsequently been reformulated within complexity theory, systems biology and ecology. Engaging with these theoretical and historical accounts allows us a more detailed and nuanced way of grasping how relational and distributed agencies flow through open systems, which not only are key to comprehending the specific case of computer-based trading but are pervasive within digital media ecologies.

Nonlinear agencies

Cybernetics emerged as a field of academic inquiry during the 1940s and 1950s from the collaboration of a transdisciplinary group of academics including Norbert Wiener, Warren Weaver, Gregory Bateson, John von Neumann and Margaret Mead. The term 'cybernetics' was coined by Wiener (1948) in *Cybernetics: Or Control and Communication in the Animal and the Machine*, and as the title denotes, cybernetics aimed to explore mechanisms of control and communication alongside organizational and configurative

patterns common to living and nonliving systems. From its inception then, cybernetics muddies the distinction between living and nonliving systems (George 1977: 2). In addition to examining biological and technical entities, cyberneticists recognized that 'it is certainly true that the social system is an organization like the individual, that it is bound in a system of communication, and that it has dynamics in which circular processes of feedback play an important part' (Wiener 1948: 24), additionally blurring the boundaries between individuals and collectives.

The histories and legacies of cybernetics are not only relevant in terms of their demarcation of feedback and nonlinear dynamics though; the branch of cybernetics associated with Claude Shannon and Warren Weaver's information theory, and Jon von Neumann's work around digital computers are pivotal to the technological genealogies that manifest today as pervasive networks of digital devices. Equally, as we will see later, the paradigm of control and communication has been advocated as the fundamental logic or diagram that defines contemporary societies, for example, in Deleuze's work surrounding societies of control. Conversely, later strands of systems theories that pay a genealogical debt to cybernetics include systems biology, complexity theory and Earth Systems theory, which are key fields for science-led comprehensions of the Anthropocene. As a consequence of cybernetics' influences upon contemporary discourses of technology, control and ecology – the central themes of this book – it is useful to recount various strands of cybernetic praxis in order to elucidate how they came to be so influential, in addition to contrasting the models of agency that arise from these differentiated and often contradictory models.

Cybernetics effectively formed as a discipline from a series of conferences held in the United States between 1946 and 1953, commonly referred to as the Macy conferences, that were formally titled 'Feedback Mechanisms and Circular Causal Systems in Biological and Social Systems'. Feedback loops occur when elements are causally connected so that an initial causal factor circulates around the system, so that effects feed back to the start of the loop. Whereas in a linear chain of causality A effects B which effects C which effects D, in a system with circular causality (feedback) A effects B which effects C which effects A. Wiener uses the example of a man steering a boat as an example of a feedback-based system; the steersman's job is to visually assess any deviation from the desired course and compensate by moving the ship's rudder to counter-steer. This may even overcompensate, in which case the steersman reassesses the situation and alters direction. As such, the steersman navigates through a process of continuous feedback. Indeed, the term cybernetics originates from the Greek word *kybernetes*, meaning steersman, as cybernetics studies processes of control or steersmanship.

Early cybernetics research explored a diverse array of feedback-based systems: biological systems, such as human coordination in walking or picking up cigarettes; mechanical systems, such as the thermostat and the

governor of a steam engine; and systems which link living and nonliving components such as the steersman. In all of these examples, 'the feedback tends to oppose what the system is already doing, and thus is negative' (Wiener 1948: 111). Negative feedback is self-corrective or homeostatic; feedback counteracts systemic perturbations. Positive feedback, by contrast, involves feedback which reinforces change, leading to vast alterations given only minute changes to inputs, as difference becomes iteratively magnified. Although cyberneticists discovered the equations governing positive feedbacks, they were largely conceptualized as undesirable noise which led to systems rapidly becoming unpredictable. Consequently, positive feedbacks were neglected by cybernetics research, which was characterized by minimizing noise while explicating processes of homeostatic balance. Later, however, positive feedback was found to be crucial within systems biology, complexity theory and self-organization. Indeed, the behaviour of AT and HFT in iteratively amplifying structural risks in financial markets are an example of a positive feedback.

Feedback loops denote configurative relationships that are found within systems ranging from biology, to social structures, to machines. The circular nature of feedback loops is not a physical structure but a nonlinear pattern of causality which is found across heterogeneous biological, technological and physical structures. This circular causal process is key to grasping the nonlinear dynamics that occur across open systems ranging from algorithmic financial trading and trending social media content to climate change and ecosystem population dynamics. It is important to grasp that linearity in this formulation departs from how the term is usually employed within media studies. In the fields of mathematics, cybernetics, nonlinear dynamics and complexity theory, the term 'nonlinear' demarcates an equation or function pertaining to a system, whereby changes in output are not proportional to changes to inputs. Whereas within a linear system, a small increase in input will lead to a small increase in output, within a nonlinear system, a small increase in input may result in no difference or exponential change.

This definition of nonlinearity, which is inexorably related to processes of feedback, diverges from how it is typically employed within media studies, whereby linearity refers to a unidirectional flow of information (Rosenberg 1994). Thus defined, linear forms of media include audio cassettes or television programmes, where media can only be accessed as a single predefined temporal flow, through a single interface. Nonlinear material, by contrast, can be accessed in numerous ways, often through various interfaces. The importance of introducing the notion of nonlinearity used in cybernetics is that if we are interested in mapping the entanglements of digital technocultural systems, then we must have a grasp of the fundamental mechanisms and processes through which complex, dynamical entities act.

Feedback and nonlinearity relate to agency through the way that these concepts decouple media ecology from any positivist or physicalist notion

of simply being able to add together factors to accurately map a complex system. Exploring nonlinear agencies within flows of symbols, electrons, images, voltages and sound waves found in media ecosystems entails not merely examining difference but differences that make a difference (Bateson 1972: 487), interventions that are able to substantively alter the trajectory of systems. Within digital culture we encounter the notion of content going viral; escaping the long tail of social media platforms such as YouTube and Twitter through being picked up by those platforms' trending algorithms which form a positive feedback loop, creating more views, more likes and more shares which result in further attention for that material. Understanding feedback and nonlinearity is crucial to comprehending how social media newsfeeds, search engine rankings and other digital algorithms affect the types and forms of content people encounter.

The history of cybernetics involves multiple interwoven lineages of thought that run across some of the disciplinary and political fault lines that characterized the formation of the discipline at the Macy conferences. One prominent way of categorizing cybernetic thought has been the separation of first- and second-order cybernetics. In this schema, first-order cybernetics is associated with Wiener, von Neumann and the Shannon/Weaver model of information theory, which sought to reduce questions of communication to mathematical problems of transmitting accurate information through a noisy channel. Furthermore, first-order cybernetics is associated with a tendency towards dematerialization through the abstraction of informational patterns from material structures, and so allegedly 'holds onto humanist and idealist dualisms that describe the world in terms of an equivocal dialectics of matter and form, of substance and pattern, in which the immaterial wrests agency away from the embodied' (Clarke and Hansen 2009: 4).

These claims are particularly associated with Wiener's (1989: 103/104) suggestion in *The Human Use of Human Beings*:

> The fact that we cannot telegraph the pattern of a man from one place to another seems to be due to technical difficulties, and in particular, to the difficulty of keeping an organism in being during such a radical reconstruction. The idea itself is highly plausible. As for the problem of the radical reconstruction of the living organism, it would be hard to find any such reconstruction much more radical than that of a butterfly during its period as a pupa.

Wiener's focus on the transference of an informational pattern is problematic, especially with regard to its proximity to vernacular transhumanist discourses that suggest we will soon be able to upload the human mind into digital neural networks, thereby falling prey to the seduction of an immaterialist digital immortality (Hayles 1999).

We should, however, remind ourselves that digital computation affords the apparent transference of the informational pattern of multiple media formats – books, music, film, photographs and so on – into the universal language of binary code. While this transformation is not the complete substitution of one entity for another, as the specific media in question have differing material affordances, such as the compression artefacts in digital imaging or the different modes of temporal degradation that occur with deteriorating celluloid and bitrot, the informational encounter between a human user and Pink Floyd record or the same song as an FLAC file has clear parallels in terms of informational content, even if they are not congruent. Similarly, the use of genetically modified agrobacterium to modify the DNA of plants is an example of transferring informational patterns between living entities. This process is again far from immaterial, depending on advanced scientific knowledge, tools and processes allied with the specific materiality of the agrobacterium, which transfers DNA from itself to the plant. In both cases then, the material properties, whether of silicon, digital storage and compression algorithms, or agrobacterium, DNA and plants are key to grasping these informational transferences.

Using Wiener's own example, the material transformation from caterpillar into butterfly requires the larval form to release enzymes that digest all its tissues, excepting the imaginal discs that use the resulting protein-rich soup to fuel the process of metamorphosis. Despite this near-total process of bodily dissolution and reformation, evidence exists that memories from the experience of the caterpillar can be recalled by adult moths and butterflies (Blackiston, Casey and Weiss 2008), further demonstrating how informational patterning can under certain material conditions be transferred. While these examples are far removed from the hypothetical notion of transferring human consciousness into or through machines, they do at the very least sketch the embodied material basis for thinking seriously about the transference of informational patterns across biological and technical systems. In each case, however, there are key questions surrounding the specific material processes of mediation which afford these transferences, rather than a mystical process of dematerialization.

Second-order cybernetics, sometimes referred to as the cybernetics of cybernetics – which was the title of a book chapter by Margaret Mead (1968) and a collection edited by Heinz von Foerster (1974) – is widely understood to be centrally concerned with the recursive and reflexive interactions between systems and environments, drawing on the work of Gregory Bateson, Humberto Maturana and Francisco Varela alongside Mead and von Foerster. One of the key concepts associated with second-order cybernetics is that of autopoiesis, or self-making, which Maturana and Varela (1980) posit as key to grasping how biological organisms are operationally closed but thermodynamically open systems. Viewed this way, life is composed of bounded entities that maintain their structure at points

balanced away from equilibrium, and this process of self-making necessarily requires these structurally closed entities to be open to transferences of energy, primarily those associated with ingesting food, drinking water or photosynthesizing sunlight.

While there are numerous differences between the writings of Wiener and Shannon in the 1940s and 1950s, and those of Maturana and Varela in the 1970s and 1980s, the apparent schism between first- and second-order cybernetics is more complex and nuanced than this reductive binary would suggest. Key authors associated with second-order cybernetics, such as Bateson, Mead and von Foerster were all present at the Macy conferences, indeed, von Foerster was the editor of transactions of the Macy conferences from 1949 to 1955. Bateson and Mead have argued that the fundamental split was not between first- and second-order cybernetics but between the engineers, typified by Weaver and Shannon, and the general systems group, in which they ally themselves with Wiener (Brand, Bateson and Mead 1976). As shown in Figure 1.1 Bateson's sketch foregrounds the difference as being that the systems group includes the observer (Winer, Bateson and Mead) within the model, foregrounding the reflexive, feedback-led process through which the observer engages with the phenomenon being observed, denoting that the reflexivity and role of the observer that is frequently attributed to second-order cybernetics was also present within the heterogeneous tradition of first-order cybernetics.

Additionally, there were important political differences between the engineers and systems theory groups within first-order cybernetics, which

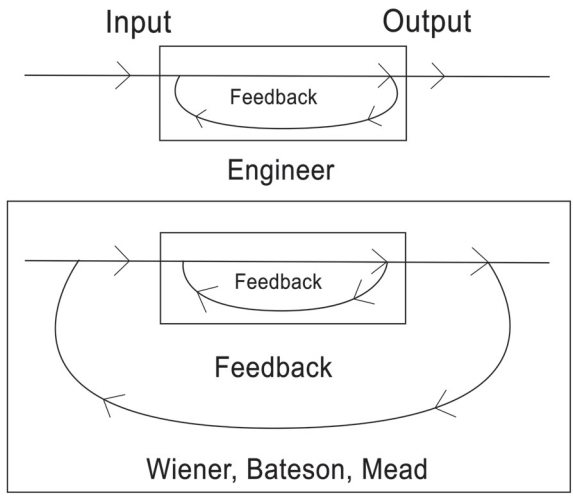

FIGURE 1.1 *Bateson's cybernetic models.*

are elided through a first-/second-order opposition. The engineers were closely associated with military research and development; indeed, von Neumann was a principal member of the Manhattan project and a key proponent of the implosion-type nuclear weapons used during the Second World War. He was also a member of the target selection committee which decided that Hiroshima and Nagasaki would be targeted by nuclear weapons. Conversely, while Wiener worked on anti-aircraft tracking weapons during the Second World War, by the 1950s he was strongly opposed to accepting military-linked work, arguing that following the use of nuclear weapons against urban populations, 'it is clear that to provide scientific information is not a necessarily innocent act and may entail the gravest consequences' (Wiener 1989: XXVII). In *The Human Use of Human Beings*, Wiener's position approaches the cybernetic eco-philosophy of Bateson (which will be explored in detail in the next chapter), arguing that the pace of ecological transformation associated with industrial societies which appears as increased human control over nature simultaneously involves an enhanced dependence upon the finite resources of the planet:

> The more we get out of the world the less we leave, and in the long run we shall have to pay our debts at a time that may be very inconvenient for our own survival. … We have modified our environment so radically that we must now modify ourselves in order to exist in this new environment. We can no longer live in the old one. Progress imposes not only new possibilities for the future but new restrictions. (1989: 46)

Given this outlook, it is hard to square Wiener's politics with the claims levelled by critics such as N. Katherine Hayles (1999) that first-order cybernetics homogeneously turns machines into people and people into machines, a process that effectively empowers the subjugation and domination of de-humanized people. This position would not, however, be an unfair characterization of the politics of von Neumann.

As is often the case, the either/or first/second opposition turns out to be a rather reductive and misleading way of approaching the differences between the various traditions and texts associated with cybernetics. Second-order cybernetics is perhaps better understood as the continuation and refinement of the systems theory strand's interest in reflexivity and observation than an epistemic break with first-order cybernetics, as has been claimed in recent texts that have sought to characterize a fundamental schism between the 'bad', first-order cybernetics of dematerialization and the 'good' second-order cybernetics of reflexive embodiment. That said, the concept of autopoiesis and its delineation of coupling between systems that are organizationally closed but thermodynamically open and their environments does represent an important shift away from the model of distributed cognition that Bateson

proposes, where the organism-in-environment forms a single cognitive circuit, entailing that the lines between the organism and its environment are fictitious, a lie that the ego tells the organism:

> Let us consider for a moment the question of whether a computer thinks. I would state that it does not. What thinks and engages in trial and error is the man plus the computer plus the environment. And the lines between man, computer and environment are purely artificial, fictitious lines. They are lines across the pathways along which information or difference is transmitted. They are not boundaries of the thinking system. What thinks is the total system which engages in trial and error, which is man plus environment. (Bateson 1972: 491)

In this formulation, it is not the human actants which provide agency, but their concrete relational situation within material networks. Agency is not innate but is an emergent property arising from complex interactions within assemblages which encompass human and nonhuman elements. When we apply this to media systems, we end up with a model of agency which contends that technologies have agential capacities, but these are not congruent to those exercised by human actors.

For Maturana and Varela on the other hand, cognition is dependent upon an organism's embodied observations of an environment which 'may be carried out only on the basis of self-referential closure, but that closure, because it produces both environmental complexity and semantic overburdening, produces more possibilities for connection, more openness' (Wolfe 2010: 114). This interplay between organizational closure and entropic openness within bounded autonomous biological systems, and between the cognitive biological entity and the environment it senses and observes in response to the need for sustenance, leads to an embodied or enactivist model of cognition whereby living systems do not simply access the world to construct an accurate depiction of it, they 'enact a world' (Stewart et al. 2010), actively constructing and bringing forth a world through a perspective generated via their interactions with the environment. Consequently, within autopoiesis we have a coupling between system – the bounded biological organism – and environment – everything outside of that system's boundaries – which marks a fundamental difference from Bateson's single cognitive circuit.

Correspondingly, there are significant differences in the construction of agency between Bateson's cybernetic epistemology and Varela's autopoiesis. Whereas for Bateson agency is a relational property that exists distributed across the total system, autopoiesis suggests that we can only discuss the presence of a teleological agent as 'a self-constructed unity that engages the world by actively regulating its exchanges with it for adaptive purposes that are meant to serve its continued viability' (Di Paolo 2005: 443).

While the exchange between system and environment is still key to this agential formulation, and the model of autopoietic agency does extend agency beyond the human to other biological organisms, the limitation of agency to purposive behaviours conducted by self-constructed unities appears deeply problematic when applied to technocultural systems such as AT and HFT algorithms. While these technical agents do act in a purposeful way, they do not meet the test for autopoietic systems as defined by Varela, who argued against the transposition of the concept to technical and social systems, bluntly stating, 'I am absolutely against all extensions of autopoiesis, and also against the move to think society according to models of emergence' (quoted in Protevi 2009). Consequently, despite the issues present in Bateson's total circuit that does not distinguish between organism and environment, the model of distributed agency he posits avoids the reduction of agency to biological entities that we find in autopoietic accounts.

Recently, Donna Haraway's (2016) critique of the Anthropocene has substantively engaged with theories of autopoiesis, suggesting that the focus on autonomous organisms coupled to environments can be read as part of a misplaced focus upon individual autonomy that she characterizes as pervasive within Anthropocenic and Anthropocentric approaches where competitive individualism tends to dominate narratives of agency. Alongside autopoiesis, Haraway posits the concept of sympoiesis, of making-together, drawing upon Lynne Margulis's (1993) work on symbiogenesis which demonstrates that the origins of complex multicellular life involved the symbiosis of multiple organisms. For Haraway (2016: 61), autopoiesis and sympoiesis are not an opposition, but foreground different elements of how biological systems function as a generative enfolding. This focus upon multispecies becomings, sympoiesis and symbiogenesis stands as an important corrective to the individual cognitive entities found in autopoietic discourse.

Multispecies becoming does not mean returning to the undifferentiated cognitive totality posited by Bateson, but it does productively undermine the notions of closure and autonomy found in autopoietic accounts. As the anthropologist Anna Tsing argues with reference to the sympoietic multispecies assemblage of pine wilt nematodes, sawyer beetles and trees, organisms must immerse themselves in webs of coordination that exceed the autonomous cognitive spheres of autopoiesis. Addressing individual biological actors as bounded cognitive entities necessarily fails to recognize the inherent entanglement of collectives. For Tsing (2015: 157), 'if we want to know what makes places liveable we should be studying polyphonic assemblages, gatherings of ways of being. Assemblages are performances of liveability'. I next turn to Deleuze and Guattari's highly influential concept of assemblages in order to further address questions of emergence and agency in complex systems.

Assemblages

Assemblages are a way of describing the process by which collective entities of humans, nonhuman biological organisms and nonliving actors (such as technologies) are composed. As such, assemblages destabilize the boundaries that have traditionally been drawn between humans, technology and 'nature', instead forming what Deleuze and Guattari describe as the machinic phylum, a single lineage that combines these three classes of entity. According to Manuel DeLanda (2016: 1) the term 'assemblage's' translation from the French word *agencement* loses the duality of meaning through which the original term describes both the resulting collective entity and the constitutive process of assembling, of bringing the heterogeneous components together.

This process of assembling presents a useful way of thinking beyond systems as either holistic totalities, as we saw in Bateson's cybernetic epistemology, or in terms of autopoietic individuals.

> What is an assemblage? It is a multiplicity which is made up of many heterogeneous terms and which establishes liaisons, relations, between them, across ages, sexes and reigns – different natures. Thus the assemblage's only unity is that of a co-functioning: it is a symbiosis, a 'sympathy'. It is never filiations which are important, but alliances, alloys; these are not successions, lines of descent, but contagions, epidemics, the wind. (Deleuze and Parnet 2006: 52)

Unlike the process of autopoiesis in which bounded entities make themselves and produce offspring, thinking in terms of assemblages asks us to consider collectives as emergent sympoietic systems, as contagions, as epidemics, as dynamic, mutable flows of becoming-together rather than discrete, sculpted and solidified individuals. Thinking in terms of assemblages means going beyond isolated objects-in-themselves, instead studying the configurative relationships between entities. Homologous to Karen Barad's theorization of entanglement, the basic unit of existence in this schema is not an isolated subatomic particle but relational phenomena. Things do not exist alone, or as connected individuals, but as entangled, intra-active assemblages.[2]

This position is held in contradistinction to physicalism, the dominant metaphysical framework of classical physics, which contends that all knowledge proceeds from the laws which govern subatomic particles, that complex structures can be deconstructed into smaller systems which

[2]Barad suggests the term 'intra-active', rather than the more commonly employed 'interactive', as the latter suggests a coming together between two pre-formed, stable entities. Intra-action then designates the formative nature of the encounter and the dynamism of things.

maintain all the information necessary to analyse larger structures. Within physicalism, causality is always attributed to the micro-level and can be traced upwards as a linear set of determining forces. By isolating and studying parts of systems, a great volume of information can be gleaned, and this methodology has produced the majority of technological and scientific advances that have shaped contemporary societies. Despite these successes, however, during the twentieth century, scientists encountered numerous phenomena where micro-causality fails to provide an adequate description of events, as by isolating and analysing phenomena, physicalism divorces them from the context in which they occur, the way that the components of assemblages collectively produce emergent properties.

We can understand emergence as situations whereby the system as a whole demonstrates qualities that are more than the sum of its constituent parts. Consider the case of the relative stability of species' populations within an ecosystem as an example of emergence: while each population can grow exponentially, within the framework of the ecosystem the agglomeration of species exhibits a state of dynamic balance through various feedback loops such as symbiotic and predator/prey relationships. The relative stability of an ecosystem, which is necessary for the survival of species within it, is an emergent property where the feedback structures do not belong to any individual species but to the community as a whole. Similarly, we can consider emergence within board games such as chess. We cannot merely add together the number of individual pieces in play to comprehend which player holds an advantage; the value of the pieces depends on their relations to one another. One player may have several extra pieces, but this is irrelevant if his opponent has an imminent checkmate. The emergent game state therefore not only depends upon the internal properties of the pieces but additionally requires an assessment of how they are connected to one another, what we can understand as their capacities or affordances. We can understand emergent properties, then, as being dependent upon the specific interacting entities, but being irreducible to those entities in isolation. Alongside its internal proprieties, each individual entity possesses a range of capacities or affordances, properties that are only realized through connections to other entities and whose realization depends upon the specificities of the entities and their intra-actions.

Emergence precludes the formation of unifying and transcendental laws, instead requiring detailed analysis of the specific relations between systems' constituent parts at various scales to account for behaviours. Emergence, then, provides a framework which rejects dualism and essentialism, but avoids the reductionism evident in physicalist accounts. The potential pitfall of an emergentist approach, however, is that while it removes atomistic (micro-level) reductionism, it can lead to holistic (macro-level) reductionisms whereby systems are posited as fully determining their constituent parts. Within numerous disciplines, analytical methodologies

have been predicated upon precisely this mode of macro/micro dualism: micro-/macroeconomics, political economy/reception studies within media studies, global/local concerns within geography or structure/agency debates within sociology. In order to escape this dualistic ontology, the concept of assemblages proves useful.

Assemblages are entities formed by historical (evolutionary) processes whereby a heterogeneous array of elements is combined with individual entities. The activities and capacities of the assemblage are, however, not fully determined by either the properties of the parts (micro-reductionism) or the totality of the assemblage (macro-reductionism). Instead, the emergent properties of the assemblage are a consequence of the relational capacities of the parts, potential states which exist but are not actualized until parts enter into relation with other parts. Consequently, thinking in terms of assemblages allows us to conceptualize emergence in terms of the material interactions between relational capacities, rather than as a problematic form of holism:

> Unlike wholes in which 'being part of the whole' is a defining characteristic of the parts, that is, wholes in which the parts cannot subsist independently of the relations they have with each other (relations of interiority) we need to conceive of emergent wholes in which the parts can retain a relative autonomy, so they can be detached from one whole and plugged into another one. (DeLanda 2010: 3–4)

Consequently, thinking in terms of assemblages does not present holistic totalities but posits a series of nested systems whereby the parts of particular assemblages are themselves assemblages of parts that exist as smaller scales.

Consider the man-horse-stirrup assemblage that Deleuze and Guattari employ as an exemplar; this entity brings forth new forms of activity through the way that the technical part allows the mounted rider lateral stability, allowing the human to hold weapons differently (such as tucking a lance under one arm), thereby altering military strategies, battlefield outcomes and subsequent regimes of territorial governance. Here we begin to envision how assemblages exert causal forces 'upwards' upon larger assemblages. Simultaneously though, we can conceive of each part as itself being an assemblage; while humans commonly think of themselves as single, bounded wholes, research into the sympoietic human assemblage argues:

> The microbes that live inside and on us (the microbiota) outnumber our somatic and germ cells by an estimated 10-fold. The collective genomes of our microbial symbionts (the microbiome) provide us with traits we have not had to evolve on our own. If we consider ourselves to be a composite of microbial and human species, our genetic landscape a summation of the genes embedded in our human genome and microbiome, and our

> metabolic features a coalescence of human and microbial traits, the self-portrait that emerges is one of a 'human supraorganism'. (Turnbaugh et al. 2007: 804)

The human, then, is an emergent multiplicity rather than a singular whole. Just as assemblages exert determining pressures upwards towards larger collectives, they exert pressures 'downwards' on their constituent parts. For example, the human-fire-meat assemblage altered the physiological make-up of humans by externalizing the work of digestion and chewing, allowing the human's digestive system to become substantively smaller than similar-sized primates (Pollan 2013). Assemblages therefore exert causal pressures both upwards and downwards, existing in the middle and moving outwards, rather than macro/micro dualisms that move from the top down or bottom up.

I propose that the field of ecology and Haraway's more recent work surrounding sympoiesis begin to provide us with a language which explores the differential forms of coupling between the various entities that form technocultural assemblages. Perhaps the best-known relationships are the two oppositional forms: predator/prey and competition between species. Alongside these, however, there exist four modes of symbiotic relationship. These are parasitism, which denotes a relationship in which one entity – the parasite – receives benefits to the detriment of the host; commensalism, an association where one party – the commensal – receives benefits while the other entity remains unaffected; amensalism, whereby one organism negatively impacts another while receiving no tangible benefit; and mutualism, a phenomenon by which distinct species interact in ways which provide benefit to both species.

> Mutualisms have often been neglected in the past compared to other types of interaction, yet mutualists compose most of the world's biomass. Almost all of the plants that dominate grasslands, heaths and forests have roots that have an intimate mutualistic association with fungi. Most corals depend on the unicellular algae within their cells, many flowering plants need their insect pollinators and many animals carry communities of micro-organisms within their guts that they require for effective digestion. (Begon, Townsend and Harper 2006: 381/382)

The preponderance of mutualistic relationships reveals that far from being composed of individual species competing against each other in oppositional relationships – as implicit in the widely encountered dogma that depicts life as the survival of the fittest – ecosystems are comprised of assemblages of species which co-evolve, depending upon others for their continued survival and proliferation. Fitness, understood in this manner is not the social Darwinist construct of individual autonomy that draws upon

highly anthropomorphic notions of fitness as strength, a place from which to exercise power over the weak, but instead denotes the ability of organisms to adaptively situate themselves within an evolutionary ecological context, their ability to 'fit' into a particular niche.

Consequently, a micro-reductionism which seeks to isolate species from their ecological community ignores vital aspects of evolutionary survival strategies, including co-evolved features of other organisms. This is a crucial point for an ecological model of agency as it gestures towards mapping the confluence of agencies which flow through multi-scalar assemblages, rather than designating that agency exists within any particular node, human or otherwise. From this perspective, we are misled by consciousness to consider individual humans as singular, complete, wholes. By means of illustrating this point, we should recall that like all vertebrate forms of life, the human gastrointestinal tract contains a community of mutualistic microbiota, without which the host human would be unable to convert energy from food. Like other backbone-bearing organisms, humans are dynamic assemblages composed of many forms of life. Dissolving the subject into an assemblage in this way de-centres social constructivist approaches, instead positing agency as a distributed property.

Although conscious agencies may play dominant roles in certain circumstances, they are always constrained: an imbalance in the microbiota in your guts or a proliferation of the influenza virus within your body exerts limits and pressures to the types of behaviour that your body can perform, the affective capacities it can actualize at any given moment. It is also vital to emphasize that the boundary of the skin is not the boundary of the assemblage. Technologies are, as McLuhan correctly asserted, crucial sites for how pace, scale and pattern are constructed through a process of extension, although there never was the stable pre-technical and sensorially harmonious human that McLuhan's thesis of extension is built upon. With specific reference to digital media ecologies, there exist a range of technological agencies that invite, permit, afford, constrain, suggest or otherwise impact the potential capacities of individual and collective actions.

Approaching agency in this way presents a departure from the neo-Kantian version of agency that is attributable to the intentional or purposive activity of humans, and its structural counterpart within macro/micro sociological accounts. While structures are not understood to be entirely passive, their role is limited to functioning as constraints upon the active intentional behaviours that are construed as the sole preserve of the human. In contrast to this dualistic model of anthropocentric exceptionalism, the agential model of assemblages suggests that humans and nonhumans 'have always performed an intricate dance with one another. There never was a time when human agency was anything other than an interfolding network of human and inhumanity' (Bennett 2010: 31). In the contemporary conjuncture where we are surrounded by an ever-

expanding array of networked digital technologies, on the one hand, and a growing realization that this technocultural arrangement has catastrophic consequences for a broad range of biological and ecological systems, on the other, the entanglement between humans and nonhumans has become increasingly difficult to dismiss.

As we saw in the introduction, the increasing mediatization of everyday life entails that today we find that increasing volumes of our 'selves' – such as our abilities to access 'our' memories, to contact others, traverse spaces or access information – are mediated through digital assemblages of hardware, code and content. In this situation, our ability to connect to, communicate with and perceive the world around us changes in multiple ways which often bring tangible benefits in terms of speed and convenience, but at the same time mean that our distributed and externalized cognitive system is opened up to new forces associated with loss or damage to those geographically distributed technological memory supports. Furthermore, the commodified nature of mobile computational systems entails that these mnemotechnical transductions of ourselves involve a dependence upon systems that the philosopher Bernard Stiegler describes as the industrialization of cognition, as pivotal parts of the assemblages identified as our selves are now owned by profit-driven corporations who employ this data to predict and influence our future behaviours. By exploring the ways that digital assemblages augment and alter our abilities and modes of perception, communication and organization, this book seeks to both foreground these concerns and consider how we might take actions to re-organize the distributed and networked assemblages of digital technoculture.

Returning to the Flash Crash through the conceptual prism of assemblages, we are confronted by a multi-scalar ecosystem that has been historically individuated through the singular development of the Chicago Mercantile Exchange, Globex, Standard and Poors and the E-Mini among other agents. The assemblage of futures trading markets includes a vast array of active components that includes algorithmic and human traders, real-time databases, networked digital computers, specific buildings and places, stocks, shares, hedge funds, investment banks, pit-traders and other financial actors. Smaller assemblages, such as specific HFT programs are composed of code, digital storage, processors and memory alongside the fibre-optic and microwave networks that allow them to connect to other entities. What we find is not a systemic totality, an autopoietic system and environment, or active humans paired with structural constraints, but a swarm of distributed agencies whose flows traverse the assemblages which collectively comprise contemporary financial systems. While the capacities of HFTs to operate at beyond-human speeds are often misunderstood for a kind of dematerialization that resonates with certain rhetoric associated with early cybernetics, media ecology emphasizes the multi-scalar materiality of

these assemblages and the ways that this materiality affects the capacities and behaviours of the system.

The transmission of electronic data through fibre-optic cables at close to the speed of light has led to mistaken claims that barriers surrounding time and space have effectively been removed from communicative exchange, that contemporary digital communications are instantaneous (Virilio 1995). Although this may be the way that this appears from the standpoint of embodied human perception, where reaction times to visual stimuli are approximately 200 milliseconds, this is absolutely not the case for computerized financial markets and AT systems, which are able to react in less than a single millisecond. While the time it takes data to travel at the speed of light through optical fibres is incredibly brief, it still takes time; at light speed, moving from the Merc in Chicago to the Nasdaq matching engines in New Jersey would take 4 milliseconds. Consequently, for the owners of algorithmic trading systems, and particularly for HFTs, being located as close as possible to the exchanges where they operate is paramount to reduce these temporal delays, with co-location (placement inside the same building) being the preferred solution. However, electronic trading entities operate across multiple exchanges, and certain forms of HFT exploit the time differences between these venues:

> Because Chicago is the traditional primary site of derivatives trading, and New York of share trading, the fibre-optic links between Illinois (originally Chicago, but now also Aurora) and New York/northern New Jersey are the US system's 'spinal cord'. Until August 2010, the best one-way transmission time available on those links was around eight milliseconds. However, high-frequency trader Daniel Spivey persuaded venture capitalist James Barksdale to fund the creation of a new cable, which unlike the old routes (which largely follow railway lines) is as direct as possible. The project conducted largely in secret cost around $300 million. To speed construction, 125 teams worked in parallel, in places even creating what are essentially little tunnels through the rock of the Allegheny Mountains. The resultant link runs from downtown Chicago (the South Loop) to New York and to the site of the southernmost of the New Jersey matching engines, Carteret. Leasing 'dark fibre' in the cable (i.e. fibre for one's own private use) shaves around 1.3 milliseconds off the previously fastest one-way time, and this enables the link's owner, Spread Networks, to charge fees reported to be as much as ten times higher than those of older routes. (Mackenzie et al. 2012: 287)

Contrary to claims of digital instantaneity, we see that place and time delays are still hugely important within financial assemblages. Indeed, today HFTs are typically transmitted across land through the air via microwave networks that are able to exceed the speed of fibre-optic connections. For example,

private microwave networks operating between Chicago and New York reduced latency by around 5 milliseconds (Zook and Grote 2017: 128). While speeds have increased to the point that humans cannot intervene and regulate actions in real time, the micro-temporal delays experienced at light speed are absolutely central to decisions surrounding the construction of digital infrastructure. In Chapter 6, I explore the ecological and social consequences that arise from this infrastructural activity, further rebuking claims surrounding the immateriality or dematerialization of digital ecologies while arguing that we must pay close attention to the social and environmental harms associated with digital technologies if we are to produce more equitable and resilient technocultural systems.

The model of dynamic and distributed agencies that emerge across, within and between assemblages that permeate the boundaries of the human, the biological and the technological presents an account of agency that significantly departs from the neo-Kantian active human subject and the sociological constraints of structures. However, in order to think about why the Flash Crash happened precisely when it did and why, I next move from thinking about distributed agency and assemblages towards the agential capacities of attractors and bifurcations, what Deleuze and Guattari describe as abstract machines.

Open systems and abstract machines

Ecology involves the study of open systems, entities which require a constant flow of energy in order to maintain their structure at points far removed from entropic equilibrium. Without energy from the sun – or in the case of ecosystems that exist deep undersea, heat from the earth itself – ecosystems cannot function. Unlike the thermodynamically closed systems explored by classical mechanics, which have reached a stable state, displaying a minimum amount of free potential energy or entropy in accordance with the second law of thermodynamics, open systems require a constant intake of energy in order to remain at a point of balanced disequilibrium. To close a dissipative structure, to isolate it from the dynamic flows of matter and energy which constitute the world, to reach a static point of equilibrium, equates to the destruction or death of that system. Importantly, complexity theory and ecology go beyond the scope of autopoiesis here, insofar as they study negentropic systems which are not just biological but encompass physical systems such as tornadoes and oceanic oscillations, as well as systems that combine biological and non-biological components.

Whereas mechanistic science was concerned with stability and order, complexity theory highlights instability, fluctuation and nonlinearity. Rather than scientific knowledge equating to predictive certainty based upon the analytical model of physicalism, nonlinear dynamics and complexity theory

emphasize probability, multiple choices and uncertainty, qualities which had previously been thought to be limited to human action and free will. According to Ilya Prigogine, a Nobel laureate in chemistry for his work on dissipative structures and self-organization, the shift from linearly deterministic classical mechanics to the probabilistic determinism of nonlinear dynamics, creates 'the birth of a science that is no longer limited to idealized and simplified situations, but reflects the complexity of the real world, a science that views us and our creativity as part of a fundamental trend in nature' (Prigogine 1997: 7). This shift is important, as it allows for the construction of a non-dualistic onto-epistemology that does not posit a determinate nature that is fundamentally separated from creative humans who can choose between alternative courses of action or between biological and physical systems, as with Varela's model of autopoiesis.

The stable subjects of classical physics were time reversible. As Albert Einstein (1955) famously commented, under the paradigm of classical mechanics 'the distinction between past, present, and future is only a stubbornly persistent illusion'. Temporal reversibility allowed Newtonian physicists to calculate not only the future states of a system based on initial conditions but also past behaviours. Relegating time to the realm of phenomenology, however, clearly contradicts our common-sense perception of the everyday world, where we frequently observe phenomena which are not time reversible: processes of biological growth, ageing and death. As Henri Bergson (1959: 1331) remarked, 'Time prevents everything from being given at once. … Is it not the vehicle of creativity and choice? Is not the existence of time the proof of indeterminism in nature?' Indeed, the importance of the constructive and irreversible role of time in negentropic systems has been a central tenet of recent works associated with new materialism which have emphasized the importance of becoming and fragility (Connolly 2011) alongside the vibrancy of matter within a political ecology of things.

Self-organizing, negentropic systems can exhibit 'chaotic' behaviour. The iterative processes central to the generation of novel complexity via positive feedback entails that these systems display extreme sensitivity to initial conditions, so they behave in an unpredictable, apparently random manner. This sensitivity is commonly referred to as the butterfly effect (Lorenz 1993: 14), with the accompanying example of climatic sensitivity, whereby the miniscule atmospheric disturbance caused by a butterfly flapping its wings in Fiji can be iterated upon until eventually it is responsible for causing a tornado in Texas. Although chaotic systems behave in apparently random ways – as suggested by the term 'chaos' whose vernacular application indicates disorder – they are in fact governed by strictly deterministic, though nonlinear, mathematical equations; they are both fully deterministic and quantifiably unpredictable. Despite an inability to define a description of the (singular) trajectory of a chaotic system, we can make qualitative statements

based on probabilities. This dictates that unlike the quantitative solutions inherent in linear equations, 'the laws of chaos have to be formulated at the statistical level' (Prigogine 1997: 37). Consequently, it is possible for predictions about the future of the global climate to be made without requiring a precise understanding of the chaotic short-term noise within the system, what we generally refer to as weather. This is important insofar as it demarcates a rupture across scales, whereby one does not need to be able to predict what the temperature will be in two weeks' or two months' time in a particular place in order to describe the longer-term tendencies of the climatic system; that the global climate will be warmer if we continue to emit billions of tonnes of greenhouse gases into the atmosphere.

Within nonlinear dynamics, this probabilistic prediction typically involves analysing the phase portrait of systems, an abstract space introduced by mathematician Henri Poincare which allows systems' trajectories to be reduced to a two-axis graph where every point in space represents a different state the system can occupy. Within this space, there are typically a series of points or zones that exert an influence upon the system, compelling it to behave in a particular way, and these entities are described as attractors as they notionally 'attract' the system. Several distinct types of attractors exist; point attractors compel systems to move towards a specific point, periodic attractors (also known as limit cycles) create cyclical trajectories and strange attractors form fractal patterns. Mapping attractors presents a geography of the virtual, which allows the topographical examination of complex systems, allowing detailed probabilistic predictions to be made about their behaviour, thus clearly differentiating them from genuinely random actions. In terms of agency, we can understand the nonlinear determinism invoked by attractors as demonstrating the limits of the humanist model which divided beings into those which did and did not possess agency. Attractors compel systems to move in particular directions, but the outcome of this attraction depends upon the specific distribution of other attractors within the system's basin of attraction. These relational arrangements comprise what Deleuze and Guattari (1982: 562/563) describe as abstract machines, the virtual patterns of potentiality which form a nonlinear field of pressures and limits for systems. Although abstract machines are not tangible structures, they thereby exert a form of nonorganic agency over systems.

While abstract machines may sound worryingly close to Platonic ideals, they return to the cybernetic notion of an organizational pattern that exerts an influence over heterogeneous structures, but which are always immanent to them, rather than transcendentally existing as ideal types or essences. Attractors thus become a way of describing a nonlinear determinism which is immanent though abstract, presenting a very different model of agency to that which has been traditionally invoked by humanist accounts. The trope of the attractor has become increasingly popular within the domain of cultural theory, albeit one which is often applied in a metaphorical way

to sociocultural systems (Thrift 1999). As a concept, it is useful to media ecologies insofar as it provides a way of mapping the topology of a system's potential evolutionary trajectories, exploring the various forces and factors which affect this evolution.

Alongside attractors, bifurcations provide a further source of indeterminacy within complex dynamical systems. Nonlinear dynamical systems display extreme sensitivity at certain points, as processes of positive feedback repeatedly iterate upon the system, dramatically altering the system's trajectory and the composition of its phase portrait. In these circumstances, there may be the appearance of new attractors, the disappearance of existing ones and even the transformation of attractor types. These systems are described as being 'critically unstable', and the exact points of critical instability are termed bifurcation points. Bifurcations are junctures in the evolution of a system whereby pathways abruptly diverge, presenting sudden and often dramatic and irreversible alterations to the system's phase portrait. These points of critical instability are unique to nonlinear systems which operate far from equilibrium, which range from cloud formation to social organization, from social media trends to ecosystem population dynamics.

Across various forms of open system, there are languages which recognize the systemic changes enacted by bifurcations. Within the fields of evolutionary biology and palaeontology, there has been a move away from the type of phyletic gradualism associated with Darwinism, whereby evolution was thought to move in an incremental, slow and steady manner, towards an understanding of the history of life as being characterized by punctuated equilibria. This change dictates that 'the history of evolution is not one of a steady unfolding, but a story of homeostatic equilibria, disturbed only rarely … by rapid and episodic events' (Eldredge and Gould 1972: 84). Within media studies, the homologous notion that technologies are naturalized or stabilize themselves within defined parameters after a period of initial experimentation and fluctuation is common (Winston 1998; Friedman 2005). Within the language of complexity theory, we can describe this as the process of settling towards one of the many metastable attractor states possible with any given technology.

Within the fields of climate change and Earth Systems science, tipping points – thresholds which, once crossed, bring about irreversible, potentially catastrophic systemic changes as we bifurcate from one basin of attraction to another – are crucial elements of the scientific literature. Frighteningly, according to Rockström et al. (2009), the climatological tipping points surrounding atmospheric greenhouse gas concentrations, the rate of species extinction and alterations to the global nitrogen cycle have already exceeded safe values. Finally, the hypothesis of disaster capitalism advanced by Naomi Klein (2007) demonstrates how neoliberal governments have

utilized moments of critical instability, notably environmental, social and political crises, to implement rapid legislative changes that would have been unthinkable during the longer periods of relative social stability, highlighting how organized social forces can leverage bifurcations. While the political outcomes of disaster capitalism – which broadly speaking, have been privatization, precarity, environmental degradation and rising social inequality – are far removed from the goals of an ecological politics, these events demonstrate that organized movements can utilize moments of critical instability to generate substantive social change.

In the case of the Flash Crash, there were several key structural factors in play that collectively afforded the type of extreme event that played out. As Foresight remark, 'It is something of a cliché to say that CBT can lead to "Black Swan" events, i.e. events that are extremely rare but of very high consequence when they do occur. … However, as far as financial stability is concerned, the more interesting and significant aspects have to do with the general *nonlinear dynamics* of the financial system' (Beddington et al. 2012: 11). It is important to grasp that no single entity caused or unilaterally determined the Flash Crash; it was dependent upon the wider political–economic context in addition to a range of actors whose behaviours collectively contributed to the unfolding event.

On 6 May 2010, there were significant concerns surrounding the European debt crisis (which was itself a direct legacy of the 2007/8 global financial crisis allied with the sociopolitical and economic situation of the eurozone), meaning that markets were both unstable and trending downwards before any unusual activity from computer-based trading systems occurred. These contextual determinants entailed that the large AT sell order was not able to be easily absorbed as had happened with the two larger E-Mini sell orders that had been placed in the previous twelve months, so these factors coalesced to bifurcate the system from one basin of attraction to another far less stable one.

The assemblages that affect financial systems are not just the specific actions of algorithmic trading programs, but include the downward causality exerted by global economic systems, which in turn are affected by the irrational behaviour of particular micro-assemblages. Consequently, we need to reconceptualize agency in terms of systems dynamics and entanglement rather than as a property that is possessed by individual entities. The activity of HFTs which began rapidly selling the stocks they had accumulated at 2:41 p.m. forms a further bifurcation, which saw the value of the E-Mini nosedive. The pause in trading then forms a third decisive change to the trajectory of the system. Attractors and bifurcations thereby provide us with a way of qualitatively describing the structural pressures and abrupt tipping points associated with nonlinear systems, a way of sketching distributed, nonhuman agencies.

Markets and cyborgs

Throughout this chapter, I have argued that addressing questions surrounding technology and agency in digital media ecologies requires moving from the notion of agency associated with the human subject towards thinking about the agencies of assemblages and abstract machines. Cybernetics has been a key genealogical touchstone for this type of systems thinking, through the way that various strands of cybernetic practice and thought have influenced: (1) the paradigm of digital computing; (2) mechanisms of feedback, nonlinearity and circular causality; (3) the lineage of second-order cybernetic thought that feeds into systems biology and autopoiesis; and (4) the ecological models of complexity theory and open systems, which are pivotal to scientific comprehensions of anthropogenic climate change and served as the inspiration for the geo-philosophy of Deleuze and Guattari. This section examines a fifth and final strand of influence that cybernetics has had on contemporary approaches to the agential couplings between and within biological, technological and human assemblages, through the figure of the cyborg and the subsequent discourse of posthumanism.

In the mid-1980s, Donna Haraway adopted the figure of the cyborg – a portmanteau of cybernetic organism – in order to illustrate how the increasing volume of interactions between humans and technological systems entailed that humans could no longer reasonably construct themselves as somehow existing independently of their technological environments; 'By the late twentieth century, our time, we are all chimaeras, theorized and fabricated hybrids; in short we are cyborgs' (Haraway 1991: 150). At the time, the dominant cultural associations of the cyborg were the quasi-fascistic figures of technological control and mastery portrayed by Arnold Schwarzenegger in *The Terminator* and Peter Weller in *RoboCop*. This connotation of technology being linked to social and military hyper-masculine control produced an oppositional eco-feminist discourse which equated scientific and technological knowledge with the domination of men over women and humans over nature.

Haraway's cyberfeminism, on the other hand, argued that beneficial social and environmental changes do not require the rejection of advanced technologies, but their reorientation towards cooperative and communal strategies designed to enhance relationships between humans and ecological systems. This fusion of cybernetics and distributed agency alongside the socialist feminism advocated by Haraway is a central feature of many more recent accounts which identify with the label posthumanism, albeit with many accounts of posthumanism being highly critical of particular elements associated with cybernetic practice, especially those associated with the militarized versions of technological mastery and control and the notion of disembodied information (Hayles 1999; Wolfe 2010; Crogan 2011).

These connections between computation and systems of control have obvious contemporary relevance when we consider both the ubiquitous governmental and corporate surveillance of digital information (Lyon, Ball and Haggerty 2012) and the discourses of transhumanism and the quantified self (Lupton 2016; Nicholls 2016) that seek to employ digital technologies to augment, measure and extend various human capabilities. Here, transhumanism and Haraway's cyborg resemble the theory of technological extensions found in Marshall McLuhan's mid-twentieth-century medium theory. For McLuhan, not only were changes in scale, pace and pattern the primary message of any technology, but technologies allow humans to extend themselves into their environment. While the wheel extends the foot, and print extends the eye, according to McLuhan, electrical technologies re-create society as a 'global village', with the decentralizing effects of cool (participatory) electrical media, especially television, heralding the re-tribalization of society, forming a decentralized, democratic and creative society (McLuhan and Fiore 1967). This return to sensory balance following the dictatorship of the eye under typographic technics presents a redemption narrative which echoes McLuhan's strongly held Catholic beliefs and a teleology in which electrical technoculture necessarily manifests a series of positive social consequences.

Extending a static notion of consciousness and returning to an original, pure and idealized balance of senses – as suggested by McLuhan's (2003: 85) claims that 'in this electric age we see ourselves being translated more and more into the form of information, moving towards the technological extension of consciousness' – positions a pre-technical and essentialized human. These claims are disputed by numerous contemporary accounts of technocultural evolution, which instead maintain that humans have always evolved alongside tools and technologies (Stiegler 1998; Pugliese and Stryker 2009). Thus defined, humanity has never been a stable entity to which there can be ante- or precedent states defined by engagements with technology. Consequently, Stiegler (2013: 112) contends that posthumanism merely restates the fundamental technical character of being human, while failing to adequately address the issues relating to specific modes of becoming associated with contemporary digital technics. From this perspective, humans have always been cyborgs, with the transformation of the digestive system through the technological process of cooking food presenting a pertinent early example of how technical objects have defined human becomings.

For Stiegler, the always-cyborgian condition of becoming human involves the application of mnemotechnical technical supports that engenders a process of proletarianization, whereby as we externalize our memories we correspondingly lose the knowledges and ways of living that are externalized, echoing McLuhan's thesis that as we extend our bodies via technologies the extension is accompanied by numbness within body itself. However, Stiegler departs from McLuhan's teleological determinism,

contending that the deployment of mnemotechnics constitutes a crucial contemporary political question. Mnemotechnologies can be dissociated from anamnesis – the embodied act of remembering – in which case they displace memory into the hands of multinational corporations or the state, acting as proletarianizing organs of the control society (Stiegler 2010b: 68). Alternatively, when associated with anamnesis, mnemotechnologies can be used to create commonwealth by allowing new knowledges and ways of living to emerge. Stiegler thus contends that in the contemporary context, digital technics present pathways leading towards the commodification of cognitive systems and the industrialization of memory, while concurrently opening possibilities for alternative processes of transindividuation and the consequent creation of a commons-based sociopolitical system of collective care which he terms an economy of contribution (Stiegler 2010a: 48).

Focussing upon technological prosthesis and the process of epiphylogenesis supports McLuhan's claims that technologies alter the ways in which humans (individually and collectively) perceive time and space; however, the decisive departure from a McLuhanite model of technology is Stiegler's emphasis on technology as pharmakon, simultaneously both poison and cure. This opens up a range of potential ways in which technologies can affect sociocultural formations and crucially positions technology as a site of political struggle whose outcomes are far from certain. Technologies have political affordances; they are neither value-free entities that are solely inscribed with human agencies as we typically find in social constructivist accounts, nor do they present teleological determinisms whereby technology X has outcome Y, as we find with McLuhan, for whom, 'Electricity does not centralize but decentralizes' (2003: 55). Such straightforward pronouncements regarding technological effects homogenize the diverse sociocultural consequences of technologies predicated upon electricity. Centralized electricity generation based on coal-burning power plants clearly contradicts McLuhan's claim pertaining to electricity's decentralizing nature, demonstrating that electrical technologies can be centralizing or decentralizing. Equally, in the case of using a centralized electrical grid to run a distributed network of computers, technologies can simultaneously embody tendencies towards both centralization and decentralization, convergence and fragmentation.

Another highly evocative account that reconfigures conceptualizations of cyborgian agencies and posthuman assemblages in a way that sharply brings the politics of contemporary technoculture into focus appears in Sean Cubitt's (2016: 34) *Finite Media*, which rejects the dominant figure of the cyborg as a technologically augmented humanoid:

> Fantasy cyborgs look like human beings with technological implants. Actually existing cyborgs are huge agglomerations of technologies with human implants. Corporations like Enron and FirstEnergy are such cyborgs, composed of nonhuman actors with human biochips embedded

> to carry out specialist tasks like those involving human resource management and public relations. Corporate cyborg agency is distributed but not communal, not least in electrical grids connecting aggressively active users (who can scarcely be caught in the term *consumers*), the unmanaged turbulence of deregulated and automated markets, and the inhuman drive for corporate profit. Such actor networks are realized socio-political agencies whose other-than-human standing is confirmed by their lack of shame. Frankenstein monsters created out of the logic of advanced capital, their sole motive is profit, regardless of all other consequences. Their environment is not the physical world but the financial, a world where human affairs appear only as inputs and price fluctuations. … The corporate cyborg not only risks the future of humanity and its environment but its own future in actions which, in a human being, would be deemed suicidal.

Cubitt's intervention is to productively reconceptualize the cyborg as an assemblage that exists at a different scale to that which is introduced by Haraway and advanced through subsequent discourses around cyborgian agency. Cubitt asks us to rethink the corporate assemblage as cyborg, an individuated entity which melds technological and biological systems into an inhuman logic based on short-term profitability at all costs, whose ramifications currently reverberate throughout ecological systems as the conjuncture known as the Anthropocene.

A similar argument about algorithmic financial trading is advanced by legal scholar Tom Lin who describes 'cy-fi', a cybernetic financial assemblage in which AT systems, computational and networking hardware, software and protocols collectively form a financial ecology where both systemic risks and short-term profitability are increasingly prevalent. In both Cubitt's and Lin's accounts, the key departure is from an anthropocentric frame where individual biological/technical hybrids resemble humanoids, towards re-imagining vast financial or corporate assemblages as historically individuated cyborgian entities. Within these cyborgs, human values of empathy, compassion and kindness have effectively been eliminated by a light-speed drive for efficiency and profit.

The suicidal logical that Cubitt explicates, that of cybernetic organisms which relentlessly seek to externalize costs onto ecosystems precisely because it does not recognize that this common world is required for its own survival, is one that should be familiar from the Flash Crash. The systemic instability that HFTs propagate potentially threatens the futures of not just investment banks and hedge funds but the financial security of the millions of workers whose pension funds are bound up in these automated financial systems. Italian Autonomist-Marxist Christian Marazzi has insightfully outlined the transformative process of financialization, in which household savings and retirement funds have been funnelled into stock

markets from the 1980s onwards. Whereas under the mid-twentieth-century paradigm of Fordism industrial workers were able to define their identities and class interests in opposition to capitalism, 'with their savings invested in securities, workers are no longer separate from capital, as they are, by virtue of its legal definition, in the salary relationship' (Marazzi 2008: 37). Consequently, the risks caused by computer-based trading systems which have been demonstrated to periodically behave in irrational and destructive ways should be of significant concern for nurses, teachers, bus drivers and other workers whose future economic security is now beholden to the inhuman agencies of cyborgian financial systems.

Nevertheless, the competitive advantage gained by employing faster-than-human computational trading systems entails that not using them simply isn't an option in the current financial ecosystem. The question which this situation logically proffers is, why are these inhuman agents which create no use value and significantly increase the chances of catastrophic systemic failure not regulated out of existence? The answer is that within the inhuman logic of the market that Cubitt outlines, medium- to long-term systemic instability is understood as a risk worth taking for the short-term profits AT and HFT provide. Put simply, the values of the system are effectively self-destructive if we look beyond immediate temporal horizons. Here we begin to glimpse the temporal connections between the destructive short-termism of digitally enabled financial ecologies and the broader ecological conjuncture of the Anthropocene whereby the speed of change outpaces the capacity of a multitude of species to adapt. In both cases, there are serious issues with a self-destructive, myopic focus upon short-term advantages that detrimentally impacts upon the resilience and long-term outlook of systems.

In the wake of the Flash Crash, analyses tended to concur that the 5-second pause in trading was key to the subsequent recovery, and so consequently the SEC approved a circuit breaker to securities which would come into effect if that security experienced a change in price of over 10 per cent during any five-minute period. Since 2010, however, there have been a worrying number of events with similar dynamics to the Flash Crash. In October 2012, the Indian National Stock Exchange saw almost US$60 billion temporarily wiped off markets. In April 2013, the Associated Press Twitter account, which had been hacked, erroneously claimed that Barack Obama had been injured in explosions at the White House. As HFTs cross reference newsfeeds, they immediately began selling futures contracts, with the result being a 143-point fall in the Dow Jones industrial average followed by a rapid recovery. In October 2016, with concerns over a 'Hard Brexit' looming, the British pound saw a flash crash in which it lost around 6 per cent of its value against the US dollar in two minutes. Across these examples, HFTs have been blamed for the severity and speed of these events, and the implementation of circuit breakers has not prevented them from occurring, only from spiralling completely out of control.

There is a serious case to be made then for implementing regulations designed to preclude forms of AT that increase the systemic risk of these events occurring. These entities have no underlying use value, they merely act as parasites that feed off other exchanges and events in ways that are demonstrably detrimental to the overall system. Regulating markets and banning particular trading technologies, however, is a strategy that contradicts the ideologies of the free market and neoliberalism, which despite being discredited by the global financial crisis of 2007/8 are still deeply ingrained within financial ecosystems and political elites. Surveying this situation reminds us that 'there is an ecology of bad ideas just as there is an ecology of weeds, and it is characteristic of the system that the basic error propagates itself' (Bateson 1972: 489).

Further addressing the logic of neoliberalism and the inhumanity of contemporary corporate cyborgs requires us to move away from conceptualizing agency – questions of who or what can act – and towards questions of how we come to evaluate whether those actions are positive or negative, and how assemblages collectively and intentionally mobilize to enact particular outcomes. In order to address these questions, the next chapter focuses upon ecological ethics and politics, and how ecological praxis can be applied to digital media ecologies.

2

Ecology, ethics and collectives

Whereas the previous chapter explored issues surrounding technology, complexity and agency, using the Flash Crash as an example to assemble various strands of cybernetic and ecological thought to outline a model of distributed agency, this chapter shifts focus towards questions surrounding media ecology, ethics and politics. Conventionally, ethics are understood as inquiry into the prescription and rationalization of good and bad values, which inform how individuals should act, whereas politics is the venue within which ethics are negotiated and collectively implemented. The traditional division between ethics and politics then (assuming that politics is understood as collectively organizing around shared values, rather than the formal political administration of an area) relies upon a distinction between individuals and collectives which the model of assemblages and entanglement outlined in the previous chapter fundamentally undermines.

Understanding ethics as the domain of the individual human subject helps clarify why contemporary ethical discourses are both highly prominent and highly problematic. Within the discourse of neoliberal capitalism – whereby quantifiable competition between individuals through deregulated markets is fetishized as a near-universal ideal form of social relation (Harvey 2005; Peck 2010; Brown 2015; Beer 2016) – there is a concerted drive away from collective interventions into public life that are explicitly designed to benefit citizens. This does not mean that states no longer build roads, run health services or schools, but that these activities are increasingly subjected to a logic of competition and marketization (Gilbert 2014). Neoliberal dogma contends that markets are efficient and just arbitrators of social disputes, that our frequent participation in financial exchanges entails a greater level of democratic engagement than electing political representatives once every few years. There is, undoubtedly, a very real

disconnection between many people and party politics;[1] however, we should remember that representative democracy rests upon each citizen receiving one vote,[2] whereas consumer participation in markets is directly proportional to financial resources. A system that empowers the wealthy to participate more than the poor unsurprisingly reflects an ideology that presents competition between individuals as key to judging the success and worth of those humans. Consequently, 'mainstream' neoliberal solutions to contemporary ecological crises champion the oxymoron of market-based solutions which will allegedly be realized through acts of ethical consumption.

This conception of ethics sees atomized individuals being able to positively alter the trajectory of climate change through purchasing LED light bulbs, the global plastics crisis through not buying bottled water and eliminating e-waste through using certified recycling schemes. While these actions are not inherently harmful, the rhetoric that postulates them as solutions to Anthropocenic crises is ludicrous, and if taken seriously, removes attention and energy from the collective mobilizations that are required to address the global and geological scales at which these issues operate. The scalar disconnection between individual acts of consumption and the problems they supposedly address is further emphasized through a realization that the majority of greenhouse gas emissions, plastic and electronics waste are related not to individual, domestic consumers but to industrial, corporate, military and governmental operations (Pachauri et al. 2014; IEA 2016). In many cases, then, advocating ethical individual consumption as the solution to Anthropocenic crises demonstrates a fundamental failure to grasp the scale and scope of contemporary issues.

Furthermore, ethical consumption can only address issues of production through the mediation of the market. When we consider the complex, global supply chains that are endemic to microelectronics, actions that solely address consumption are far less likely to effectively address harmful and exploitative processes of production than national and international regulation. Similarly, while individual consumers purchase smartphones,

[1]Especially surrounding liberal and social democratic parties that in the wake of the global financial crisis – which demonstrated the total failure of deregulated financial markets to sustainably self-organize – have clung to the narrative that there is no alternative to neoliberalism. Indeed, where left-wing parties have seen a resurgence, be it the Corbyn-led Labour Party in the United Kingdom, Podemos in Spain or Syriza in Greece, there have been explicit rejections of austerity and neoliberalism.

[2]Although the reality of political funding systems ensures that powerful economic interests are frequently able to amplify their voices and influence. This is a fundamental issue that must be addressed if democratic politics is to be worthy of the name.

wearable computing devices, smart televisions and so on, they do not typically procure data servers, cellular towers, undersea fibre-optic cables, GPS satellites or other back-end infrastructure that is necessary for consumer devices to function. Consequently, ethical consumption can only ever reach the tip of the technocultural iceberg. As a strategy for the type of radical systemic transformation that is necessary to address the scale and complexity of contemporary ecological crises, ethical consumption is a woefully inadequate strategy.

We should also note that the additional financial and temporal costs associated with ethical consumption ensure that for those already struggling within a generalized state of precarity and financial inequality, ethical consumption is an unaffordable luxury; if you're working sixty hours a week and struggling to pay rent and bills, then buying organic food, avoiding plastic packaging and conducting the research to find less exploitative and environmentally destructive consumer goods are simply not viable options. Often then, ethical consumption is predominantly accessible to the middle classes; market-led solutions favour those who succeed financially, whereas the poor who have failed in their 'duty' to succeed fiscally subsequently fail as ethical consumers. That is not to say that there is no merit to enacting small-scale changes such as using LED light bulbs, adopting a plant-based diet or reducing the use of single-use plastic. As we shall see, an ecological ethic asks us to practice the types of change we wish to see, but crucially this requires us to enact forms of connectivity and collectivity that far exceed the market-based individualist strategies of ethical consumption.

Consequently, this chapter follows the ethico-onto-epistemology of Karen Barad in 'rejecting the metaphysics of individualism that serves as a foundation for traditional approaches to ethics' (2007: 393). Within this formulation, ethics is not separate from our ways of knowing (epistemology) or becoming within the world. Rather than an abstract way of thinking about idealized situations, ethics are enacted through performative processes: 'Ethics is not simply about responsible actions in relation to human experiences of the world; rather, it is a question of material entanglements and how each intra-action matters in the reconfiguring of these entanglements, that is, it is a matter of the ethical call that is embodied in the very worlding of the world' (Barad 2007: 160). This emphasis upon ethics as an enacted material process blurs the boundaries between a second category that has often been used to divide ethics and politics – thought and action – with ethics being associated with values and politics being the materialization and enactment of those values through worldly activity. This distinction, in which ethical purity can be contrasted with the Machiavellian world of political action, rests upon a problematic dualism that seeks to divide the world into an individualized interior world of thought and a collective world of action, in contradistinction to the ecological model of distributed agency and multi-scalar assemblages that was outlined in the previous chapter.

This chapter builds upon this model of agential assemblages, elaborating an ecological ethic that follows Barad, Bateson and Guattari in rejecting key tenets of the main strands of Western ethics. I begin by outlining virtue ethics, deontology and consequentialism as the three major strands of Western ethical theory, foregrounding some of their inadequacies from an ecological perspective, before outlining how concepts advanced by Bateson, Guattari, Barad and Deleuze can form the basis for an ecological ethic centred upon connectivity, collectivity, affect and speed. The chapter subsequently addresses the politics of collective mobilizations and commons, before concluding with a summary of how the insights surrounding ecology, ethics, technology complexity and agency that have been explored in Part 1 of this book will be applied to the scales of content, code and hardware in Part 2.

Ethics and anthropocentricism

Western ethical philosophy has three major branches: virtue ethics, deontology and consequentialism. Virtue ethics is among the oldest forms of ethical philosophy, with advocates including Plato and Aristotle. It contends that abstract virtues exist and that they constitute positive character traits such as wisdom, courage, temperance and justice.[3] Virtue ethics stresses the importance of acquiring these virtues; once courage has been acquired, an individual will habitually act in a courageous way, embodying the virtuous trait. Aristotle emphasized that the goal of ethics, the highest form of good for humans, was *Eudaimonia*, a term which is often translated as happiness but which transcends contemporary applications of the term, coming closer to 'human flourishing' (Robinson 1989). For *Eudaimonia* to be attained, Aristotelian virtue ethics contends that an individual must acquire virtues and exercise reason, the faculty which purportedly separates humans from nonhumans. Consequently, virtue ethics is often critiqued for relying upon teleology and essentialism; by positing virtues as abstract qualities which exist outside of real-world interactions, virtue ethics present an ontological essentialism which departs from the materialist approach to technoculture presented in the previous chapter. Despite this, however, philosophers such as Patrick Curry (2011) contend that virtue ethics provides the most promising tradition from which an ecologically sensitive ethic may emerge, arguing that because virtue ethics emphasizes embodied habits rather than exercising pure reason, it is closer to an ecological praxis in which ethics arise through everyday activity rather than abstract rational–critical philosophical constructions.

[3]According to Plato, these are the four cardinal virtues

A second major branch of Western ethical thought is deontology, whose etymology derives from the Greek term *deon* meaning duty. Deontology maintains that ethics correlate to duties – what is due or right – which must be enacted irrespective of material consequences if actions are to be considered ethically just. Deontology, then, presents moral questions over whether actions are right or wrong, with no ethical space for derelictions of duty. Deontology was most famously championed by Immanuel Kant, who responded to David Hume's claims that whereas science and mathematics were the realms of reason, ethics were the domain of passions, sympathies and emotions, with the formulation of the categorical imperative, which mandates: 'Act only according to that maxim whereby you can at the same time will that it should become a universal law without contradiction' (Kant 1995: 30). By aiming to create a rationalist ethics predicated upon universals, Kant sought to ground ethics upon reason and the notion of rights, which has proven to be important in developing modern political discourses, especially those surrounding human rights. Consequently, the Kantian tradition of deontological ethics is still popular today, largely through the strand of rights-based ethics derived from the works of American political philosopher John Rawls.

Regarding the kinds of agents this justice applies to, Rawls contends that the 'status of the natural world and our proper relation to it is not a constitutional essential or a basic question of justice' (1993: 226). Consequently, we can understand deontological ethics to be firmly anthropocentric. Indeed, for Kant the only reason to treat animals with consideration was as practice for treating humans well. By contending that humans are the sole source of value, deontological ethics thus departs from an ecological ethics. Furthermore, we should ask serious questions regarding the viability of applying universalist concepts such as the categorical imperative to the contemporary ecological conjuncture; following Timothy Morton (2013), we can note that climate change makes hypocrites of us all insofar as simply by sustaining ourselves as living entities by eating we contribute to the problem.[4]

For our individual actions to be ecologically sustainable if extended to over seven billion humans, we would have no air travel, no cars, no computers, no smartphones and so on. Aside from the practical implication that few humans would choose to give up many of the comforts of modern life, we should note that those few individuals who are both inclined and economically privileged enough to buy land and live directly off it in an

[4]The issue with such a universal declaration of hypocrisy is the failure to acknowledge the heterogeneous contributions to climate change, with 10 per cent of the human population contributing half of greenhouse gas emissions and the poorest half of the population contributing just 10 per cent of emissions. Nonetheless, Morton's work does significantly problematize a deontological ethic of purity in relation to climate change.

ecologically non-harmful way are sufficiently disconnected from the rest of society to practically ensure that they will not contribute to collective, political solutions to ecological crises. An ethic of moral purity which ignores collective crisis, instead focusing on a misplaced sense of individual importance is of little use precisely because of its scalar misidentification. Consequently, an ecological ethic must seek to enact change to collectives, rather than exclusively focusing on a puritanical individualism.

Consequentialism presents a third ethical position, which is often cast as the antithesis of deontology. Whereas deontologists assert that ethical behaviour requires the observance of morals regardless of consequences, consequentialists contend that the ethical character of actions 'derive entirely from the value of consequences' (Blackburn 1994: 77). For consequentialists, what matters are outcomes rather than intentions. The dominant form of consequentialism, derived from Jeremy Bentham and J. S. Mill is known as utilitarianism and contends that ethical actions result in advancing the greatest amount of happiness for the greatest number of people. Although this can be understood to address some of the problematics surrounding inflexibility and individualism within the deontological tradition – by addressing notions of the common good – there are serious issues to be raised with the notion of to whom and what the greatest good applies.

Whereas for Bentham and Mill this meant living humans, there are powerful arguments for extending the common good to future generations of humans and to nonhumans, at the very least to sentient animals clearly capable of experiencing pleasure or pain (Singer 1977). This requires that serious questions are asked pertaining to how calculations surrounding collective happiness can be derived. How does the happiness of current humans compare to that of future humans or even to that of nonhuman biological entities? Such questions are especially pertinent when we consider that Anthropocenic crises are fundamentally orientated towards the future and are likely to result in extinction for innumerable nonhuman species.

Another weakness inherent to consequentialist ethics is the assumption that there are knowable and calculable outcomes that can be derived from specific actions. While in certain scenarios we can reasonably expect to predict the immediate ramifications of specific actions, extending the nonlinear consequences of these actions across time and space soon becomes impossible, largely as a result of the impacts of feedbacks and bifurcations, whereby seemingly insignificant actions may have grave consequences, and apparently important actions may have minimal impacts. Resultantly, the moral cost–benefit analysis proposed by consequentialism appears entirely unworkable within an ecological agential framework. Perfectly understanding the consequences of actions – even with hindsight – is often impossible, so it makes little sense to base an ecological ethics upon such problematic foundations, even if we disregard its anthropocentricism and presentism.

The ecological ethics outlined in this chapter reject aspects of all three of the dominant ethical traditions of Western philosophy. Unlike virtue ethics, ecological ethics reject essentialism and teleology. Unlike deontology, ecological ethics do not contend that universalization is necessary for an act to be ethical or that consequences do not matter. Departing from consequentialism, ecological ethics contend that happiness/good cannot be objectively calculated and that ethics must include future generations, despite the future being defined by a lack of certainty. Additionally, ecological ethics contend that the anthropocentric focus implicit in each of these traditions is problematic and that, instead, an ethic of the multiple, or a logic of the AND – which considers varying overlapping and interconnected points of view (human and nonhuman, current and future) – is required.

Furthermore, ecological ethics require a focus upon action rather than reflection and pure reason, aligning it with Barad's ethico-onto-epistemology, which contends that embodied processes of becoming are inseparable from our ways of knowing and acting upon and with the world, and Francisco Varela's approach to ethical know-how, which combines insights from autopoiesis and enactivist theories of cognition with elements of Buddhism. For Varela, Western ethics have grossly neglected the role of skilled behaviour (habit), in favour of deliberative and intentional analysis: 'Praxis is what ethical learning is all about. If we don't practice transformation we will never attain the highest degree of ethical expertise' (Varela 1999: 63). For Barad and Varela, ethical behaviour is learned through enacting beneficial transformation, rather than calculating ethical cost–benefit analyses or adherence to the categorical imperative. Situating ethics in this way additionally means unmasking the universalism present in Western ethical philosophies, whereby a white, male, bourgeois position problematically presents itself as an abstract, disembodied arbiter of truth. Ethical praxis therefore has to recognize the colonial, sexist and classist dimensions of Western thought.

Experimentation and creativity, acting and learning from the complex consequences of actions are therefore key to this ethic. This marks a departure from green ethics that are predicated upon the precautionary principle (Curry 2011; Riordan and Cameron 1994), which propounds that if actions present risks to the public or environment and potentially adverse effects are not entirely understood, then action should not proceed. The precautionary principle has been deployed in varying ways by conservation and preservation groups to undertake ethically and politically important tasks such as protecting rainforests from clear-cutting; however, the principle – or at least any strong reading of it – is somewhat dubious given the impossibility of understanding the potential implications of actions. As uncertainty and risk are pervasive in complex systems, prohibiting actions predicated upon uncertainty makes little sense. As we have seen, points of critical instability may be breached with little forewarning, leading to

rapid change which may be systemically catastrophic or lead to increased complexity. While there may be probabilistic ways of considering the likelihood of particular bifurcations occurring, the type of control over risk, or ecological cost–benefit analysis, implied by the precautionary principle is effectively unworkable.

Humanity has never been capable of observing the world without disturbing it. Indeed, at a time where technocultural activities are having devastating consequences for ecological systems, with the prospect of considerably worse to come, we cannot extricate ourselves from the ethical imperative to act: '"Do I dare disturb the universe?" is not a meaningful question, let alone a starting point for ethical considerations. Disturbance is not the issue. … There is no such exterior position where the contemplation of this possibility makes any sense' (Barad 2007: 396). Adhering to the precautionary principle entails that few if any actions could be considered ethical, and many promising avenues for affecting positive change would be rejected on the basis of uncertainty. Far from an ethic of praxis and change, the precautionary principle presents an ethic of inaction and paralytic stasis.

Such a position is, of course, entirely in keeping with the tradition of environmentalism as conservation, whereby the central premise of environmental action is to conserve and preserve presently existing elements of the 'natural' world. Conservationism, while generally well-intentioned, appears seriously flawed when we adopt an ecological approach which emphasizes the world as a dynamic system which is constantly becoming, flowing and evolving. From this vantage point, conservationism aims to enact cultural practices which are fundamentally 'unnatural' in their attempts to sever ecosystems from flows of change. Rather than preserving nonhuman nature, conservation in fact seeks to create an artifice of ecological stasis which is primarily predicated upon the valorization of specific aesthetics associated with anthropocentric projections of the nonhuman world that frequently align with a colonial ideology whereby lands existed in a natural state of harmony prior to European discovery.

Consequently, conservationism frequently focuses upon the plight of charismatic megafauna, species such as polar bears, giant pandas and elephants, which have affective resonances with humans, but which, objectively speaking, are no more important than microbial life forms or beings that are negatively categorized as pests, vermin and invasive species. That is not to suggest that pests and invasive species cannot be immensely problematic, insofar as they can rapidly reduce biodiversity and leave ecologically fragile monocultures in place, but there are also instances whereby nonhumans are considered to be objectionable, perverse or deviant life forms for questionable reasons predominantly based upon aesthetic judgements, such as animals successfully adapting to localized anthropocentric ecological alterations which conservationists

routinely characterize as degradation caused by human interference with a romanticized (nonhuman) nature (Holm 2012).

Focusing upon the conservation of 'nature' underpins rhetorics of sustainability which advocate that environmentally beneficial practices are those which somehow segregate presently existing systems from any sense of dynamism and change in order to preserve contemporaneous relations or revert them to a lionized pre-industrial past. As political ecologists Bram Büscher and Rob Fletcher (2015) illustrate, such rhetoric has become deeply ingrained in neoliberal conservation practices that have commodified natural resources and 'wilderness reserves' while displacing the human inhabitants of these areas to make way for international ecotourism. Effectively, neoliberal economic policy is unironically applied to address the ecological devastation caused by those same policies. Consequently, an ecological ethic, does not seek the conservation or preservation of a static nature which is ontologically removed from humanity but considers how we can bring forth the kind of world that we wish to inhabit and bequeath to future generations of humans and nonhumans. In order to explore this ecological ethic in more detail, I begin by returning to the work of Gregory Bateson, the cyberneticist, biologist, anthropologist and ecologist whose pioneering work examined how feedback and systems thinking impacts upon ethics and politics.

The three ecologies

In *Steps to an Ecology of Mind*, Bateson (1972) advances the notion that environmental and social crises are created by pathological epistemologies. The dissemination of erroneous premises leads to the introduction of bad habits, actions rooted in epistemological principles so deeply ingrained into the fabric of our lives that we do not question their validity. These bad habits take root and proliferate as an ecology of conceptual weeds. Bateson delineates that these erroneous premises stem from a hegemonic epistemology created by the mode of production and organization present in industrialized societies which he contends are primarily dominated by competitive individualism aided and abetted by a misplaced belief in humanity's ability to wield unilateral control over the environment, and the ability of scientific and technological progress to afford this apparent domination:

> On the one hand we have the systemic nature of the individual human being, the systemic nature of the culture in which he lives, and the systemic nature of the biological ecological system around him; and on the other hand, the curious twist in the systemic nature of the individual man whereby consciousness is, almost of necessity, blinded to the

> systemic nature of the man himself. Purposive consciousness pulls out, from the total mind, sequences which do not have the loop structure which is characteristic of the whole systemic structure. If you follow the common-sense dictates of consciousness you become, effectively, greedy and unwise. (Bateson 1972: 440)

In place of the agonistic ethos of industrialized culture, Bateson's cybernetic epistemology constructs the world around mutualism, the communication of difference, emergent formations and processes of feedback.

In developing this approach, Bateson introduces the concept of the three ecologies – mind, society and environment – a triadic schemata, which using the language of the previous chapter we can describe as entangled assemblages. Each ecology exists as a complex system consisting of a multitude of heterogeneous components, transversally interacting within and between the three ecologies, with balance across these entangled ecologies portrayed as essential to the continuation of human societies. For Bateson, the key is to enlarge the unit of ecological survival from thinking about individuals – whether conceived as organisms, species, nation-states or corporations – to a systemically orientated conception of the entity-in-environment: 'The last hundred years have demonstrated empirically, that if an organism or aggregate of organisms sets to work with a focus on its own survival and thinks that is the way to select its adaptive moves, its 'progress' ends up with a destroyed environment. If the organism ends up destroying its environment, it has in fact destroyed itself (Bateson 1972: 457). Whereas the anthropocentric model of competitive individualism encourages the externalization of harms onto the environment precisely because the environment is viewed as an external entity, Bateson contends that this perspective is premised upon an epistemological blindness that fails to recognize our dependence upon that environment. Consequently, instead of competitive individualism, Bateson advocates adopting an ecological ethic that thinks in terms of communities and ecosystems instead of atomized, competing individuals.

It is worth foregrounding the resonances between Bateson's model of the three ecologies and the multi-scale approach that is applied within the contemporary science of ecology. In *Ecology: From Individuals to Ecosystems*, Begon, Townsend and Harper (2006: xi) explain that ecology is concerned with relationships at three distinct scales of organization:

> The individual organism, the population (consisting of individuals of the same species) and the community (consisting of a greater or lesser number of species populations). At the level of the organism ecology deals with how individuals are affected by (and how they affect) their environment. At the level of the population, ecology is concerned with the presence or absence of particular species, their abundance and rarity, and with

> the trends and fluctuations in their numbers. Community ecology then deals with the composition and organization of ecological communities. Ecologists also focus on the pathways followed by energy and matter as these move between living and non-living elements of a further category of organization, the ecosystem, comprising the community together with its physical environment.

Consequently, the textbook is separated into three sections, with each section addressing a particular scale: from organisms, through populations, and finally to communities and ecosystems. While the differing scales are not identical, the triadic structure allied with similar categorization demonstrates the way in which the ontology of ecology has been transposed by thinkers such as Bateson into social and political theory. Given the catastrophic predictions associated with the Anthropocene, the merits of adopting approaches based on ecological principles are that they provide an alternative ethic to those of industrial culture, which may point towards more ecologically resilient and socially equitable futures.

There are, however, dangers in seeking a basis or justification for ethics in the nonhuman world. Various conceptions of nature have been mobilized in support of ideologies that have vehemently promoted racism, sexism, colonialism and anthropocentrism. Eugenics and social Darwinism are particularly acute examples that reinforce why drawing upon particular elements of the nonhuman world to mobilize support for political projects may be ill-advised. Similarly, the language of ecology is often mobilized today by venture capital and Silicon Valley techno-utopians to naturalize socially and ecologically destructive elements of neoliberalism and platform capitalism. Alongside these politically regressive naturalisms, there are, however, longstanding radical alternatives, notably Peter Kropotkin's anarchism which drew upon ecological mutualism to propose a human society based upon mutual aid, which has some striking parallels with the contemporary works of Haraway and Lynne Margulis.

While these accounts do stress collaboration and mutualism, they should not be read as totalizing models that suggest mutualisms or latent commons are universally good things. Multispecies collaborations create spaces that suit some entities and are inhospitable for others. Species that are left out of mutualistic relations may find themselves outside of an ecological niche. As Tsing (2015: 255) insightfully remarks, 'The best we can do is to aim for "good enough" worlds, where "good enough" is always imperfect and under revision.' In contrast to the utopian biocentrism of deep ecology, this kind of compromise does not mean a world where everything can succeed. We need to evaluate how and why we take actions that foster certain forms of becoming while closing others off, while acknowledging that although humans will never completely control ecological processes, we do already play important roles in their ongoing assembly.

While Bateson first advanced the concept of the three ecologies, it is perhaps more commonly encountered today through the work of Felix Guattari, the French philosopher, activist and psychoanalyst who is best known for his collaborations with Gilles Deleuze. Despite often being considered a fervent anti-statist, towards the end of his life, Guattari unsuccessfully stood as a green party candidate. Guattari's ecosophical position, synthesizes his earlier collaborative endeavours that fuse Marxism, poststructuralism and complexity theory with elements of Bateson's ecological epistemology, contending:

> Environmental ecology, as it exists today, has barely begun to prefigure the generalized ecology that I advocate here, the aim of which will be to radically decentre social struggles and ways of coming into one's own psyche. … Ecology must stop being associated with the image of a small nature-loving minority. Ecology in my sense questions the whole of subjectivity and capitalistic power formations. (Guattari 2000: 52)

Guattari rejects the value system valorized under neoliberalism (Guattari's own term is 'integrated world capitalism') in which economic growth is viewed as the sole determinant of a societies' worth, aligning his perspective with Bateson's rejection of economic determinism. Guattari and Bateson's ecological models diverge, however, in that whereas Bateson's framework is predicated upon cybernetic models of homoeostasis, Guattari additionally incorporates insights derived from complexity theory where both positive and negative feedbacks are pivotal. Whereas for Bateson ecological balance was a homeostatic point of equilibrium, the focus upon iterative processes of self-making within Guattari's ecosophy denote that any sense of balance is temporary, unstable and open to new forms of becoming.

We should note that Guattari departs from Maturana and Varela's definition of autopoiesis, advocating for technical systems to be considered autopoietic:

> Varela reserves the qualification 'autopoietic' for the biological domain. Social systems, technical machines, crystalline systems and so forth are excluded from the category. That is the sense of his distinction between allopoiesis and autopoiesis. But autopoiesis, which thus encompasses only autonomous, individuated and unitary entities that escape relations of input and output, lacks characteristics essential to living organisms, such as being born, dying and surviving through genetic phyla. It seems to me, however, that autopoiesis deserves to be rethought in relation to entities that are evolutive and collective, and that sustain diverse kinds of relations of alterity, rather than being implacably closed in upon themselves. Thus institutions, like technical machines, which, in appearance, depend on allopoiesis, become ipso facto autopoietic when

> they are seen in the framework of machinic orderings that they constitute along with human beings. (Guattari 1993: 17)

By extending the realm of autopoiesis to include technological and institutional systems, Guattari's ecosophy rejects the individualism that, as we have seen in the previous chapter, pervades Varela's version of autopoiesis. Rather than delimiting autopoiesis to biological systems, Guattari's interest lies in the ways that biological, technical and social systems demonstrate a shared set of characteristics surrounding circular causality, emergence and dynamism.

Illustrating this position, Guattari draws upon the work of Samuel Butler, who deconstructs the notion of bounded species by providing the example of pollinators and co-evolved reproductive organs:

> It is said that machines do not reproduce themselves, or that they only reproduce through the intermediary of man, but does anyone say that the red clover has no reproductive system because the bumble bee (and the bumble bee only) must aid and abet it before it can reproduce? The bumble bee is part of the reproductive system of the clover. … We are misled by considering any complicated machine as a single thing. In truth it is a city or a society. (Butler 1965: 159)

This move, as we saw in the previous chapter, takes us from understanding individuals as wholes towards grasping them as sympoietic assemblages in which agencies are diffuse, distributed and relational. Consequently, the onto-epistemological shift required by the paradigm of mental ecosophy leads from the Cartesian 'I think', to a collectivist 'we think', whereby humans comprise knots within entangled meshworks which encompass flows of machinic and biological life, information and affects, bound together in complex feedback-based patterns.

The reconceptualization of the self as an assemblage is one area where Deleuze and Guattari depart from conservationist forms of environmentalism which attempt to preserve the environment without enacting wider changes to the self or society. For example, discourses surrounding environmental activism frequently maintain a rigid nature/culture dualism, such as 350.og founder Bill McKibben's (1989: 64) forceful claim: 'We have ended the thing that has defined nature for us – its separation from human society. That separation is quite real.' While McKibben accepts that scientists and artists have argued against this dualistic ontology, he maintains that 'on the inside none of us quite believe it' (McKibben 1989: 64). According to Deleuze, Guattari and Bateson, this epistemological pathology – the maintenance of the nature/culture dualism – is precisely what must be addressed.

In contrast to Manichaean perspectives, Deleuze and Guattari (1972: 2) contend: 'Everything is a machine. …There is no such thing as man or nature

now, only a process that produces the one within the other and couples the machines together.' Rather than human culture and nonhuman nature, Deleuze and Guattari present both humans and nonhumans as open systems governed by the logics of self-organization and complexity. Contradicting common-sense constructions of the self, this approach asks us to accept that the boundaries between the self and the environment are not as clearly defined as we typically imagine. 'The individual mind is immanent but not only in the body. It is immanent also in pathways and messages outside the body; and there is a larger mind of which the individual mind is only a subsystem' (Bateson 1972: 467). Just as humans are dynamic assemblages of life which are entirely dependent on the ecology of microbiota within our digestive tracts to extract sufficient energy from food to maintain ourselves, what we perceive to be a static and external nature is in fact a dynamic multi-scalar assemblage which humans – collectively and individually – inhabit as active subsystems.

An ecosophy predicated upon negentropy and openness contradicts the 'balance of nature' argument presented by environmentalists such as Al Gore, which erroneously advocates that nature was harmoniously balanced prior to exposure to industrial–cultural activities which threaten the continued existence of both nature and culture (Herzogenrath 2008: 2). Nature is not a closed and static system, but an open and turbulent one; anthropogenic climate change does not present the destruction of stasis but involves altering the speeds and viscosities of flows of change beyond the resilience of many species which evolved at slower speeds of ecological change. This also provides a key distinction between Deleuze/Guattari's naturalism and that presented by deep ecologists, such as Arne Naess (1973) and Derrick Jensen (2006), whose appeals towards a pre-industrial 'golden age' (Naess 1989: 176) and natural mysticism present essentialist and idealized approaches to a romanticized nature which allegedly requires protection from human culture (Hayden 2008: 39).

One of the key insights here regards the importance of speed; rates of change are key to knowing whether systems can adapt to environmental alterations. Deleuze (1992c: 627) articulates this as ethology, which he defines as 'the study of the relations of speed and slowness, of the capacities for affecting and being affected that characterize each thing'. Ethology presents considerable overlap with ecology, insofar as both are concerned with flows or, more precisely, with the rates and viscosities of flows through complex systems. Ethology also considers phenomena as existent within a multiplicity of entangled scalar assemblages rather than as discrete and isolatable individuals: 'A thing is never separable from its relations with the world. The interior is only a selected exterior, and the exterior a projected interior' (Deleuze 1992c: 628). An ecological ethic then is concerned with affective capacities and the differential speeds that alter flows of energy and matter. In the current conjuncture, the speeds of 24/7 digital capitalism

are simply incompatible with those of earth's ecological systems. As digital capitalism is ultimately reliant upon these ecological systems, this temporal imbalance places social and environmental systems on a pathway towards ecological catastrophe.

Scale and network politics

Addressing this impending devastation, whereas deep ecologists promote an anti-technological primitivism which seeks to enact the impossible task of reverting cultural damage to pristine nature, Guattari elaborates,

> Wherever we turn, there is the same nagging paradox: on the one hand, the continuous development of new techno-scientific means to potentially resolve the dominant ecological issues and restate socially useful activities on the surface of the planet, and, on the other hand the inability of organized social forces and constituted subjective formations to take hold of these resources in order to make them work. (Guattari 2000: 31)

Media ecology does not advocate abandoning technology; instead, it promotes a fundamental reorientation of techno-scientific practices. In many cases this means moving away from competition, marketization, enclosure and commodification, towards creating new commons and publics designed to benefit ecosystems rather than individuals.

In addition to a critique of contemporary technics, this passage suggests the failure of ecology as a science to present sufficiently moving and humanized accounts of looming ecological crises. As Eric Heroux (2008: 183) observes, 'While science continually delimits its statements for value-neutrality in the traditional project to preserve its objectivity from subjective distortions, this approach proves to be too simplistic and inadequate for a human ecology.' Consequently, Guattari argues for the formation of an ecosophy predicated upon an ethico-aesthetic paradigm which goes beyond the affectively detached observational practices of an ecological science which provides ecological insights, but not ecological technocultural practices.[5] This model of ecosophy is always inherently contested and politicized, rather than gesturing towards a politically neutral objectivity, thereby situating media ecology alongside the approach of political ecology which defines itself

[5]We should note that there are now several high-profile examples of climate scientists explicitly taking political stances as a consequence of decades of scientific data doing little to produce political change. This is exemplified by the scientists blogging at RealClimate, which is discussed in chapter three. The critique of the Anthropocene as a technocratic and depoliticized concept, however, demonstrates that this kind of engagement is far from ubiquitous.

through an explicit rejection of the apolitical approach to ecology often encountered within the sciences (Robbins 2004). Political ecology works to denaturalize social and environmental phenomena, demonstrating that they are not inevitable or simply how the world functions, but are the consequences of particular power relations, and therefore can often be altered to provide more equitable, sustainable and resilient outcomes.

While there are currents within *A Thousand Plateaus* that advocate for forms of micropolitics, this does not denote the dissolution of large-scale collective action in favour of limited and local actions, a claim frequently advanced by critics which cast poststructuralist or postmodernist positions as being inherently conservative due to an alleged inability to confront globalized power structures and political/ecological issues (e.g. Herman 1999; Myerson 2001; Bookchin 1995). Indeed, Guattari quite explicitly proposes that successful responses to certain ecological crises require actions that can only be realized on a global scale: 'The ecosophical perspective does not totally exclude unifying objectives such as the struggle against world hunger, an end to deforestation or to the blind proliferation of the nuclear industries; but it will no longer be a question of depending on reductionist, stereotypical orderworlds which only expropriate other more singular problematics' (Guattari 2000: 44). Addressing issues such as world hunger and deforestation – which we can productively extend to contemporary crises such as climate change, the sixth mass-extinction and the global plastics crisis – as global objectives clearly contradicts critiques which allege that new materialist, poststructuralist and Deleuzo-Guattarian positions exclusively focus upon localized forms of micropolitics.

This focus on operating transversally, across multiple entangled scales does, however, mark a distinction between the position of Deleuze and Guattari and those associated with Bruno Latour and Actor Network Theory (ANT). Media ecology and ANT share notable features insofar as they both approach agency as a distributed and relational phenomenon and extend agential capacities to nonhumans. However, media ecology's engagement with political conflict and scales that range from the imperceptibly fast speeds of digital computation through to the global and geological scales of the Anthropocene departs from the disinterest with power structures, domination, oppression, inequalities and forms of resistance that are associated with ANT. As Nick Couldry (2008: 7) surmises, 'What limits the usefulness of ANT as a research tradition for media analysis and social analysis generally is its relative lack of interest in the long-term power consequences of networks' establishment for social space as a whole and its equality or inequality. For all its intellectual radicalism, ANT comes charged with a heavy load of political conservatism.' Latour would likely retort that the notions of 'long-term power consequences' and 'social space as a whole' are both highly problematic, idealized concepts which are abstracted from the specificities present in the particular networks of relations between actors,

therefore obscuring rather than producing insightful analyses. However, this does not confront the fact that the micro-ethnographic approach of ANT largely ignores hierarchies and inequalities, particularly when these traits manifest themselves over prolonged spatio-temporal durations.

Consequently, Latour (2004: 276) has argued that 'it is useless to denounce capitalism – on the contrary, denunciation only reinforces it'. This formulation contends that discussing capitalism reifies it as a totalizing system from which society cannot escape, so a range of diverse economic practices and policies become an immutable and homogeneous system. Latour contends that discussing capitalism in this way during the Anthropocene inverts premodern approaches to nature and culture; nature becomes radically modified by anthropogenic activity, while culture is governed by fundamental and indisputable economic laws. Consequently, Latour (2014: 9) argues that discussing capitalism merely invokes affects of helplessness and despair: 'I get no other feeling than an increase [*sic*] sense of helplessness. The mere invocation of capitalism renders me speechless. … It might be best to abandon the concept entirely.' Totally abandoning the concept of capitalism, however, has the effect of making ideologies predicated upon competitive individualism invisible and synonymous with common sense. While we should distinguish between various capitalisms, such as mercantile, social democratic and neoliberal capitalism, abandoning the term entirely obscures historical continuities between earlier practices of colonialism and exploitation that have shaped and continue to shape the systems of trade, governance and media that exist today.

Latour has argued that after an initial indifference to the term ANT, he warmed to the metaphor of a researcher taking on the role of an ant, blindly following pheromone trails in order to painstakingly compose a picture of the subject of interest, a process which resembles the methodology employed in studies such as *Laboratory Life* (1979). While this form of analysis reveals the inner workings of a particular scale of practice, the metaphorical figure of the ant also suggests the limitations of ANT when working with larger-scale systems. The ant is a member of a colony, a super-organism whose collective intelligence far exceeds that of its members. The individual ant, however, is destined to remain ignorant of the larger-scale phenomena which are addressed by the scale of the colony. Consequently, when contemporary media scholars such as Jose Van Dijck (2013) have utilized ANT as a method to approach social media, it has been accompanied by political economy in order to additionally address macro-scale phenomena. However, this move simply results in reinforcing the macro/micro and local/global dualisms which ANT seeks to resist through its focus upon networks as a form which allegedly 'allow us to pass with continuity from the local to the global, the human to the nonhuman' (Latour 1991: 121).

In contrast to ANT then, media ecology employs the concept of scale to engage with political conflicts that exist within digital phenomena ranging

from voltages and pixels to global satellite networks and the geological temporalities of plastic waste. While aspects of ANT, particularly nonhuman agency, relationality, and the re-connection of nature and culture, resonate with the conceptual and agential foundations of media ecologies, there are significant differences surrounding their political and ethical imperatives.

Rhizomatic and arborescent tendencies

Perhaps the ecological trope within *A Thousand Plateaus* which has received the greatest volume of attention within accounts of digital media has been the rhizome. The form of the rhizome closely approximates a dynamic distributed network, whereby there is no central point from which information flows. Indeed, a rhizome cannot even be said to be polycentric, with multiple centres of competing power; rhizomes are decentred structures. Information flows through horizontal channels of communication, rather than being sent down a vertical causal chain. Any point of a rhizome can connect to others, much like the peer-to-peer system of the internet. Without a centre, or even rigid and determinate connections, rhizomes present extremely resilient structures. Whereas an individual tree can be killed by severing its centre, its trunk – the vertical foundation on which the leaves and branches sprout forth from – you can plunge a stake into the centre of a rhizome, only for it to grow around the ruptured ground, again echoing the genealogy of the internet as a decentralized telecommunications system that was designed to function after nuclear warfare had annihilated urban centres.

The homologies between the organizational structure of the internet – as a dynamic, distributed network of peers who can freely connect to one another – and Deleuze and Guattari's evocation of rhizomatics has led a strand of media studies to proclaim that the internet presents an example of a rhizome (e.g. Froehling 1997; Poster 2001: 27). Claims that a technological assemblage is rhizomatic, rather than being dominated by rhizomatic tendencies, immediately contradicts Deleuze and Guattari's claims that the rhizome is an organizational model which is always balanced to some extent by arborescent tendencies: 'There are knots of arborescence in rhizomes, and rhizomatic offshoots in roots' (Deleuze and Guattari 1982: 22).

A rhizome is the subterranean mass of roots which comprise the stem of plants including ginger, banana plants, tree ferns and cabbage trees. While the horizontal growth of rhizomes can be understood as a counterpoint to the vertical stem of most arborescent, or tree-like, structures, the key to this metaphor is the fact that certain trees are also rhizomes, and specific rhizomes are also trees. There is not, therefore, an arborescent/rhizomatic binary opposition at work here but an interplay of verticalist and horizontal tendencies which exist alongside one another. The configurations explored

by Deleuze and Guattari, then, are not idealized or essentialized forms but denote attempts to produce a language geared towards mapping the dynamic movements and becomings of complex assemblages across multiple dimensions relating to control, hierarchy and freedom. Using the language of the previous chapter, we can grasp these tendencies as the abstract machines that exert pressures upon assemblages.

While the peer-to-peer structure of the internet seemingly presents a far more inclusive, horizontal and participatory structure than media such as television and radio, it still contains lines of arborescence, such as the tendency of search engine algorithms to direct traffic towards certain areas (Hess 2008) or to produce results that denigrate minorities (Noble 2018), the relatively few pathways that exist for transcontinental communication through undersea fibre-optic cables (Starosielski 2015), and the Domain Name System that requires websites to be registered to an identifiable individual owner (Galloway 2004). Indeed, a cursory examination of the political economy of contemporary internet reveals its domination by a handful of corporations including Facebook, Google, Yahoo, Tencent, Comcast, Verizon, Apple and Samsung. In other words, this is the antithesis of an egalitarian and rhizomatic structure. The globalized telecommunications industry of platform capitalism in the twenty-first century is in many ways typified by a greater degree of arborescent centralization than its nationalist twentieth-century predecessors, despite the fact that these networks and platforms frequently offer users the chance to become (inter)active creators of user-generated content. What we see then, are metamorphic combinations of rhizomatic and arborescent tendencies within existing assemblages of networked digital telecommunications.

While media theorists have frequently misread Deleuzian tropes, it is equally true that Deleuzian theorists have misunderstood digital media. Ian Buchanan (2007) articulates the issues with conflation of rhizomes and the internet; however, he conflates the internet with the World Wide Web and consequently erases the structural differences between the peer-to-peer model of the internet and the web's dependency upon the demarcation between clients (periphery) and servers (centre). Indeed, this difference is expounded by cybercommunists such as Dimitri Kleiner (2010: 8) as the difference between peer-to-peer communism and the client–server capitalist state; whereas the internet is a system of equal peers, the web segregates (most) users from the servers where information is stored, creating a hierarchical division between data seekers and data storage.

More recently, however, there have been commercially successful movements towards harnessing the architecture of the internet to deliver application-based services limited to specific mobile platforms such as Apple's iOS and Google's Android. This usage of the internet presents a significant departure from the open protocols of the web, which, as we shall see, were designed to be hardware neutral. App stores instead form platform-

specific walled gardens which effectively lock users into using hardware from particular vendors. While such moves are obviously advantageous to these corporations, they effectively stifle competition, as prospective new platforms are locked out of the millions of apps found in the iOS and Google Play stores, and thus become a less attractive option. The prominence of these closed, proprietary systems, which shall be explored further in Chapter 4 denotes the existence of additional arborescent tendencies within the contemporary internet.

Equally, we should note that the documents revealed by Edward Snowden expose numerous ways that governmental and intergovernmental signals intelligence agencies leverage the internet and other digital technologies such as mobile phone SIM card identifiers to conduct surveillance at a scale which would have been unimaginable prior to the widespread diffusion of mobile networked digital technologies (Pugliese 2010; Taffel 2015). As David Lyon (2014) demonstrates, corporate and governmental surveillance are mutually beneficial regimes, with the data used by social media platforms to provide targeted advertising requiring these platforms to harvest a range of data associated with real-name user profiles, providing a rich vein of material for state agencies such as the NSA, who can access these data streams through platforms such as Xkeyscore and Prism.

Across this broad range of examples drawn from across political economy, surveillance studies, software studies and critical infrastructure studies, what we see are various new modes of hierarchy and corresponding concentrations of knowledge and power that are made possible by the digital telecommunications environment. Consequently, we must address the internet not as a rhizome, but as an assemblage which contains both specific rhizomatic tendencies and arborescent reterritorializations. Mapping the rhizomatic and arborescent tendencies within media assemblages, considering the potentialities for radical change and the ways that this potential is negated and foreclosed through reterritorializations, therefore becomes an important task for media ecology.

Process philosophy and politics

Ecology focuses upon flows of energy and matter through entangled assemblages. From the perspective of ecological process philosophy, a central epistemological pathology is a misplaced focus upon individual objects, such as an iPhone, rather than the diverse flows of energy and matter that traverse multiple spatial, temporal and relational registers. An iPhone requires the assembly of geographically distributed materials that have taken millennia to coalesce. The energy required to mine, manufacture and power the device requires the combustion of fossil fuels whose formation involves a similarly slow temporality. Once discarded, the ‘waste’ materials

will continue to transform ecological systems for durations that humans struggle to comprehend. iPhones additionally require terrestrial networks of cellular towers, transoceanic fibre-optic cables and orbital GPS satellites to function. While it is typical to think of the iPhone as a discrete possession, an individual object, it is part of multiple flows of matter and energy whose ecological affects are rarely explored or understood precisely because we mistakenly conceive devices as existing in isolation from systems and infrastructures.

Consequently, an ecological ethics seeks to map these differing types of movement and flow across ecological registers. Following Deleuze and Guattari, we should grasp that not all change is desirable, lines of flight (bifurcations) and modes of cancerous growth can lead to destructive as well as emancipatory change:

> If you blow apart the strata without taking precautions, then … you will be killed, plunged into a black hole, or even dragged towards catastrophe. Staying stratified – organized, signified, subjected – is not the worst that can happen; the worst that can happen is if you throw the strata into demented or suicidal collapse, which brings them back down upon us heavier than ever. This is how it should be done: lodge yourself on a stratum, experiment with the opportunities it offers, find an advantageous place on it, find potential movements of reterritorialization, possible lines of flight, experience them, produce flow conjunctions here and there, try out continuums of intensities segment by segment, have a small plot of new land at all times. (Deleuze and Guattari 1982: 178)

Examples of catastrophic change where structures are blown apart into a suicidal collapse include the sociopolitical upheavals surrounding regime change in Iraq following the second Gulf War and Libya during the Arab Spring. In both cases there were lines of flight that saw radical change enacted upon populations and organizational structures; however, those changes – which in both cases saw the removal of oppressive, hierarchical dictators – preceded precisely the kind of collapse into even more repressive systems that Deleuze and Guattari elucidate. While *A Thousand Plateaus* presents an ethic that accords importance to speeds, affect and becoming, this does not mean that rapid change is always valorized. Indeed, returning to climate change, it is precisely the velocity of eco-systemic alteration and the potential for crossing points of critical instability that pose such grave threats to the continuation of life as we know it.

This ethic of experimentation with flows and intensities is ontologically grounded in the abstract machines of attractors and bifurcations which were explored in the previous chapter. As these abstract machines are equally constitutive of both organic and nonorganic dynamical systems balanced far from equilibrium, Manuel DeLanda (1992: 153) argues,

'We are all inhabited by processes of nonorganic life. We carry in our bodies a multiplicity of self-organising processes of a definite physical and mathematical nature – a set of bifurcations and attractors.' In place of the binary oppositions of (human) culture and (organic) nature, and the living and inert substrata of nature, there stands what Deleuze and Guattari describe as the machinic phylum. Not only are humans no longer ontologically distinct from other life forms, but open systems of living and nonliving matter are also connected and created by the same nonlinear processes and are thus governed by the same abstract machines, an arrangement which is equally applicable to tornadoes and tsunamis on the one hand and tomatoes and turtles on the other.

DeLanda consequently argues that human societies, as complex dynamical systems, evolve via bifurcations between numerous temporarily stable configurations and thus that 'an ethics of everyday life, in these terms would involve finding the relative viscosities of our flows, and giving some fluidity to hardened habits and making some fleeting ideas more viscous – in short, finding, through experimentation, the "right" consistency for our flows … the exact consistency that would allow humanity to self-organize without the need for coercion and war' (DeLanda 1992: 153/154). This position suggests that autopoietic systems operate within a finely tuned range described as the 'edge of chaos' (Kauffman 1995); if a system is too structured then its inability to flow limits its adaptive capacity to evolve and adapt to changes within its environment. On the other hand, if a system is too susceptible to small changes, that is, if it is too chaotic, then it will not be sufficiently stable to maintain its existence. For dissipative systems to proliferate requires this fine balance between order and chaos, change and stability.

There are, however, acute differences between the positions of Guattari/Deleuze and DeLanda when we move from ethics to political methods of collectively enacting ethical frameworks. This is visible with regard to their respective stances concerning the enduring value of previous paradigms of social change, particularly Marxism, which DeLanda (2010: 43) contends was Deleuze and Guattari's own 'Oedipus, the little territory they did not dare to challenge'. While DeLanda has a point, insofar as Marx's labour theory of value is predicated on a humanism which is inconsistent with the approach favoured by Deleuze and Guattari,[6] his critique neglects the ways that Deleuze and Guattari depart from Marxist analyses, contending that 'although Marx's writings still have great value, Marxist discourse has lost its value' (Guattari 2000: 43/44).

[6]We should again note Marx's (1976: 637/638) argument surrounding the metabolic rift of capitalism which robs both the worker and the soil. This posits that value derives from interactions between humans and environment.

This departure from orthodox Marxist perspectives have seen Marxists such as Jodi Dean (2009: 8) and Slavoj Zizek contend that Deleuze is 'the ideologist of late capitalism' (Zizek 2004: 293), that the focus upon fluidity, dynamism, horizontal organization and minor politics are all strategies which have become central to neoliberalism, and thus the politics of *A Thousand Plateaus* has itself been reterritorialized. There is undoubtedly an element of truth to claims that elements of the radical politics of Paris in 1968 – especially notions that difference and cultural diversity are in and of themselves somehow opposed to capitalism – have subsequently been reterritorialized by neoliberalism. We should, however, bear in mind that as theorists of movement and dynamics, of how radical deterritorializing possibilities are nullified and integrated into capitalist systems through processes of reterritorialization, Deleuze and Guattari's positions surrounding the dynamism of capitalism pre-empts precisely the type of criticisms levelled by Dean and Zizek. Additionally, it is important not to lose sight of the distance between the rhetoric of corporate flexibility, horizontality, social and environmental responsibility and the underlying practices which accompany them; a marked rise in mental health issues, economic inequalities and ecological exploitation; a range of undesirable impacts across the registers of the three ecologies. Consequently, claims that the ethics and politics espoused by Deleuze and Guattari are compatible with, let alone exemplified by, neoliberalism appear to be well wide of the mark.

Furthermore, we should emphasize the central thematics of the later writings of Deleuze and Guattari when considering their relation to contemporary politics. This chapter has explored Guattari's ecosophical position and his critique of integrated world capitalism, but of parallel importance is Deleuze's work surrounding societies of control. For Deleuze, by the 1990s – when neoliberalism was widely considered to have succeeded Keynesianism – societies were decisively moving away from the disciplinary model outlined by Michel Foucault (1970), towards one dominated by cybernetic prescriptions of control. Deleuze argues that this transition is marked by the supersession of entropic mechanical machines by computers, of Fordist factory production by flows of financial capitalism and marketing, and of subjects who were predominantly formed in the distinct spaces of the school, factory and prison to the datafied 'dividual', which is constantly being modulated, analysed and reformulated.

Deleuze resists the urge to rank regimes of disciplinarity and control as being better or worse than one another, arguing, 'There is no need to ask which is the toughest or most tolerable regime, for it's within each of them that liberating and enslaving forces confront one another. … There is no need to fear or hope, but only to look for new weapons' (1992b: 4). This new societal logic requires novel strategies for resistance and constructing ways of living that leverage the material affordances of computation, while

accepting that particular tools and tactics that had proven effective under the logic of disciplinarily – such as trade unions – are likely to be less potent within societies of control.

The focus upon cybernetic-derived control as forming the diagrammatic logic of contemporary societies, on the one hand, and radical ecosophy, on the other, illustrates precisely why Deleuze's and Guattari's analyses are central to my theoretical framework for media ecologies. Bearing this in mind, it is difficult to reconcile their positions with claims that they are ideologically aligned with neoliberal capitalism. Writing from a position parallel to the tradition of Marxism, they seek to update and advance the movement which animated the majority of anti-capitalist struggles for social justice throughout the twentieth century. This contrasts with the approach adopted by DeLanda, who identifies broadly with the left, and convincingly argues for the need for left-wing politics to be grounded in a materialist ontology – something he holds in common with Marxists – but which largely fails to address the potential rejuvenation of Marxist or socialist traditions, as he finds little value within them.

My own writing is in this sense politically closer to that of Deleuze and Guattari, and contemporary authors who have similarly sought to situate their work in relation to contemporary social movements such as Bernard Stiegler, Antonio Negri and Franco Berardi. These theorists stress the necessity of connecting political philosophy to existing social structures and activist movements, rather than existing within a theoretical vacuum. In the following section, I explore how these contemporary theorists have advanced arguments surrounding an ecology of the common, and how specific calls around openness and commons can influence media ecology.

Commodities and commonwealth

Since the 1970s, society has undergone a paradigm shift which has seen older forms of left-wing politics rendered redundant by transformations to institutional structures. These changes are traced by Hardt and Negri to the countercultural movements of the 1960s and 1970s, the hippy, feminist, civil rights, LBGT, punk and other subcultural movements that expressed dissatisfaction with the homogenized manifestations of mass culture. Consequently, capitalism had to reinvent itself, reterritorializing the field of identity politics and transforming politics into biopolitics: 'Capital had to confront and respond to the new production of subjectivity of the proletariat. This new production of subjectivity reached (beyond the struggle over welfare) what might be called an ecological struggle. A struggle over the mode of life' (Hardt and Negri 2000: 269). Resultantly, the contemporary mode of capitalism that Hardt and Negri term 'Empire' reaches beyond the Foucauldian disciplinary society that was based upon

vectors of subjectification that were tied to specific locations such as the school, the prison and the factory.

Instead, in a manner heavily influenced by the control society depicted by Deleuze (1992b), Hardt and Negri contend that today power circulates within a cybernetic system that leverages digital computers to provide automated and continually modulating forms of feedback-based control over subjects. Following Foucault, they describe this as a move from the power exercised by a sovereign state to that of biopolitics, of control exercised of and over life itself. From this perspective, difference is no longer a threat to the singular composition of 'the people', but has become an opportunity to increase profitability by selling countless alternative consumer lifestyles to differentiated subjects. Hardt and Negri (2000: 138) therefore argue that 'postmodernist and postcolonial theorists who advocate a politics of difference, fluidity and hybridity in order to challenge the binaries and essentialism of modern sovereignty have been outflanked by the strategies of power'.

The exploration and critique of contemporaneous moves towards the commodification of difference, identity and desire resonates strongly with the central thematic of Franco Berardi's writings. Like Negri, Berardi was both a member of the Italian autonomist movement and a close friend of Guattari. Berardi contends that since the 1980s, societal changes wrought by the introduction of digital computing technologies have seen the human faculties, which in previous eras were considered to be constitutive of the soul – our capacities for language, creativity, emotion and empathy – become increasingly central to the economy through the commodification of desire:

> Putting the soul to work: this is the new form of alienation. Our desiring energy is trapped in the trick of self-enterprise, our libidinal investments are regulated according to economic rules, our attention is captured in the precariousness of virtual networks: every fragment of mental activity must be transformed into capital. (Berardi 2009a: 24)

Whereas for autonomist Marxists such as Berardi, this commodification of human attention is characterized negatively as the new form of alienation endemic to neoliberalism, it should be noted that for liberal capitalists such as Clay Shirky (2010), this development is lauded as the generation of a 'cognitive surplus'. Here the emphasis is upon the integration of what had previously been 'unproductive' leisure time into the production of monetary value. While the novelty of this situation may be contested by analyses of the political economy of the media which have long emphasized the role of the audience commodity (Smythe 1981), it is worth noting how voices which both valorize and decry the marketization of attention highlight the commodification of attention as a crucial feature of the contemporary

technocultural milieu. Consequently, exploring flows of attention will be one of the central themes of the following chapter which explores ecologies of digital content.

Hardt, Negri and Berardi all agree upon certain strategies likely to effect beneficial changes to this system, surrounding re-evaluating value and wealth. Whereas neoliberal definitions approach wealth in a strictly quantitative manner dependent on gross domestic product, entailing that wealth equals money, a perspective Berardi (2009a: 169) derides as 'economistic fanaticism', these authors instead propose that wealth is approached from an ecological perspective, which surpasses a humanist theory of value.

> Whereas the traditional notion poses the common as a natural world outside of society, the biopolitical conception of the common permeates equally all spheres of life referring not only to the earth, the air, the elements, or even plane and animal life but also to the constitutive elements of human society, such as common languages, habits, gestures, affects, codes, and so forth. Whereas for traditional thinkers such as Locke and Rousseau, the formation of society and progress of history inevitably destroy the common, fencing it off as private property, the biopolitical conception emphasizes not only preserving the common but also struggling over the conditions of producing it, as well as selecting among its qualities, promoting its beneficial forms, and fleeing its detrimental corrupt forms. We might call this an ecology of the common – an ecology focused equally on nature and society, on humans and the nonhuman world in a dynamic of interdependence, care and mutual transformation. (Hardt and Negri 2009: 171)

The emphasis on understanding commons as distributed wealth, which flows through not only human but broader ecological systems, is a crucial concept in an ecological theory of value, which enlarges understandings of wealth, contending that economic wealth is merely one form among many, including personal psychosocial and physiological well-being, social justice and equitability, environmental diversity and resilience.

This ecologically informed approach to wealth and value, and the importance of the commons to it, resonates with debates over Free/Open Source and proprietary forms of software, whereby software is produced either as a commodity or as commons. Indeed, software is seen as an exemplary case study of how the infrastructure of the network society affords the capacity for the distributed, collaborative construction of an informational commons, a point that is emphasized by theorists such as Michel Bauwens and Stiegler, who like Hardt and Negri claim that the free software movement demonstrates that open systems which peer-produce commonwealth provide positive externalities which exceed economic impacts, benefiting subjective, social and ecological systems.

If this activity merely takes place at the scale of software, however, there remains a danger of creating an opposition between the 'creative', 'valuable' work of coding and the relatively undervalued task of producing the hardware required for this creative activity. Consequently, Stiegler, Bauwens, Hardt and Negri all contend that models of peer production must go beyond the realms of software and Creative Commons-licensed content, and extended to incorporate hardware: 'Such an infrastructure must include an open physical layer (including access to wires and wireless communications networks), an open logical layer (for instance, code and protocols) and an open content layer (such as cultural, intellectual and scientific works) (Hardt and Negri 2009: 308).

The remainder of this book takes up Hardt and Negri's call by examining models of openness and commonwealth across the differing scales of content, software and hardware, exploring innovations and considering the obstacles these systems face in terms of constructing media ecosystems which enact alternatives to neoliberal models predicated on privatization and consumerism.

We should, however, sound a note of caution surrounding an unconstrained valorization of openness. As we shall see in Chapter 4, while the cooperativism of open source software may be antithetical to a rigid ideology that competition in deregulated markets is the ideal and most efficient economic form, in practice capitalism has always been more dynamic than this and has repeatedly proved capable of reterritorializations precisely because of this flexibility. As a result, we have seen corporations such as Google, IBM and Microsoft successfully utilize open source software to enhance profitability. While the early rhetorics of free and open source software (much like those of the early internet) were of a radical alternative to corporate capitalism, with Microsoft's Steve Ballmer describing it as 'communism' and a 'cancer', much of that radical potential has now been harnessed as a means of increasing corporate profitability while leveraging the benefits of free or crowdsourced labour.

A conceptual toolbox for media ecology

The ecological ethics and politics outlined in this chapter contend that media ecology should present pragmatic alternatives to contemporary practices that currently orientate societies towards ecological catastrophe. Rather than casting ethics as the means to adjudicate actions as right or wrong (using either deontological or consequentialist logics), an ecological ethic is orientated towards an experimental praxis. It approaches conflicts surrounding commodification and commons in digital assemblages to enact bifurcations that form new mutualisms and which internalize externalities in order to bring forth more equitable and resilient technocultures. This

ethic therefore departs from normative understandings of how schemata of right and wrong behaviours for individual subjects are rationalized (Singer 1986), instead positing that ethics relate to collective assemblages rather than atomized individuals. Building on the previous chapter's exploration of technology, complexity and agency, I have considered how ecology and entanglement suggest a series of onto-epistemological and ethical shifts. Based upon the framework of the three ecologies espoused by Bateson and Guattari in conjunction with Hardt and Negri's call for open physical, logical and content layers, I am interested in how a parallel approach to media ecology explores content, code and hardware in order to consider questions of commonwealth, commodification, openness and ecological resilience when exploring the political, ethical, affective and agential dimensions of contemporary digital media systems.

This chapter also explored how an ecological model of value departs from the normative model provided by neoliberalism, whereby quantitative economic value is presented as the primary determinant of wealth. An ecological approach posits value at a multiplicity of levels, including subjective well-being (where notions of the subject or mind always exceed the notion of an atomized individual), social justice and ecological resilience. Whereas neoliberalism is associated with the externalization of extra-economic costs onto social and environmental systems, an ecological system of value seeks to internalize these costs into systems of valuation. Gaining short-term profitability at the expense of long-term ecological resilience repeats the epistemological error described by Bateson, which will ultimately see the collapse of the purposive system seeking to maximize individual (personal, corporate, national or other individual forms) benefits while damaging its ecology. Broadly speaking, ecology values difference and biodiversity over monocultural uniformity and building commonwealth and community over commodities. In each case, these pairs should not be reduced to binary oppositions, but thought through as poles on a continuum which offer a multiplicity of potential futures, following the Deleuzian logic of the AND. The choice is not either/or, but between the precise balance of combinations which are actualized at any moment.

In Part 2 of the book, I seek to apply an approach informed by the theoretical content that has been outlined during Part 1 to technocultural systems viewed through the scales of content, code and hardware. While in practice these components are entangled and therefore inseparable, by approaching them individually we can see how various conflicts and tensions sit within and across these three areas. Each of these chapters eschews the familiar approach of the singular case study which frames the phenomena being examined, instead assembling a diagram from numerous different cases that foreground the multiple scales that are operative within the major focus of the chapter. Rather than each scale being a singular and bounded whole, they are approached as assemblages that are themselves composed

of assemblages. Following Barad, each section of the chapters forms a cut that allows us to perceive these assemblages from a different vantage point, and by making a series of these cuts we build a partial portrait of key sites of conflict and interest within digital media ecologies. Rather than a smooth space of uniformity, this method explores scalar ecologies through difference and bricolage.

The next chapter explores ecologies of content across various scales. It begins by exploring discourses, practices and architectures surrounding the economy of attention and thinking about how Big Data alters how we comprehend content, before moving on to examine the specific case of Climategate, an episode where an international news scandal developed following the release of emails sent by climate scientists which were originally published on climate change sceptic blogs. Methodologically, this gleans different types of insight about information and attention from very different methods of analysis. Following the theoretical approach which has been outlined in Part 1 of this book, media ecology seeks to synthesize what emerges from these different scales of content about the relationships between contemporaneous relationships between communication and capitalism, activism and agency.

The subsequent two chapters contained in Part 2 operate on a homologous basis. Chapter 4 examines forms of software that range from firmware to networking protocols, as well as exploring open source and closed/proprietary modes of software production, whereas Chapter 5 explores the linear life cycle of digital devices where planned and perceived obsolescence are key design parameters, in addition to specific issues that arise at numerous key junctures within that cycle, from extracting raw materials from the crust of the earth through to the disposal of toxic electronic waste. Each chapter demonstrates how multiple scales are operative within and across each of these entangled digital ecologies. Through a process of assembling, a range of sites and spaces of conflict are introduced in order to consider the political ecologies of digital media.

PART TWO

Ecologies of content, code and hardware

3

Flows of attention and data

Any attempt to address the political ecology of digital content is immediately confronted with the enormity of the domain of contemporary digital mediation. Whereas in the late-twentieth-century information and media were (relatively) scarce due to the expense associated with production and distribution, today digital information is inexpensively produced by billions of humans and nonhumans. The enhanced scope of digital mediation sees everything from bodily functions, such as the number of steps taken and minutes slept each day, through to urban traffic and financial transactions now producing digital data which is networked, databased and used to predict and affect future behaviours (Amoore 2013).

In this new media ecology, exploring the affordances associated with the speeds and volumes of digital mediation alongside the viscosities and affects of flows of data and attention is key to grasping the spatial, temporal and political transformations being enacted. Consequently, this chapter begins by examining some of the claims surrounding informational abundance and how this produces an economy of attention, whereby attention displaces information as the systemically scarce property within mediated ecologies. This is followed by a critical exploration of Big Data, explicating numerous limitations associated with data-driven positivism, a discourse which contends that newfound access to connectable, real-time digital datasets renders critical, theoretical and qualitative investigation redundant in the face of the allegedly self-evident empirical truth. Furthermore, the assumed objectivity of Big Data frequently builds existing inequalities into opaque technological systems that are difficult to challenge precisely because they are mistaken for ideologically neutral mathematical technics.

After examining the attention economy and Big Data, I then shift scale to consider how the public sphere has been altered by the move towards a networked information ecology. Whereas the earlier parts of the chapter are

relatively technical, this section is more closely concerned with how human actors within digital assemblages produce meaning and knowledge from online encounters. To provide a useful overview of the ecology of content, we must consider the technical, political–economic and human discursive elements of the assemblage together, rather than solely focusing upon human/discursive or nonhuman/material components. Using the example of 'Climategate', this section of the chapter provides a very different aperture through which to view digital content, albeit one that again raises questions surrounding attention and speed.

The chapter concludes by bringing key insights into conversation with the model of communicative capitalism, which argues that communication has become a key driver of growth for contemporary capitalism. Whereas early rhetorics of the internet as a postmodern public sphere celebrated globalized, participatory communicative spaces as politically emancipatory and democratizing, communicative capitalism argues that digital communications effectively forecloses critical political debate. The conclusion asks how it may be possible within this technocultural context for the left to meaningfully engage in digital discourse that escapes the filter bubbles constructed by social media algorithms and goes beyond tokenistic clicktivism.

Economies of attention

A commonly heard mantra within vernacular discourses of digital culture is that the internet is fundamentally divorced from the logic of informational scarcity. Famously, Google CEO Eric Schmidt stated in 2010 that we now create as much information every two days, as the human race had created from the dawn of existence until 2003,[1] somewhere in the region of 5 exabytes[2] of data. By 2016, the amount of information being globally generated had risen to over 16 zettabytes[3] a year (Press 2016), 3200 times more information than was produced in 2003. This rate of data growth is still increasing, in no small part due to the massive increase of networked digital devices commonly known as the internet of things which is forecast to grow from two billion devices in 2006 to over 200 billion devices by 2020 (Intel 2017). As Jonathan Crary (2013) notes, whereas the rhetoric of the digital revolution suggests a singular moment of disruption followed by stabilization, the reality is that the changes associated with digital

[1]There are doubts over the accuracy of Schmidt's original claim, with a Berkeley University study from 2003 finding that there had been 5 exabytes of information produced in 2002 alone.
[2]An exabyte is 10^{18} bytes; one million terabytes.
[3]A zettabyte is 10^{21} bytes; one thousand exabytes/one billion terabytes.

technologies are increasing in pace. This begs the question as to whether humans can or will ever 'catch up'.

It must, however, be emphasized that the expansion of data storage and transmission is a thoroughly material process in which the microscopic spatial scale of microelectronics affords the storage of vast volumes of data in comparison to older media forms such as books. To highlight this, we can consider the different amounts of space taken up by books and magnetic hard disk drives by comparing the space occupied by the seventeen million books held in the US Library of Congress with Google's data centres. The Library of Congress holds a 'mere' 136 terabytes of information, less than the volume of data contained within a single rack within a contemporary data centre.[4] While information has been spatially condensed from the letters on each page to the nanometre-sized magnetized grains found upon hard disk drive platters or the similarly microscopically sized transistors within solid state disk drives, it is in no way dematerialized or magically transformed into free-floating information. The key point here is that computational hardware operates at miniscule spatial scales and that the technical processes which play a pivotal role in the expansion of digital culture are often poorly understood by the general public and cultural theorists.

While the microscopic materialities of media technologies are often mistaken for dematerialization, the global networks of fibre-optic cables, internet exchange points, cellular towers, server farms and other infrastructure of the internet are equally obfuscated by the metaphors of cloud computing and virtualization. Media ecology seeks to foreground the material processes of mediation and the mattering of technology as a way of drawing attention towards architectures of digital culture and the social and environmental impacts associated with digital infrastructures, while foregrounding the fallacy within the common-sense perception that the internet is a static or homogeneous thing. As work in critical infrastructure studies has demonstrated, technological infrastructures require an enormous expenditure of energy, labour and attention to continue to function smoothly as maintenance and repair are vital to their functioning, but this activity is typically invisible as infrastructures only become visible when they cease to function (Graham and Thrift 2007; Mattern 2018). Consequently, media ecology approaches the internet as a dynamic assemblage, a constantly evolving network of networks within which bandwidth – the carrying capacity of the network infrastructure – is regularly being both maintained and increased in order to cope with the growing volumes of devices and traffic. Indeed, the changing bandwidth afforded by this expanding infrastructure affects the form in addition to the volume of information which is transmitted.

[4]In 2017, a single 60-disk 4U server contains up to 480TB of storage.

When the internet predominantly utilized copper telephone wires and dial-up modems with speeds of around 28 kilobits per second, text and heavily compressed low-resolution images were the main media forms utilized. Following the advent of broadband internet, with speeds of over 1 megabit per second (1,000 kilobits per second), video became viable as a medium. YouTube, which was founded in 2005, initially allowed videos to be streamed at a resolution of 320x240 pixels. As the bandwidth and connection speeds available to both YouTube's servers and its users' PC connections increased, so did the maximum resolution of the videos, with resolutions of 480x360 and then 1280x720 becoming available in 2008, followed by 1920x1080 in 2009 and 4096x2160 (4K) in 2010.[5]

Alongside the spatial resolution of images, their bitrate is key to the file size, and thus the requisite bandwidth required to view videos as a real-time stream. Video streaming services such as YouTube and Vimeo use low bitrate, long group of pictures (GoP) codecs (compression/decompression algorithms – see Mackenzie 2008) in order to allow high spatial resolutions to be achieved while requiring relatively low bandwidths. A long GoP codec compresses the information in such a way that most of the individual frames in the video stream[6] do not contain all of the pixel-level information. Instead, these frames use macroblocks which scale in size (depending upon the specific codec utilized) between 2x2 and 8x8 pixels based upon the amount of movement within the particular region of the frame.

Rather than requiring per-pixel data, the codec deals with macroblock movement by applying a vector to them, thus requiring far less data to accomplish the same movement as a pixel-level transformation. This does not result in an apparent loss of quality to the viewer, as typically there are large regions of a video image which remain unchanged between most frames. For example, within a close-up shot there is only likely to be significant movement around the mouth and eyes. The rest of the frame, which has minimal movement, can be divided into larger macroblocks without perceptibly altering the image. The exception, where it is important to have full-frame pixel-level data is when there is a cut to another scene or shot, where typically every pixel in the image changes, so each cut is followed by a keyframe that ensures that this new arrangement is accurately rendered.

Long GoP codecs (such as the popular h264 (MPEG-4) codec) often utilize P (predicted) and B (bi-directionally predicted) frames, which depart

[5]As of 2018, average connection speeds were 18.7 megabits per second in the United States and 16.9 megabits per second in the United Kingdom. South Korea has the fastest average connection speeds of 28.8 Mb/s. The global average is 7.2 Mb/s.

[6]Typically, 24 frames per second for digital cinema, 25 frames per second for regions which historically adopted the PAL system for television broadcast and 30 frames per second for regions who traditionally used the NTSC system.

from I (intra-coded) frames which contain macroblocks which are coded with reference only to the pixel data of the frame itself. P and B frames both require prior decoding of other elements of the image stream to be calculated; P frames use macroblock data from previous images to determine the vectors of movement within the frame, and B frames use predicted data from both preceding and following frames to determine the motion vectors to apply to the macroblocks. The end result is the production of files whose size is often miniscule in comparison to codecs which use pixel-level data for each frame. For instance, the popular ProRes 422 and DNxHD codecs used for editing and mastering both support 1920x1080 footage at bitrates up to 220 megabits per second, whereas material encoded at the same spatial resolution using the h264 codec for commercial Blu-ray disks have a maximum bitrate of 48 megabits per second and YouTube's h264 1080p streaming uses a bitrate of 8 megabits per second.

A crucial point which arises from this is that because of the technicalities associated with compression, the volume of information or size of a file do not necessarily relate directly to changes in content which are perceptible to end-viewers. Although high-definition YouTube videos are of noticeably lower quality than Blu-ray disks because of the bandwidth constraints of streaming, commercial Blu-ray disks are not usually of a noticeably lower image quality for playback than ProRes files which are over four times the size. While there are significant differences between the two files, these are primarily in terms of the amount of computational power required to decode the image stream in real time and the extent to which data which can be manipulated and altered within the image. When keying[7] or colour grading video footage, the extra detail from the per-pixel information and extra colour depth is useful in being able to accurately extract regions of the image for specific postproduction processes, explaining why ProRes and DNxHD are primarily employed within postproduction workflows, as these advantages are largely irrelevant to the end users of media content.

The point of engaging in this level of technical detail with regard to digital data is that this case demonstrates that when discussing volumes of digital information, the number of magnetized regions on a hard disk drive does not necessarily reflect human perception of that data, especially in terms of how much attention is required to engage with that information. The 136 terabytes of information in the US Library of Congress would require many lifetimes for a single human to read every page of each book, but that same volume of information only comprises approximately 100 hours of uncompressed RAW 4K video footage.

[7]Chroma keying is the technical name for the digital postproduction process whereby a selective colour is removed from a scene, typically a bright green and which is commonly referred to as greenscreen.

While the contemporary telecommunications ecology creates a situation whereby the relative scarcity of information before the twenty-first century has been replaced by concerns of information overload (Carr 2008; Andrejevic 2013), it would be wrong to assume that this new milieu removes the constraints of scarcity. While those humans who have internet access do not suffer from an inability to acquire diverse forms of content, the issue of scarcity moves from accessing materials to having the time to meaningfully engage with this content. 'A wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes. What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention' (Simon 1971: 40). Scarcity is thus understood as a systemic property which exists within a technocultural assemblage composed of human and nonhuman elements. Where the transformation of particular lines within the meshwork increase flows, another area now becomes the site of blockages or scarcity. Consequently, attracting and maintaining human attention becomes a driving force within the digital economy (Crogan and Kinsley 2012).

Early versions of an internet-derived economy of attention are found in the works of Michael Goldhaber (1997) and Georg Franck (1999), whose work productively identifies the limits of the discourse of informational abundance, but who argue that information technology will generate an economy of attention which is wholly removed from material production and scarcity. Such claims that an economy of attention leads towards a post-industrial model of cognitive capitalism fail to recognize the complex material processes which underpin computational capitalism. Franck accordingly argues that the dematerialized economy of attention is 'an already practically experienced preliminary stage of future ecologically non-harmful lifestyles', assuming that telecommunications networks have no harmful material impacts. Whereas various deleterious impacts pertaining to digital hardware are explored in detail in Chapter 5, at this juncture it is worth signalling that many theorists of the attention economy conflate computational assemblages with immateriality, before moving on to consider how digital economies of attention are argued to affect what Guattari and Bateson refer to as mental ecologies.

Franco Berardi's work in this area centres upon the discrepancy between a 'cyberspace' which often appears limitless because of the exponential increases in computational processing power, storage and bandwidth over the past thirty years, and a 'cybertime' whereby the organic machinery underpinning the lived experience of temporality – the human brain and body – is unable to match these increases in speed.

> The acceleration of information exchange has produced and is producing an effect of a pathological type on the individual human mind and

> even more on the collective mind. Individuals are not in a position to consciously process the immense and always growing mass of information that enters their computers, their cell phones, their television screens, their electronic diaries and their heads. However, it seems indispensable to follow, recognize, evaluate, process all this information if you want to be efficient, competitive, victorious'. (Berardi 2009b: 40)

The pressure on the human elements of the assemblage to keep pace with the accelerated rate of technological change presents itself via socially undesirable behaviours and increases in anxiety and mental health issues. This is primarily attributed to human attention becoming increasingly occupied by a range of competing corporate platforms and devices who use a wealth of personal data to provide individualized and quantifiable media experiences, rather than spending time building unquantifiable relationships with other humans which go beyond clicking 'like' or sharing emoji or GIFs.

Along similar lines, N. Katherine Hayles has argued that the contemporary technocultural milieu has produced a shift in cognitive modes, away from the deep and sustained attention which was dominant throughout the nineteenth and twentieth centuries, and towards a form of hyper attention which is characterized by having attention split between multiple forms of simultaneous mediated communications, such as playing a videogame while listening to music or web browsing on a tablet while watching television. Drawing upon work which examines processes of synaptogenesis and neuroplasticity, whose conclusions resonate with her earlier writing on posthumanism which contends that technical environments co-produce human subjects, Hayles (2007: 192) makes the case that humans growing up in contemporary media rich cultures 'literally have brains wired differently from those of people who did not come to maturity under that condition'.

This diminished capacity of young people to engage in a sustained manner with a single text demarcates an issue which challenges the central mode of learning within traditional academic contexts that valorize deep attention. Hayles goes on to explore the correlation between the technocultural mode of hyper attention associated with digital media cultures and the rise in attention deficit hyperactivity disorder (AD/HD), contending that the shift towards a more fragmented and stimulated mode of attention has led to a dysfunctional society in which 'compensatory tactics are employed to retain the benefits of deep attention through the artificial means of chemical intervention in cortical functioning' (Hayles 2007: 192) through the widespread prescription of pharmaceutical drugs such as Ritalin and Dexedrine.

Although Hayles does present some nuance within her argument, emphasizing that her model of cognitive modes must be understood as a

spectrum in which the contemporary technocultural milieu enacts a shift in the mean towards hyper attention, rather than a straightforward change between modes, her model is still somewhat simplistic, especially in its claims surrounding AD/HD. Whereas the diagnosis of these disorders arise out of a complex and multifaceted situation whereby a biopolitical paradigm permits particular modes of culturally coded and regulated behaviours in public spaces and increasingly disciplines bodies which breach these codes through biochemical intervention, Hayles largely reduces this system to a single technical factor – time spent with media by youths. This is not to say that the type of hyper-stimulation and regular neurochemical rewards associated with videogames, social media and other modes of digital technology do not promote particular processes of synaptogenesis which condition modes of attention but that to treat this as the only or main cause of rising AD/HD rates without considering the wider cultural ecologies in which the technologies are a part is to succumb to a technocentric ideology.

Claiming that young people today have brains which are wired differently to previous generations contains some truth, in that a different environment will engage plastic neurological systems in different processes of synaptogenesis; however, Hayles suggests that this plastic and dynamic process is far more solid and static than the neurological evidence suggests. The metaphor which asks us to consider neural pathways through the prism and engineering promotes the notion that once young brains begin developing in tandem with particular technologies they are destined to always function that way. The trope of neuroplasticity counterintuitively becomes a way of positing a hardwired subject which is the opposite of a plastic and malleable one.

A very different way of understanding the type of multitasking which Hayles negatively characterizes as hyper attention can be found in Stuart Moulthrop's work surrounding gaming, play and configuration. While being broadly critical of the zero-sum violence-driven win/lose paradigm exemplified by the first-person shooter, Moulthrop argues that as a systems-modelling medium which allows for playful and experimental encounters with complex dynamical rule-based systems, gaming can provide a useful way of understanding contemporary life:

> Games – computer games in particular – appeal because they are configurative systems within continuous loops of intervention, observation and response. Interest in such activities grows as more people exchange e-mail, build weblogs, engage in chat and instant messaging, and trade media files through peer to peer networks. As in various sorts of gaming, these are all in some degree configurative practices, involving manipulation of dynamical systems that develop in unpredictable or emergent ways. (Moulthrop 2004: 63/64)

Within game studies, similar observations have been made surrounding the tendency within competitive online games such as *World of Warcraft* or *League of Legends* for participants to form 'cross functional teams' (Gee 2008: 33), where each individual player is required to have deep knowledge of a particular specialism but must additionally comprehend the importance of other roles and how these roles interact with the rule system governing the game.

This mode of configurative systems awareness is proposed by some within game studies (e.g. McGonigal 2008) as providing a way of grasping twenty-first-century ecological and biopolitical problematics, such as understanding the complex dynamics of long-term climatic change, short-term climatic variability and the collective and individual agencies of humans to intervene in such systems. In contrast to the primarily negative view of hyper attention espoused by Hayles and Berardi, whereby information overload leads to collective depression, Moulthrop, McGonigal and Gee posit that engaging with interactive systems can productively model the kinds of complex dynamical systems that are encountered within the pervasive media culture of the network society.

Situating technology as pharmacological and invoking the logic of the AND productively emphasize that the modes of attention fostered by networked digital technoculture are not simply the path to collective panic, depression and an inability to maintain focus or the means towards an enlightened mode of engagement with complex dynamical systems. Elements of both perspectives are present in contemporary culture which precludes arriving at a straightforward value judgement. Indeed, doing so risks the type of ideological mystification which misidentifies qualities of the entire complex technocultural assemblage with those of a particular part, in this case that of informational overload or ecologically aware configurative practices. However, highlighting technology as poison and cure does not mean that it is applied each way in equal measure, nor does it mean that the technology is a neutral canvas upon which human agency and action inscribes itself.

Configurative or systemic awareness does not inevitably lead to ecologically motivated interventions. As William Connolly (2013) demonstrates, in the contemporary political and economic context, financial markets are the self-organizing dynamical system to which certain modes of attention are most often paid. While the type of systems-modelling behaviour outlined by Moulthrop and Gee may be useful in grasping the salient features and probable impacts of climate change alongside the potential for human agencies to affect its impacts, the same form of configurative knowledge is leveraged by industries whose goal is manipulating dynamic financial systems, whose inherent riskiness and focus upon short-term profitability was examined during Chapter 1. Knowledge of dynamical systems does

not inexorably lead towards ecological action; indeed, exploiting systems for short-term benefit while increasing systemic risk leads towards an inattentiveness to larger-scale biopolitical issues such as climate change due to a myopic focus on the present.

Consequently, it is useful to consider the current debates surrounding economies of attention via the ethological politics of speed in digital capitalism. In the previous chapter, we saw how climate change is not the anthropogenic alteration of a static biosphere but involves accelerating the pace of change far beyond the adaptive capacities of other biotic systems. Another way of framing Berardi's concerns about the discrepancy between cyberspace and cybertime is via an analogous concern about rates of change, whereby the epiphylogenetic technological ecology in which humans are located is currently undergoing a pace of change which results in long-term thinking and forms of collective care being abandoned in favour of dealing with the here and now. From this vantage point, the unyielding torrent of digital information associated with the attention economy often precludes the type of critical distance necessary for achieving the configurative systems awareness outlined by Moulthrop, outside of very narrow purposive behaviours such as speculative financial trading and viral marketing. For the social media corporations, public relations agencies and online advertisers who seek to leverage information, attention and data, the emphasis is upon obtaining quantifiable attention and data through hits, clicks and likes, not on promoting systemic understanding. It is precisely this drive towards the commodification and quantification of attention driven by the need for immediate financial returns which leads towards dissociated milieus, where an ethic of social and ecological care breaks down in favour of a systemically blind short-termism.

Understanding content through Big Data

One highly prominent way of addressing the scale of digital content is the lens of Big Data. Precise definitions of what does or does not constitute Big Data are themselves contested, as it is not simply the size or volume of data that is in question; indeed, if it were, then, centuries-old datasets such as national censuses would likely count as Big Data. Instead, Big Data refers to the ability of large-scale computationally stored datasets to be algorithmically searched, flexibly combined with other datasets due to their common mathematical representation, and to be dynamically updated, often in real time, unlike relatively static datasets such as a national census which are typically only updated once per decade.

One of the most comprehensive attempts at mapping the salient characteristics of Big Data is found in Rob Kitchin's *The Data Revolution*, which argues that Big Data are

- huge in *volume*, consisting of terabytes or petabytes of data;
- high in *velocity*, being created in or near real time;
- diverse in *variety* in type, being structured and unstructured in nature, and often temporally and spatially referenced;
- *exhaustive* in scope, striving to capture entire populations or systems (n = all), or at least much larger sample sizes than would be employed in traditional, small data studies;
- fine-grained in *resolution*, aiming to be as detailed as possible, and uniquely *indexical* in identification;
- *relational* in nature, containing common fields that enable the conjoining of different datasets;
- *flexible*, holding the traits of extensionality (can add new fields easily) and *scalable* (can expand in size rapidly). (Kitchin 2014: 68)

While not all Big Datasets adhere to all of these attributes, they provide a useful series of criteria for understanding how Big Data departs from previous forms and may provide a means for identifying specific types of Big Data which are predicated on some or other of these criteria.

Big Data has generated a huge amount of excitement within sectors ranging from sport to surveillance, commerce to academia, with enthusiastic claims that Big Data produces 'profound change at the levels of epistemology and ethics. Big Data reframes key questions about the constitution of knowledge, the processes of research, how we should engage with information, and the nature and the categorization of reality' (boyd and Crawford 2012: 665). By enabling the collation and algorithmic interrogation of enormous, real-time datasets drawn from user-generated materials on social media, geo-locational data from cellular devices and Wi-Fi networks, IP address tracking, browser cookies, transactional data and other forms of digitally encoded information, researchers, businesses, governments and activists have access to new forms of information, which open up novel avenues for investigating sociocultural phenomena.

One way of approaching Big Data and associated data analytics are as a means to explore the ecology of content at a scale which was previously problematic for humanities or social science research: obtaining qualitative datasets requires time-intensive processes such as interviews, focus groups, ethnography or participant observation, where temporal constraints generally preclude studying large groups. Equally, quantitative methods tended to mobilize surveys and questionnaires whose scope and reach was

still relatively limited compared to many forms of Big Data, and which could not capture the degree of detail and long-term engagements implicit in the systems used by entities such as Facebook and Google. Data analytics present ways of conducting macro-scale research into these areas, where the posthuman assemblage of algorithms, data analysts, cookies, computers, programmers and other agents allows research to be conducted using vast quantities of data that were not made tangible and searchable by previous technocultural milieus.

Indeed, there have been notable claims that Big Data heralds a paradigm shift in the sciences, social sciences and humanities, effectively rendering old methodologies and practices of deductive analysis obsolete. Chris Anderson (2008), a former editor of *Wired* magazine, vehemently argues,

> Massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behaviour, from linguistics to sociology. Forget taxonomy, ontology, and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With enough data, the numbers speak for themselves. … The new availability of huge amounts of data, along with the statistical tools to crunch these numbers, offers a whole new way of understanding the world. Correlation supersedes causation, and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all. There's no reason to cling to our old ways. It's time to ask: What can science learn from Google?

From this perspective, the wealth of empirical data which can now be gleaned from Big Data entails that there is no longer any need for theorization, modelling or the formulation of hypotheses, as empirical data can simply speak for itself in an entirely neutral way, free from the ideologies, biases and framings which are introduced by traditional research methods. Such an empirically guided epistemology closely approximates the straightforward positivisms of the past, but contends that Big Data allows areas of investigation which were previously impossible to apply objective, evidence-based inquiry towards, namely the humanities and social sciences can now escape the shackles of subjectivism and ideology. As Bruno Latour (2010: 145) muses, 'Numbers, numbers, numbers. Sociology has been obsessed by the goal of becoming a quantitative science. Yet it has never been able to reach this goal.' According to Anderson the new empiricism afforded by Big Data makes this transition possible.

However, if we subject these claims to scrutiny, there are serious flaws inherent to claims that Big Data presents neutral, objective facts which require no interpretation. To help focus upon why these claims are problematic, let us look at an example of leveraging data using Google Trends, a free online

tool which allows users to compare and contrast the relative popularity of search terms which have been input into Google's search engine.[8] Within Google Trends, I input the search terms 'Climate Change', an issue which is frequently referred to as one of the greatest challenges and threats facing humanity in the twenty-first century; 'X Factor', a popular reality television show which originated in the United Kingdom and which has franchises on every continent; and 'Dota 2', a popular multiplayer online battle arena videogame. In plotting the popularity of these terms, Trends produces the graph in Figure 3.1.

Simply presenting the data does little to analyse the relationships between the terms, let alone to contextualize how the data analytic tool itself impacts upon the results and interpretative frameworks we apply to them. What is most instantly obvious from the data is that 'Climate Change' is a relatively unpopular search term compared to 'X Factor' and 'Dota 2', with the overall

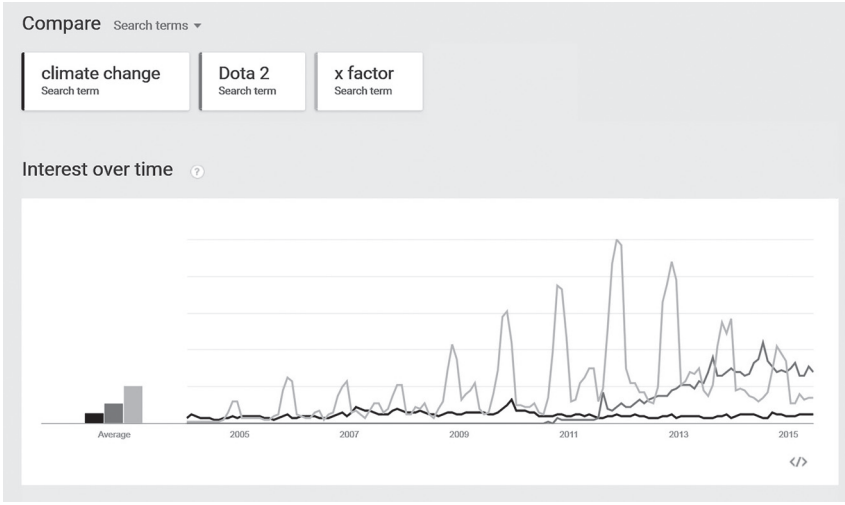

FIGURE 3.1 *Google Trends data for 'Climate Change', 'X Factor', 'Dota 2', January 2005–15.*

Data source*: Google Trends* (https://www.google.com/trends).

[8]Trends also presents data for related search terms and delineates the most popular regions for each term which is used. Google Trends is just one of the many Google-run data analytics and visualization tools which include Google Analytics (a tool for analysing traffic and audiences for specific websites you maintain), Google Correlate (which allows users to explore relationships between terms), Ngram Viewer (which plots the popularity of specific phrases within a database of books) and Google Public Data (which displays visualizations from publicly available datasets from agencies such as the World Bank and United Nations).

averages indicating that 'Dota 2' is twice as popular as 'Climate Change' as a search term, whereas 'X Factor' is four times as popular as 'Climate Change' over the decade-long period covered.

The interest over time for 'Climate Change' as a search term is relatively stable, with small upward rises in 2007, which correspond with the publication of the Intergovernmental Panel on Climate Change's fourth assessment report, and in December 2009, which correlate with the onset of controversy surrounding hacked emails from climate scientists working at the Climatic Research Unit (see later in this chapter). This contrasts starkly with 'X Factor', which has an annual spike in popularity which coincides with the broadcast of the series in the United Kingdom and the United States each year. After the series finishes, the term's popularity declines drastically, and from 2005 to 2010, the trough in the off season falls below the popularity levels of 'Climate Change'. 'X Factor' peaked overall in terms of popularity in 2012 and has seen popularity levels fall by over 50 per cent from 2012 to 2015, partially due to *X factor USA* not being renewed after 2013. Dota 2, on the other hand, has virtually no presence until mid-2011, when the game was first unveiled during the annual Gamescom trade fair. Following an initial spike, Dota 2's popularity steadily builds, with small spikes in popularity in July 2013, which coincides with the game's official launch, and July 2014, during The International, the Dota 2 e-sports tournament, whose winners took home over US$5 million in prize money, making it the then highest paying e-sports tournament.

Our first look at the data may generate somewhat concerning hypotheses; does this suggest that humanity is more interested in videogames and reality television than climate change? Have attention spans dwindled to the point where the long-term threats posed by climate change become impossible to grasp by consumers immersed in a hyper-stimulated corporate culture industry? Or can we posit other plausible explanations, such as Dota 2's popularity as an online search term reflecting the fact that other information sources such as television news, newspapers and radio are considerably less likely to devote coverage to tactics and strategies for a videogame than exploring news stories pertaining to climate change? Such an argument, however, probably does not extend to the *X Factor*, which does generate a significant volume of broadcast and print media coverage, especially leading up to the show's finale each year. In this case, we might begin to think about different types of new stories with regard to duration, and particularly the fact that in a media culture which tends to sensationalize and scandalize specific events (Castells 2009: 240–50), an ongoing issue like climate change struggles to remain visible, unlike the periodic interest generated by specific and spectacular events such as the annual *X Factor* finale.

Whether we are considering what the Google Trends data might mean, or how the trends vary over time, interpretation is required alongside a process of correlating various events with the changes evidenced within the

data. Contrary to Anderson's claims that Big Data means that we can forget causality in favour of engaging with the straightforward empirical truths of data, we see that in order to make any sense of information, we have to contextualize data with additional research and analysis. The data alone may provide answers to certain types of questions which ask 'what', but to begin approaching more complex questions surrounding 'why' and 'how', we need to go beyond simply regurgitating statistics and engage in the type of analytical and synthetic inquiry which has long been the hallmark of humanities and social science scholarship.

As well as questions surrounding how we interpret data, there are crucial questions pertaining to choices that are made when selecting data, especially given the flexible, extensible and scalable properties of Big Data, which entail that there will always be a multiplicity of options available to a researcher. Were we to alter the dates examined to only focus upon those following Dota 2's announcement, it would be over four times as popular a search term as 'Climate Change'. If instead we chose to only look at the most recent months' worth of data, we would find 'Dota 2' was six times as popular a search term as 'Climate Change', and twice as popular as 'X Factor'. Were we to simply examine the allegedly self-evident truth from that single months' worth of data, we would fail to see the annual cycle surrounding 'X Factor', which unsurprisingly correlates with the show airing on television. It is crucial, then, that the process which decides which connectable and comparable datasets are selected for analysis reflects an informed decision-making process, rather than arbitrarily suggesting that the 'truths' contained in the data must simply speak for themselves.

There are also questions which have to be raised about data access and availability. Whereas Google Trends provides a normalized 0–100 graph denoting relative search popularity, if a researcher wanted the actual numbers of searches, they would have to contact Google in order to obtain this data, and the same is true were the data to be held by other social media platforms such as Facebook and Twitter. While there are various forms of freely provided or scrapable data available from these platforms, there is additional data which is not made publicly available. Indeed, some of this data is highly guarded, as it is used by the social media platforms themselves for commercial purposes. Such data can be made available to researchers, but usually come at a price, entailing that researchers working at well-financed institutions are far more likely to obtain access to these additional datasets. Of course, if the researcher worked directly for the social media platform, accessing the raw numerical data would be significantly easier, further denoting that within the sphere of Big Data there is a hierarchy of who has access to varying levels of information, with the social media platforms themselves positioned at the apex of this hierarchy.

Intriguingly, this suggests that the more data a researcher has access to, the less likely they are to adopt a highly critical approach to its origins, due to

the relationship and proximity to the corporate entity which has privileged the researcher with access. Although there are a burgeoning number of free and open source data analytic tools, which allow for various forms of novel and interesting modes of research to be pursued, these tend to pale in comparison to the capabilities of social media platforms, whose commercial model is predicated upon the collation of Big Data and analysing this data to provide complex models of an individual's behaviour in order to target advertising material accordingly, or to sell this data and associated patterns and trends to other companies.

In addition to hierarchies among researchers, the rise of Big Data and computational data analytics creates novel forms of striation between the users of social media, researchers and the owners of the platforms. The first group comprises the billions of individuals who use the internet who create data via their web search and browsing histories, tweets, likes, status updates, online purchases, spatial movements while carrying a GPS-enabled mobile computing device and so on. The other two groups are relatively miniscule, and this novel form of hierarchy is described as the comprising the 'new "data-classes" of our "big data society"' (Manovich 2012: 11). Far from creating a cyber-utopian rhizomatic communication space marked by increased levels of equity, we find that Big Data primarily benefits elite groups who have access to raw datasets, the computational power to analyse them, the education to utilize complex statistical tools and the time in which to conduct such work. Put simply, those who are best placed to benefit from Big Data are highly privileged elites. That is not to say that others cannot benefit at all, but when mapping the affordances of Big Data, it is crucial to highlight the structural context and hierarchies which are generated, perpetuated or otherwise sustained.

It would also be misguided to universalize the data presented in tools such as Google Trends, naively conflating data from Google's web searches with an objective and accurate reflection of global public interest. While Google is the most popular search engine globally, its employment is not homogenous among all regions and states. For example, in China the most popular search engine is Baidu (Arthur 2014), in South Korea it is Naver (Kocken 2014), in Russia it is Yandex, and in Japan it is Yahoo (Graham and De Sabbata 2013). It may be that regional variation does not impact certain projects dependent upon Big Data; however, given the rhetoric surrounding Big Data as providing a series of neutral and objective facts, it is important to highlight that these facts are far from universal. The partial nature of the user base entails that while Big Data certainly captures sociocultural material at scales and speeds which are unparalleled, this does not equate to a straightforward demarcation of universal and global truths.

Indeed, we must remind ourselves that internet penetration itself is far from universal and that access (especially to broadband internet) still broadly mirrors global economic divisions. Nick Couldry and Ulises

Mejias have argued that the contemporaneous extraction of data from the developing world that is then leveraged by the United States (and to a lesser extent Chinese) digital platforms can best be understood as a new form of colonialism that 'combines the predatory extractive practices of historical colonialism with the abstract quantification methods of computing' (Couldry and Mejias 2018: 2). There is a real risk that Big Data presents a neocolonial perspective on the world beneath the guide of a non-ideological empiricism. Contrary to Kitchin's attributes, Big Data are rarely exhaustive. While they may capture a scale and scope which is far greater than traditional methods, they do not typically examine entire systems, and paying attention to who and what gets left out is vital to comprehending both the insights produced and how pre-existing forms of exploitation can be reified by big data.

To summarize, we have seen that information gleaned from Big Data is far from the presentation of straightforward and objective truths. When applied to the sociocultural sphere, the results of data always require interpretation, the selection of which data to present affects the interpretations which emerge, data depends upon access to information which is often controlled and selectively released by corporate platforms, and the various datasets themselves are far from exhaustive, so understanding what gets left out is important to contextualizing the claims being advanced. There is no such thing as raw data (Gitelman 2013).

It is also important to emphasize that Big Data are themselves active participants in the assemblages of contemporary technoculture which bring forth particular modes of becoming. They have their own agencies rather than simply being passive, transparent and neutral mediators which provide insight into the world that produces them. As David Beer (2015: 10) quite aptly states, Big Data 'are not something that exist outside of the social world. They circulate through it, reshaping it, altering and disrupting the configurations of power and decision-making. These new types of data are an implicit and integrated part of how the social world is performed and enacted.' Information, then, must be understood as a performative actant, which actively shapes sociocultural ecologies, rather than simply presenting a neutral reflection of a pre-existing culture. As Barad emphasizes in relation to quantum physics, an apparatus of measurement is never entirely separate from the phenomena being measured. Big Data are entangled with the world they map, and in doing so, can be more aptly understood as creating particular types of diffraction patterning within ecosystems in which they are constituent parts, rather than as neutral objects that reflect reality from an external vantage point.

Evgeny Morozov (2014) argues that an apt metaphor to employ here is that data is more like an engine, an active driver of social change, than a camera which passively and accurately records events. While I agree with Morozov's overall sentiment surrounding the active agency of data, the

metaphor he employs is somewhat problematic. A camera does not simply record life; it is always in the process of bringing a particular viewpoint on the world into being. The photographer's choice of aperture, shutter speed, sensor sensitivity (ISO), focal length, depth of field, focal point, composition, exposure, picture style and so on all inform the way in which light is recorded and consequently rendered into a photographic image, to the point that the result of these decisions can be so dramatically different that a viewer would be unable to discern that two photographs captured with very different settings had been taken in the same place or of the same subject. As Ansel Adams famously stated, 'You don't take a photograph, you make it.'

Furthermore, it is worth noting that many authorial choices, such as aperture, shutter speed, sensor sensitivity and focal point are now predominantly automated processes on many cameras (especially those found in smartphones), which provide the human photographer with little agency to affect parameters of the image beyond framing and composition. These decisions are instead taken by technological elements of the human–camera–environment assemblage, and through this process of automation, the transparency of the decision-making process evaporates, leaving the impression that the camera is simply recording the scene 'as it is'. Images and media are also, of course, performative actants that are capable of driving social change rather than merely documenting it, so there is a useful comparison to be drawn between Big Data and digital photographic images. Both are selective processes which performatively enact social and cultural change, but largely due to their automation by poorly understood digital technologies are commonly mistaken as presenting straightforward empirical truths.

Big Data performatively act as 'productive measures' (Beer 2015: 4). By according additional importance to what is quantifiable and measurable, Big Data create feedback loops whereby in order to be deemed valuable, phenomena must be translatable to a measurable form, thereby further enhancing the value of what can be quantitatively captured, which further extends the scope and worth of Big Data, and so on. This process of fetishizing the quantifiable, however, also sees the adaptation of behaviours, as 'people start to game the system in rational, self-interested but often unpredictable ways to subvert metrics, algorithms, and automated decision-making processes' (Kitchin 2014: 127). Ascribing value to specific types of knowledge alters social behaviours rather than simply measuring them.

A prime example of this can be seen by exploring the field of viral marketing; marketing that uses social media to create forms of advertising and promotion that spread by utilizing the free labour of social media users (Terranova 2000; Fuchs 2012). Utilizing existing communication networks in this way provides a relatively low-cost form of advertising

in comparison to traditional models such as billboards, television or newspaper advertisements. Viral marketing additionally benefits from being transmitted by individuals through trusted semi-personal social networks, rather than appearing as commercial advertising. The notion of 'going viral' draws a homology with the form of replication seen in viruses, whose model of self-division results in an exponential growth curve. Within a relatively small period of time, the virus can become an epidemic because of this nonlinear growth, and viral marketing seeks to achieve a similar pattern of reach through utilizing the positive feedback loops involved in online trending patterns, combined with a process of transmission through multiple overlapping social networks. Once a piece of content begins trending, it will be identified by various algorithms which promote apparently popular material, be it for Google's search engine, Facebook's newsfeed or Twitter's trending category, thus affording it broader exposure and increasing the likelihood that it continues to spread. Alongside this, as a topic begins to trend a large number of news and niche topic blogs will begin to run stories on the trending topic, again reinforcing positive feedback effects. This is the type of network effect that causes the logarithmic power-law distribution associated with preferential attachment.

Whereas early internet scholarship tended towards rhetoric of a postmodern public sphere (Barlow 1996; Poster 1995; Kellner 1999), where everyone becomes a pamphleteer and an equally important voice within debates surrounding normative sociopolitical behaviours, subsequent research revealed that the web does not function in the egalitarian manner envisioned by early theorists of cyber-democracy. In 1999, Albert-Laszlo Barabasi and Reka Albert published a breakthrough paper entitled 'The Scaling of Random Networks', which investigated the topography of various complex networks, ranging from genetic networks, to citations within science, to linking practices on the web, which concluded that there is a very low probability that any given node within a network will be connected to a high number of other nodes and a very high probability that the vast majority of nodes will be very loosely connected or not connected to each other at all.

Whereas a normal distribution forms a bell curve around the mean, a power law involves an exponential decay with a long tail and follows an 80/20 rule, entailing that the vast majority – 80 per cent – of the links, citations and other connections relate to only 20 per cent of the nodes within the network. Barabasi and Albert investigated the mechanisms by which complex networks grow and formulated a hypothesis of preferential attachment whereby new nodes connect themselves to nodes that are already disproportionately well-connected, further entrenching the preferentially attached position of these nodes. Reflecting upon the ramifications of his research for internet democracy, Barabasi (2003: 56/57) argues that 'the most

intriguing result of our Web mapping project was the complete absence of democracy, fairness and egalitarian values on the Web. We learned that the topology of the Web prevents us from seeing anything but a mere handful of the billion documents out there.' Rather than creating a postmodern public sphere where everyone functioned as communicative equals, the attractor of preferential attachment produces distributions where a handful of voices are disproportionately visible while the vast majority of content residing in the long tail of the web has few inbound links or visitors.

Viral marketing productively highlights how economically privileged actors exploit the nonlinear dynamics of digital media ecologies in order to leverage them to the advantage of their clients. In the torrent of information constantly being uploaded and shared online, the key is creating the initial sense of interest in order to reap the benefits of the iterative network effects associated with trending. In *Trust Me I'm Lying: Confessions of a Media Manipulator*, public relations director and strategist Ryan Holiday outlines how he would engineer interest and/or outrage in order to create initial waves of interest which would later translate into a trending tsunami. He stresses the importance of maintaining the appearance of authentic, grassroots public sphere communication, which he would initially seed by sending hot tips, scoops and scandals to small niche bloggers, a process Holiday (2012: 18) describes as 'trading up the chain'.

These bloggers promote 'their' breaking story, which is then picked up by larger blogs, and at this point the public relations agency intervenes, using multiple accounts across numerous social media sites to upvote, share, tweet and comment upon the story, ensuring that it generates a level of interest which pushes it over trending thresholds, so it appears on the front page of sites such as Reddit. As journalists from national newspapers and internationally prominent blogs such as the *Huffington Post* monitor the front pages of these preferentially connected sites, the content may now become national or international news. Importantly, once a story, video or other piece of content has passed the initial threshold for trending, it will continue to be prominently visible in comparison to the vast majority of content which resides in the internet's long tail. Consequently, a PR firm does not have to continuously promote material, it merely has to convince trending algorithms of its initial value, and then there is the appearance that the content will continue autonomously spreading itself (Morozov 2014: 157).

Indeed, Holiday (2012: 21) concludes that commercial blogs are merely 'beachheads for manufacturing news. I don't think someone could have designed a system easier to manipulate if they wanted to.' Whereas viewers of these stories believe they are receiving authentic content from the public sphere, they are in fact being fed cunningly disguised marketing material by a public relations agency which leverages the functioning of algorithms

which make trending content disproportionately visible and the desire of bloggers to achieve reach, visibility and prominence within the cacophony of online discourse. Consequently, we see a huge amount of 'clickbait' online, professionally produced content with unbelievable headlines which are designed to attract user attention in order to produce clicks and associated advertising revenue. Far from being a space of rational–critical debate among informed citizens as the cyber-utopian visions of the 1990s internet as postmodern public sphere suggested, we instead find that significant volumes of trending online content are manufactured viral marketing or fake news stories that effectively game the logic of trending algorithms.

Questions surrounding fake news and post-truth politics burst into mainstream political discussion in 2016 during the US election campaign and to a lesser extent during the Brexit referendum. Exploring viral marketing demonstrates how many of the tactics employed during these political campaigns did not arise in 2016, they had long been utilized online and their efficacy in gaming trending algorithms and garnering attention had been thoroughly demonstrated. Given their results in producing trending online content, it is entirely unsurprising that these methods were subsequently deployed in political campaigns by domestic lobbying groups and foreign governments who sought to influence the outcomes of these crucial votes. Additionally, the ability to gain significant financial reward from the advertising revenues linked to fake political news saw large volumes of material published from Veles, Macedonia, where posters claimed not to care about the election outcome, their motivation was simply making (easy) advertising money (Kirby 2016). This further demonstrates how Big Data and trending metrics do not merely measure a pre-existing social world; they are performative actants which are key to understanding contemporary economies of attention and the genealogies of digital transformations to mediated political discourse.

Understanding Big Data, then, does not simply mean being able to glean information from the growing array of tools that scrape information from social media, search engines, mobile networks and so on. It requires an engagement with the limitations and gaps of the tools, technologies and datasets, interpretation and contextualization of the information itself, and a nuanced understanding of how the assemblages of Big Data do not objectively measure and reflect contemporary technoculture but create a value system in which quantifiability and measurability are highly prized qualities. Put simply, the aperture afforded by Big Data introduces a way of understanding the world which privileges certain measures over others, and, consequently, an array of sociotechnical actors have altered their behaviours in order to manipulate metrics by gaming the algorithms which underpin them.

Climategate or the scandal that wasn't

Whereas the attention economy and Big Data raise numerous issues over ecologies of content and information at relatively large scales that address the volumes of content being generated within contemporary computational ecologies, I now turn to a more localized example which examines forms of human meaning making and activist intervention that occur within the dynamics of digital ecologies. Widely known as 'Climategate', this manufactured scandal surrounds the theft and publication of emails and associated documents from the Climatic Research Unit (CRU) at the University of East Anglia (UEA). This presents a case where climate blogs, which usually reside within the long tail of the internet, led to a major international news story, which had a marked effect on public perceptions surrounding climate change and correlates with a noticeable increase in web searches for the term 'Climate Change'. Focusing upon Climategate and climate change blogging, a heavily contested field where scientists, activists, NGOs, industry think tank and other social actors converge upon a technocultural space, presents a very different type of insight from that drawn from exploring Big Data and the attention economy, and media ecology is interested in what emerges across and between these different ways of examining flows of digital content.

On 17 November 2009, a UEA server was accessed by an unauthorized party and data was copied and uploaded to the *RealClimate* blog[9] and inserted into a spoof posting after the *RealClimate* server was hacked (Schmidt 2009). Gavin Schmidt deleted the posting and informed the CRU of the security breach later that day (RealClimate 2009a). On 19 November, prominent climate change sceptic blogs such as *Climate Audit* and *Watts Up with That* began reposting a small number of the emails that had been anonymously uploaded to the *Air Vent*, another sceptic blog, advancing claims that these materials proved that climatologists had been involved in manipulating data, perverting IPCC processes and preventing sceptical papers from being published in peer-reviewed journals (McIntyre 2009; Watts 2009a).

[9] *RealClimate* was launched in 2004, and describes itself as 'a commentary site on climate science by working climate scientists for the interested public and journalists. We aim to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary' (RealClimate 2004). Among the scientists who contribute to the blog are Gavin Schmidt, director of the NASA Goddard Institute for Space Studies (GISS), Eric Stieg, an isotope geochemist at the University of Washington and Michael E. Mann, a member of the Penn State University faculty, and lead author of the controversial Mann, Bradley, Hughes 1998 paper which recreated global temperatures for the last thousand years using palaeoclimatic proxy data, resulting in the 'hockey stick' graph, which provides evidence that current warming is unparalleled in speed and scale over the last thousand years.

The email which received the most prominent attention was from CRU director Phil Jones and stated, 'I've just completed Mike's Nature trick of adding in the real temps to each series for the last 20 years (i.e. from 1981 onwards) and from 1961 for Keith's to hide the decline.' This was highlighted for appearing to suggest that Jones was using a form of deception, to 'hide the decline', which sceptics claimed 'appears to discuss a method of overlaying data of temperature declines with repetitive, false data of higher temperatures' (Morrissey 2009). These blog posts attracted thousands of comments, the majority of which argued that the emails revealed that scientists had deliberately misled the public over the threat of climate change.

One of the changes to the media ecosystem afforded by the rise of user-generated content platforms such as blogging is the enhanced opportunities for experts to provide rapid feedback to stories without the intermediaries of professional journalists who traditionally functioned as gatekeepers to entering mediated debate. It is worth noting, as Oreskes and Conway (2010: 210–11) demonstrate, that as recently as the 1990s, scientists who sought to respond to erroneous allegations published in the mass media often had no outlet for rebuttal other than scientific journals or organizational newsletters, media with comparatively miniscule audiences. The changing media ecology afforded the scientists who author *RealClimate* the capacity to directly participate in this debate, communicating with a large and geographically dispersed public.

As early as 20 November, one day after sceptic blogs began publicizing the emails, blogs began publishing material that contextualized the information being used to suggest scientific misconduct and fraud. This clearly denotes a way that blogging has altered the pace and scale of the dissemination of scientific information. The blogosphere enables information from scientist–activists to flow far more rapidly than within previous technocultural assemblages. The contemporary media assemblages – the computational and networking hardware; blogging software, networking protocols, web browsers and operating systems; and the users and social practices of blogging, commenting and online discourse – allow knowledgeable individuals to contribute to public debates at a speed and scale which significantly departs from the situation that existed before the mid-2000s.

With specific regard to the widely circulated claims surrounding the 'hide the decline' email, the *RealClimate* group responded:

> The paper in question is the Mann, Bradley and Hughes (1998) Nature paper on the original multiproxy temperature reconstruction, and the 'trick' is just to plot the instrumental records along with reconstruction so that the context of the recent warming is clear. Scientists often use the term 'trick' to refer to 'a good way to deal with a problem', rather than something that is 'secret', and so there is nothing problematic in this at all.

> As for the 'decline', it is well known that Keith Briffa's maximum latewood tree ring density proxy diverges from the temperature records after 1960 (this is more commonly known as the 'divergence problem' – see e.g. the recent discussion in this paper) and has been discussed in the literature since Briffa et al. in *Nature* in 1998 (Nature, 391, 678–82). Those authors have always recommend not using the post 1960 part of their reconstruction, and so while 'hiding' is probably a poor choice of words (since it is 'hidden' in plain sight), not using the data in the plot is completely appropriate. (RealClimate 2009a)

Both the original *RealClimate* thread from 20 November and a follow-up published on 23 November (RealClimate 2009b) exploring other accusations stemming from the emails, received over a thousand comments, where users queried the context and meaning of the emails, and the scientists authoring the blog were able to respond and advance the discussions.

By the time the press had picked up the story, thousands of comments providing various opinions and insights from observers including scientists, sceptics, other academics and interested members of the public had been published online and the merits of their opinions discussed. The speed and scale of these informational and attentional flows departs significantly from previous media. The increased pace of communicative exchange within networked online media affords rapid responses and detailed dialogic encounters which in this instance can be understood to resemble particular elements of the vision of a postmodern public sphere outlined by early theorists of internet discourse and democracy.

The model of the public sphere expounded a communicative realm which was conceived as affording universal access and being separate from both the state and private (market) interests, thus affording a space of democratic debate and dialogue between equal participants who were able to logically and rationally debate sociopolitical issues (Habermas 1991). Habermas presents the eighteenth- and nineteenth-century coffee shop culture of bourgeois Europeans as a normative model of the public sphere, contending that earlier, premodern times did not sufficiently differentiate between public and private realms for a public sphere to exist, and that the genesis of the mass media saw the public sphere of face-to-face debate replaced by one predicated upon the consumption of industrially produced cultural commodities. Habermas consequently argues that 'the world fashioned by the mass media is a public sphere in appearance only' (1991: 171), that debates over cultural norms are primarily framed by elite corporate interests which are reflected in a commerce-driven culture of competition.

There have been numerous notable criticisms of the Habermasian model of the public sphere, which claimed that universal access was a necessary requirement, but presented a normative model which excluded women (Fraser 1990) and the working classes (Negt and Kluge 1988), that is, the

vast majority of the population. Despite this, the concept is still widely applied and was heavily adopted by early internet scholars (e.g. Poster 1995; Bohman 2004; Kellner 1999) who argued that the peer-to-peer architecture of the internet provided a technological means for remedying the issues Habermas associated with the introduction of the mass media surrounding the centralization, commercialization and distortion of communications and the public sphere:

> Democracy involves democratic participation and debate as well as voting. In the Big Media Age, most people were kept out of democratic discussion and were rendered by broadcast technologies passive consumers of infotainment. Access to media was controlled by big corporations and a limited range of voices and views were allowed to circulate In the Internet Age, everyone with access to a computer, modem, and Internet service can participate in discussion and debate, empowering large numbers of individuals and groups kept out of the democratic dialogue during the Big Media Age. Consequently, a technopolitics can unfold in the new public spheres of cyberspace and provide a supplement, though not a replacement, for intervening in face-to-face public debate and discussion. (Kellner 1995: 8)

Although such claims must be tempered by the corporate domination of the contemporary internet at the levels of platforms, code and infrastructure, it is still important to note that certain groups are empowered to engage in public discourse through networked digital media. Indeed, the tension between the multiple ways that the internet both empowers and encloses individuals and groups is a key concern regarding activism and agency in contemporary technoculture.

Having initially been published on niche climate denial blogs, with rapid responses from blogging climate scientists, the Climategate story was picked up by major newspapers within a few days, demonstrating the flow of information from blogs into print and broadcast media. Far from existing in opposition to, or standing outside of, previous media ensembles, what we observe here is the way that digital debates flow across and through a media assemblage which includes 'old' and 'new' media forms. Indeed, one of the primary ways that content which begins life on niche blogs can effect widespread change is through the process of diffusing through forms such as newspapers, television and websites maintained by corporate media networks which typically have a far greater reach than forums such as climate blogs.

The CRU officially responded to the escalating scandal on 23 November, stating that it would conduct an internal investigation into allegations (CRU 2009a), alongside a comment from Phil Jones explaining the 'trick' to 'hide the decline', repeating information published several days earlier

on *RealClimate*. The relative slowness of UEA/CRU in addressing the story was criticized as 'a textbook example of how not to respond' (Monbiot 2009): the CRU knew that the emails were circulating among climate sceptics from 17 November, and during the week that they remained silent, the story became an international scandal. This highlights how the blogosphere, and the contemporary media ecology in general, corresponds to a huge increase in the pace at which information travels, circulates and is reproduced.

Whereas in previous media ecologies waiting six days to respond to a story may have been considered adequate, by 2009 it was not. The CRU unveiled another press release on 24 November (CRU 2009b), and when this failed to stem the tide of criticism, they announced that Phil Jones would step down as CRU's director pending the results of an independent review of the scandal (CRU 2009c). Whereas the CRU initially announced that UEA would conduct the review with external support, the growing sense of crisis entailed that this position was no longer tenable, and in early December they announced a wholly independent investigation, to be chaired by Alastair Muir Russell (CRU 2009d). There were additional investigations into the affair announced by the UK House of Commons Science and Technology Committee, an external reappraisal of the science in the CRU's key publications via the Scientific Assessment Panel, and Penn State University conducted an internal inquiry into allegations resulting from the email publications which pertained to research misconduct allegedly perpetrated by Michael Mann while tenured at PSU (Penn State University 2009).

The first investigation to publish its findings was the UK House of Commons Science and Technology Committee (2010), which effectively exonerated Jones and the CRU, finding no evidence that data had been falsified, the public had been misled, or that collusion to keep opposing perspectives out of peer-reviewed journals had occurred. While the report did criticize the handling of freedom of information requests, criticisms were directed at UEA rather than Jones or the CRU. The report's publication generated further heated debate on climate blogs, with *RealClimate* (2010) and similar anti-sceptic blogs quoting key findings approvingly while highlighting that the conclusions validated statements which these blogs had made throughout the course of the scandal (Hoggan 2010; Romm 2010). Sceptic blogs covered the report by either focusing on sections which called for greater transparency in climate science (Watts 2010), the fact that one MP voted against parts of the report (McIntyre 2010a) or claiming the report was a whitewash (McIntyre 2010b).

The other inquiries: the Scientific Assessment Panel, the Penn State University investigation into Michael Mann's conduct and the Muir Russell-led independent review, all corroborated the UK House of Commons Science and Technology Committee report. Although they made minor criticisms

of CRU's work,[10] the reports unanimously concurred the CRU had not falsified data, subverted academic peer-review protocols or undermined IPCC processes. The allegations which made worldwide headlines were unsupported by analysing the emails, the CRU's publication record and evidence from interested parties, which included numerous sceptical climate bloggers who made depositions to the inquiries. Indeed, the reports emphasized that CRU's 'rigour and honesty as scientists are not in doubt' (Muir Russell et al. 2010).

Responses from climate blogs to these inquiries followed a similar pattern to events following the UK House of Commons Science and Technology Committee report. Blogs which broadly support the IPCC position, who had consistently rejected the alleged significance of the emails, saw each successive report as vindication of their judgement, whereas sceptic blogs criticized each successive report as part of an ongoing whitewash. Criticism was aimed at the choice of the panels' personnel, the terms of reference adopted, the analyses and conclusions that each panel provided. It is important to emphasize that sceptic blogs refused to accept conclusions drawn by the independent reports which contradicted their preconceived positions. Having published material claiming that the emails were clear evidence of data manipulation, fraud and subversion of peer-review/IPCC processes, having received tens of thousands of (largely) approving comments echoing these sentiments, and having seen these allegations blossom into a highly publicized international scandal, this process of becoming a major news story sufficiently reinforced ideological preconceptions for sceptics to simply reject contrary conclusions drawn by the independent investigations.

This strongly suggests that far from being a hotbed of rational analytical discourse, the blogosphere reinforces and entrenches existing views. Consequently, sceptic responses to independent investigations support Castells's (2009: 169) claim that 'information per se does not alter attitudes unless there is an extraordinary level of cognitive dissonance. This is because people select information according to their cognitive frames.' As the sceptical bloggers, commentators and readers had established an ideological framework connecting the emails to fraudulent behaviour and conspiracy on behalf of the scientists, their response to the repeated exonerations of the scientists was to re-frame the inquiries themselves within an establishment-led conspiracy, rather than abandoning the aperture through which they had previously perceived events. Even when exploring online contestation of a scientific discourse allegedly steeped in objective rationality, what

[10]The Scientific Assessment Panel report criticized minor aspects of the statistical methodologies employed alongside the informal nature of CRU's internal procedures and the Muir Russell review criticized the CRU for lacking openness regarding how they dealt with freedom of information requests.

we find instead of cold analytical reason is a highly affectively charged situation, where subjective preconceptions and ideology effectively structure proceedings.

One particularly noteworthy blog post which appeared after the conclusion of the first two investigations was published by Scott Mandia (2010), who employed web analytics to examine media responses to both the original scandal and subsequent exonerations of Jones and Mann. Mandia used the search terms 'Phil Jones' 'Climatic Research Unit' and 'Michael Mann' 'Climatic Research Unit' compiling results published during the two weeks after the story originally broke and subsequently for the two weeks after the scientists' initial exonerations. This was done as both a web-wide search and a Google news search, in order to compare and contrast web-wide coverage with that published by newspapers. This is notable insofar as it demonstrates bloggers using computational tools to publish metalevel analyses of media coverage, comparing publications across media, a task which until recently would have required a full-time researcher to compile the data. In this instance, we see that networked digital technologies not only afford novel ways of communicating, or alter the pace and scale of communications, but also enable unique methods for obtaining insights. While we have considered some of the caveats and limitations associated with Big Data, this case demonstrates one way they can be utilized by interested citizens to provide a scale of analysis which previously would have required a significant mobilization of time and resources, and thus been impractical for non-professionals.

Mandia's analysis foregrounds a huge discrepancy between the volume of reporting which accompanied the initial scandal and subsequent exonerations of the scientists. Interestingly, the scale of the discrepancy is far greater in news media than web hits; whereas the ratio for web pages was roughly 3:1 for accusations compared to exonerations, the ratio for news headlines was closer to 10:1. As we have seen, many online pieces responding to the inquiries accused them of participating in a whitewash; however, they still provided responses to the inquiries, whereas many news outlets which covered the initial accusations simply ignored the subsequent rebuttal of these claims produced by the independent investigations. This tendency to focus on the politics of scandal, whereby sensationalist headlines trump subsequent rigorous inquiries which find more mundane conclusions, correlates with Castells's (2009) observations regarding the centrality of scandal politics to commercial media networks in the network society.

Climategate, however, provides compelling evidence against Castells's (2009: 260) claim that 'while skilful manipulation of information and the shrewd weaving of facts and fabricated evidence, increase the impact of the scandal, it is the raw material provided by the extent and significance of the wrongdoing that ultimately determines the effects of the scandal'. The extent and significance of the wrongdoing here proved to be very low. Had

the initial story presented honest, rigorous scientists who did not properly deal with a torrent of disingenuous freedom of information requests from sceptics, allied with mild criticism that certain publications could be slightly improved through closer collaboration with statisticians, the story would have generated few headlines. Indeed, as Mandia demonstrates, when these conclusions emerged, the press lost interest, as the lack of sensational headlines made the exonerations of the scientists a far less marketable story within the dynamics of the attention economy.

The Climategate scandal therefore presents a useful precursor to the subsequent torrent of fake news and post-truth politics. This includes Gamergate, where the harassment of female game designers was 'justified' by a nonsensical critique surrounding standards in game journalism; Pizzagate, where during the 2016 presidential election it was ludicrously claimed that Hillary Clinton's emails contained coded messages that connected senior officials within the Democratic Party to a child sex ring; and aberrant claims during the Brexit referendum campaign that the European Union was poised to ban tea kettles. It is wrong, however, to present such non-events as a decisive break from journalistic history. There are plenty of cases where high-profile scandals were manufactured to provide a rationale for actions that may otherwise have been unpopular. For example, the Second Gulf of Tonkin incident that Lyndon Johnson used to pass the Gulf of Tonkin resolution through the Congress in 1964, providing a legal basis for commencing military action against North Vietnam, is generally regarded to be a complete fabrication. No actual attack on the US Navy occurred. Similarly, the Nayirah testimony, where a fifteen-year-old Kuwaiti girl heart-wrenchingly recalled invading Iraqi soldiers removing babies from incubators and leaving them to die was used to justify US intervention in first Gulf War. This was later found to have been false testimony delivered by the daughter of the Kuwaiti ambassador to the United States.

What we see with the recent fake news scandals, then, is not a decisive break whereby 'real' news has been replaced by fake news, but that in the context of the digital attention economy it is possible for well-organized groups with political or economic motivations to garner significant quantities of attention through producing sensationalist communications that are designed to produce doubt in received wisdom. While this occurred in the past, it was largely limited to powerful political and economic elites, however, today the ability to manufacture fake scandals has seemingly been democratized by digital media; small but dedicated groups are now able to use strategies such as trading up the chain to help game trending algorithms and garner significant attention for events which did not occur. In the cacophony of online communications, rational–critical debate is often less prominent than affectively charged sensationalism that successfully leverages the productive measures of Big Data.

A final outcome of the CRU email scandal worth discussing was the formation of a page on the *RealClimate* blog on 27 November which presents a co-creatively sourced catalogue of links to data sources and code relating to climate science. Unlike most blog posts, which appear in reverse chronological order, this page was placed in the top navigation bar of the site alongside links such as 'home' and 'about us' so that it received extra prominence. The page sought to demonstrate that far from being a secretive clique, climate scientists have made vast amounts of data publicly accessible via the internet for interested parties to explore and examine, with links to over 100 different datasets covering global and regional temperature records, tidal gauges, oceanic heat content, aerosols and cloud formation data, snow cover, palaeoclimatic data and reconstructions, source code used in global and regional climate models, and data visualization tools.

Prior to the existence of the internet, the majority of this data would have been inaccessible outside the institutions where they are maintained. The dynamic nature of many of the datasets, such as those for global and regional climate, further problematizes the notion of printing and distributing this information, as it rapidly becomes outdated. Now, however, this enormous volume of data is available for perusal by any member of the public with internet access, and the *RealClimate* catalogue presents an interface to this distributed database. The practice of creating the database, initially undertaken by the scientists running *RealClimate* and subsequently enlarged through the participation of the site's users, additionally demonstrates how professional expertise and crowdsourcing can be combined to create comprehensive catalogues of openly available online data. Changes to modes of data storage, access and communication combine here, affording far wider access to a massively enlarged database of available information pertaining to the global climate, with the interface residing on a prominent climate blog.

Alongside the enhanced pace and scale of the online debates and feedback loops surrounding the scandal, the emergence of blog postings utilizing web analytics to provide meta-coverage of the events and the crowdsourced catalogue of online climate data present examples of how contemporary sociotechnical assemblages afford new modes of interrogating and scrutinizing information. The contemporary technical ensemble affords different types of analyses and peer-based open data exchanges that simply did not exist within previous media ecosystems. While the existence of these resources invites public review of these datasets, the caveats surrounding the politics of data still apply. In order to meaningfully review these materials, the preconditions are not just access to the data but an assemblage of statistical and coding knowledges and practices allied with computational power, relevant software tools and the time to conduct this work. Meaningful access, then, is still dependent upon meeting preconditions which demarcate

that only a tiny fraction of internet users can interrogate such datasets. While open access to content does enhance public participation in science, we are still only talking about a very specific, elite group as the public here.

This does not mean that such moves are not beneficial or do not assist in democratizing scientific knowledge, but this raises questions surrounding the precise manner in which the term 'democratization' is defined in discourses surrounding digital technologies. Claims that technology, the internet, open access and user-generated content platforms are democratizing are frequently encountered, but what is often left to reader's imagination is what this process of democratization entails. While the term democracy is etymologically derived from the Greek *demos* (people) and *kratos* (rule or power) and thus denotes the rule of the people, the capacity for collective governance is quite different from indicating a broadening of access to particular resources. Although participation in public debate and dialogue can assist with democratic deliberation and decision-making, frequently we find that with reference to digital discourse, democratization has been employed to demarcate providing access to information, spaces for debate and/or users producing mediated content; but corporate ownership of platforms and infrastructures persist, so all too often little actual power for meaningful collective governance is ceded to users.

The purpose of analysing Climategate has been to explore how climate change blogging reflects key elements of the contemporary media ecosystem surrounding pace, scale and democratic engagement (or its lack thereof). While this resembles existing modes of discursive media analysis, the focus has been upon exploring how these developments affect flows of attention and information, implementing the ethological methodology proposed by Deleuze that examines the relative speeds, viscosities and affective capacities which was outlined in the previous chapter. The example of Climategate demonstrates that blogs are capable of generating international news stories through 'viral' diffusion, initially between blogs, then between blogs and blogger/journalists before appearing in print and broadcast media and reaching hundreds of millions of people spread across the globe. From the day the scandal broke, detailed, accurate information was available via climate blogs published by experts who previously would have been excluded or constrained from mediated conversations. However, that information failed to significantly affect discursive structures surrounding the scandal in the mainstream media and public perception.

During the twentieth century, the primary problematic for media activists was access, which fostered a perspective that obtaining access would necessarily entail a transformation of public opinion through rational debate in the public sphere. Within digital media ecologies, while many more actors have access to mediated communications, the scarcity of attention denotes that crucial challenges involve getting noticed within the cacophony of information and mis-information.

Content in communicative capitalism

The disparate strands of this chapter, which have examined the attention economy, Big Data and Climategate, collectively suggest rejecting claims that digital culture empowers citizens by forming the type of postmodern public sphere which was passionately advocated during the early days of the internet. While there is enhanced access, debate, discussion and participation, the type of rational–critical debate that was envisioned is often notably absent, and in its place, we find a combination of fake news, clickbait headlines and hyperbolic rhetoric proliferating from commentators whose ideological framework appears unmovable by evidence-based debate. The prevalence of democratic and progressive values such as participation, access and dialogue within networked telecommunications is part of their integration into the circuits of contemporary capitalist formations, which require massive volumes of communication and the data it produces to commodify and capitalize affective relationships, a situation that Jodi Dean refers to as communicative capitalism.

Within this new mode of social relations, Dean (2009: 21/22) argues:

> Multiple opinions and divergent points of view express themselves in myriad intense exchanges, but this circulation of content in dense, intensive global communications networks actually relieves top level actors (corporate, institutional, and governmental) from the obligation to answer embedded in the notion of a message. Reactions and rejoinders to any claim are always already present, presupposed. In this setting, content critical of a specific policy is just another story or feature in a 24/7 news cycle, just another topic to be chewed to bits by rabid bloggers. Criticism doesn't require an answer because it doesn't stick as criticism. It functions as just another opinion offered into the media-stream. … The proliferation, distribution, acceleration, and intensification of communicative access and opportunity result in a deadlocked democracy incapable of serving as a form for political change.

For Dean, networked digital telecommunications superficially appear to provide solutions to contemporary crises of political participation through affording individuals the ability to create, remix, connect and share content. However, the circulation of digital content is not a precursor to the formation of infrastructures capable of creating meaningful social change; it simply affords ever faster circulations of content, underpinned by an economic model based upon the commodification of communication and communities via surveillance in order to serve targeted advertisements.

From this perspective, the emphasis within a substantive fraction of contemporary activism upon communicative action and raising awareness, rather than building the infrastructures necessary to revitalize or form

alternatives to the socialist, communist and trade union movements which animated the majority of twentieth-century political struggles appears somewhat misguided. That is not to suggest that political struggle does not require communication, as raising awareness is often a necessary precondition for politically motivated action, but within the current context, all too often activist endeavours are limited to online awareness raising, which is understood as an end in itself, rather than being a step towards affecting social or ecological justice. According to Dean, within the technocultural context of the commodification of communicative practices, such actions, on the one hand, become sites where huge amounts of energy and passion are invested, as commentators pour untold hours of time into debates which are seen by only a handful of readers and fail to change anyone's mind, and, on the other form, a convenient avenue for attention poor citizens to feel like they have undertaken meaningful political action by liking a campaign or retweeting a message. In both cases, the underlying issue usually remains entirely unaffected by these communicative actions, returning to Bateson's cybernetic epistemology, they exemplify differences that do not make a difference.

Climate change blogs present a useful example here. Scientists have spent countless hours producing content that debunks myths surrounding climate change. Similarly, sceptic bloggers have spent vast quantities of time advancing claims that anthropogenic climate change is not happening, is a fraudulent proposition concocted by devious climate scientists, or has been dramatically overstated and is unlikely to have significant adverse ecological effects. The question which Dean's framework of communicative capitalism posits in the face of all of this endeavour is, what has this actually achieved beyond participating in flows of digital content? One could quite convincingly argue that climate blogging has failed to achieve anything substantial. From *RealClimate*'s launch in 2004 until 2018, global atmospheric carbon dioxide concentrations rose from 377 ppm to 405 ppm, while global leaders repeatedly failed to agree on the kind of binding international emission reductions that would increase the probability of averting catastrophic climate change.[11] While enormous quantities of time have gone into providing detailed knowledge of the latest scientific publications and explaining why commonly asserted counter-narratives are scientifically improbable, this has clearly not translated into

[11]While 2015 saw agreement at the UN Climate Change Conference in Paris, featuring an ambitious commitment to reduce climate change to a 1.5-degree centigrade increase over pre-industrial temperatures, the agreement requires each nation to produce a voluntary emission cut to achieve this. Based upon the cuts pledged, estimates suggest that by 2100 we are on course for between three and four degrees of warming. Voluntary solutions to environmental crises have rarely achieved positive outcomes, whereas legally binding mandatory frameworks have typically been far more successful.

effective action by governments compelled by their citizens to prevent Anthropocenic ecocide.

Conversely, one might argue that climate sceptics have had tremendous results; however, such conclusions dramatically overstate the influence of niche blogs. More realistically, we would have to consider the impact of climate blogs within the broader context Dean outlines, whereby communicative contestation and the appearance of ongoing debate simply fuels further communicative action without really impacting the issue. One important conclusion to be drawn here is that the notion of the blogosphere as a single and whole space, as suggested by the metaphor of a sphere, is undermined by the manner by which oppositional discourse traverse climate blogs. There is little in the way of reasoned debate between scientists and sceptics, and over time, the tone of the exchanges has become increasingly hostile, in part due to the frequent personal harassment and character assassination perpetrated by climate sceptics (see Oreskes and Conway 2010).

Rather than a single smooth space of conversational unity premised upon the utopian fantasy of wholeness associated with the internet as the privileged place of global politics, blogs are better characterized as occupying numerous distinct 'blogipelagos' (Dean 2010: 38), segregated and disconnected islands. While there is at least some (albeit highly antagonistic) debate across climate blogs, where there is a shared topic of conversation, the same cannot be said for online content emanating from disparate groups such as American teenage fan-fiction sites, Pakistani religious blogs and Spanish social movements. Although networks of hardware and software physically connect users to a common technological infrastructure with shared platforms and protocols, there is no conversational unity within an overarching public sphere that connects these users or discourses.

While blogs have undoubtedly increased access to and participation in mediated debates over climate science, it is worth considering the range of actors who benefit from this access. There are scientists and concerned and informed activist/citizens, but, equally, there are actors such as Marc Morano, who runs the *Climate Depot* blog, as a paid employee of the conservative Committee for a Constructive Tomorrow lobby group, and Joe Romm who is similarly employed to manage the *Climate Progress* blog for the Centre for American Progress, a progressive advocacy organization. The contributions of actors such as Morano and Romm, in terms of volume of posting, typically far outweigh those of professional scientists such as the *RealClimate* team, as their time is not predominantly occupied by another occupation, demarcating an important way that online discourse is stratified by temporal engagement and attentive capacity. There are always hierarchies implicit within internet usage and users, those involved in climate blogging are not restricted to the politics of access; those encumbered by having to sell their productive labour capacity to attain financial stability

are disadvantaged in comparison to either actors who are employed to contribute or those actors whose financial position is sufficiently secure to permit them to focus on blogging full-time. Within the blogosphere, then, actors do not function as equal participants once they have overcome the material barriers to entry, the material conditions of everyday life continue to dictate the levels to which individuals can participate.

In many cases the practice of paying bloggers to propagate a specific viewpoint represents the extension of pre-existing media campaigns by organizations who now adopt astroturfing (Lee 2010) – fake grassroots social media and UGC campaigns – to complement more conventional lobbying and advertising strategies. While the creation and adoption of networked digital media technologies opens up new possibilities for democratic debate and participatory culture through a process of deterritorialization, the subsequent deployment of these media technologies and practices as tools of propaganda by hierarchical organizations indicate their reterritorialization. Indeed, the links between blogging practices and economies of attention highlights that this terrain provides a far from egalitarian space, as certain actors are able to mobilize attention via leveraging economic power to provide vast amounts of content propagating particular positions.

Astroturf blogs financed by private interests clearly problematize notions of a public sphere delineated through its separation from both the apparatus of the state and the realm of private interest. In this case, private interests act via astroturfing within the (apparently) public spaces of the internet to propagate ideological positions, utilizing economic leverage to attain attention and influence. Consequently, climate blogs present contested spaces which combine personal and private interests, which can be understood as part of a wider cultural trend towards the amalgamation of public and private realms of life, resonating with McLuhan's notion of 'retribalization' in which the pre-industrial situation where public and private were not recognized as discrete realms returns in a mutated form.

Where McLuhan's analysis departs from the contemporary situation, however, is that apparently public persons within grassroots campaigns are frequently revealed to be private interests. While the boundaries between public and private are blurred by networked digital media, there remain differences in how discourse is perceived if it is believed to emanate from concerned citizens acting upon ethical impulses, or corporate actors purchasing time and space to propagate commercial perspectives. Here we are reminded of Holiday's claims that blogs are an ideal medium for manufacturing stories which masquerade as independent journalism but are in fact duplicitous corporate promotional materials which bypass any notional ideals of fourth-estate gatekeeping and quality control.

In considering the hierarchies found within the technocultural assemblages of climate blogging, it is also important to consider the backgrounds of the human bloggers. The shared characteristics of the authors of science and

sceptic blogs include their geographical situation in affluent countries, the receipt of a high standard of education, with the overwhelming majority of prominent climate bloggers also being Caucasian men. In other words, prominent bloggers are socially, economically and educationally privileged individuals. Indeed, the bloggers' ability to effectively communicate is undoubtedly a factor leading to the standing of their blogs, which can be (at least) partially attributed to their privileged social background; well-educated individuals are likely to have superior communicative and technical skills, so their content is more likely to become preferentially attached. This provides further evidence discrediting contentions that the internet presents a smooth space whereby offline hierarchies are rendered irrelevant. Indeed, conspicuously absent from these debates are voices from the developing world or indigenous communities, that is to say, from the groups likely to be most heavily impacted by climate change.

That hierarchies based on pre-existing social inequalities arise within networked digital ecosystems suggests claims that the technological foundations of the internet are inherently democratic, because they allow users to contribute content, are woefully naive insofar as they typically ignore how these technologies propagate existing and novel forms of inequality. Social media involves billions of users generating monetary value for the venture capitalists and shareholders who own multibillion-dollar platforms. Equally, following Dean, we should note that the social context which has emerged alongside blogs and social media is one of increasing economic inequality, with the richest twenty-six individuals on the planet owning more wealth than the poorest 50 per cent of the global population (Oxfam 2019: 6). The rise of participatory, user-generated media has not brought about a more equitable and democratic global culture, in fact, quite the opposite appears to be occurring. This power-law distribution of wealth eerily echoes that which is evident within online popularity; far from making everyone an equal participant in a global public sphere, the dynamics of the internet ensure that a handful of voices have a greater reach than ever before, while the vast majority of content and contributors are almost invisible.

The burning question for activists, then, is how to amplify particular messages so that they become visible beyond the immediate niche communities in which they arise. In many cases, this involves the process of 'trading up the chain', being noticed by prominent blogs and commercial media outlets, whose exposure will make a story trend. The pitfall here, as we have seen, is that this strategy has been more successfully pursued thus far by public relations firms and right-wing lobby groups who utilize their economic and attentive advantages to regularly attain a level of exposure which is rarely achieved by grassroots activists. Climategate provides a useful example of how an assemblage of climate denialist bloggers, conservative think tanks, lobby groups and politicians created a scandal which successfully impacted global attention towards climate change. While it is undoubtedly important

for left activists to pursue similar media strategies, we must note that such endeavours can be understood as a continuation of what Michel de Certeau (1984) describes as the tactics of the weak, which stand in contrast to the strategies of the economically, attentively and politically powerful.

In addition, it is important to emphasize that Dean's framework of communicative capitalism emphasizes the significance of digital telecommunications to contemporary neoliberal 'creative' economies and that within this technocultural context the specificity of messages often is lost within massive data flows. 'In communicative capitalism … the use value of a message is less important than its exchange value, its contribution to a larger pool, flow, or circulation of content. A contribution need not be understood; it need only be repeated, reproduced, forwarded. Circulation is the setting for the acceptance or rejection of a contribution' (Dean 2009: 27). If activists are to meaningfully effect and alter this situation, then communications must not be focused purely upon awareness raising, which effectively falls into the circulatory system Dean describes, but instead must be geared towards organization and mobilization.

Rather than simply attracting attention, such moves must instead focus upon taking actions that go beyond liking and retweeting content or signing online petitions. Indeed, this is a key conclusion which both Dean and Jonathan Crary (2013) draw from exploring the always-on 24/7 system of communicative capitalism; effective action in the twenty-first century does not require withdrawal from the digital domain (which would entail a functional invisibility), but a tactical reorientation of the activist employment of digital telecommunications towards projects which bridge the perceived, although illusory, division between a digital world of debate and an embodied one of actions, and which resists the commodification of communication.

4

Ecologies of software

Whereas the previous chapter focused upon flows of attention and information to interrogate key issues surrounding digital content, this chapter examines software, exploring a range of examples which elucidate how differing forms of software are connected to political, economic, ethical and agential concerns. These examples foreground key areas of contestation surrounding the mode of production, agencies and capacities of software. This process begins by examining prominent debates relating to software, notably those arising within the academic field of software studies and the free and open source software movements, before shifting scale to assemble a range of specific cases that traverse different elements of software ecologies, ranging from firmware and device drivers through to networking protocols, digital rights management and algorithmic filter bubbles. In each of these cases, conflicts foreground issues primarily pertaining to either the agencies of code or the contested and multiple affordances of free and open source software.

Software and society

Although studying software is not new, most approaches originate within computer science and human–computer interaction. These perspectives are predicated upon utilitarian understandings of software which entail mastering the relevant programming languages in order to use existing software platforms or produce new software applications. In both cases, the framework departs from how software's connectivity with other aspects of digital culture interfaces with material politics, affects and nonhuman agencies. These questions are, however, addressed by the field of software studies, which emerged from digital/new media studies in the late noughties. Software studies argues that despite the growing breadth

and scope of technocultural, sociopolitical and economic systems which are at least partially governed by software, that 'software is often a blind spot in the wider, broadly cultural theorization and study of computational and networked digital media' (Fuller 2008: 3).

Software studies theorists contend that approaches from new media and cultural studies primarily focus upon content, typically overlooking how software functions at registers outside of user interfaces and experiences: 'It isn't just the external appearance of digital media that matters. It is also essential to understand the computational processes that make digital media function' (Wardrip-Fruin 2009: xi). As a result, software studies enacts a shift away from the study of content and user experience, towards examining agencies and power relations within the data processes, algorithms, languages and codes which create user experiences. Importantly, this shift challenges assumptions that software systems are ideologically neutral, utilitarian tools, instead proposing that a plethora of values are built into the ways software functions and malfunctions, and that this under-theorized area requires reassessment if we are to create more realistic understandings of how software shapes societies. Lev Manovich summarizes this approach, with an oft-repeated mantra from one of the key texts of early digital media studies: 'From media studies, we move to something which can be called software studies; from media theory – to software theory' (2001: 48).

The erroneous assumption that software is immaterial is contested by software studies, which argues that such claims present a theoretical blockage which diverts attention from the materialities and agencies of code. In contrast to the dematerialization of computational technologies, software studies articulate

> an understanding of the materiality of software being operative at many scales: the particular characteristics of a language or other forms of interface – how it describes or enables certain kinds of programmability or use; how its compositional terms inflect and produce certain kinds of glitches, cross platform-compatibility, or ease of sharing and distribution, how through both artefact and intent, events can occur at the level of models of user subjectivity or forms of computational power, that exceed those of pre-existing social formatting or demand new figures of knowledge. (Fuller 2008: 4)

This foregrounds the heterogeneous agencies that are associated with the human and nonhuman elements of digital assemblages: those of programmers, hackers and users; the unintended consequences of code associated with glitches, bugs and exploits; and those pertaining to the automated decision-making and machine-learning capabilities of software. The adoption of a materialist approach to software resonates with ecological methods, refuting

the alleged dematerialization of software present in approaches predicated upon virtuality or immateriality.

Software is comprised of binary code, which is materially encoded at scales imperceptible to humans. The binary data stored on a mechanical hard disk drive (HDD) exists as discrete magnetized areas on a disc-shaped platter, which rotates at speeds between 5,400 and 15,000 revolutions per minute. The direction of magnetization indicates whether each microscopic region represents a 0 or 1, and binary code is composed of these samples, whose magnetization is detected and altered by the HDDs mechanical read/write head.[1] Each magnetic sample is a single bit of information, with 8 bits comprising a byte, and contemporary HDDs commonly contain up to 8 terabytes of storage (8,796,093,022,208 bytes). While binary data can be perfectly copied, shared or operated upon by a diverse range of algorithmic processes, these affordances stem from the specific material capacities of the networks of hardware, software and culture employed.

In the case of HDDs, the ordering of magnetization can be copied exactly, providing a congruent copy of the binary code found in the original locations. We should, however, be aware that process of bitrot entail that copies will degrade over time, so perfect copies do not retain their congruence over protracted durations (Dharini 2009). Indeed, digital media often have lifespans far shorter than their analogue predecessors. When Pixar sought to produce the DVD version of *Toy Story*, they discovered that up to a fifth of the material had been corrupted due to the short lifespan of the mechanical HDDs used for digital storage. Despite the film's digital heritage, the DVD version had to be constructed by scanning a celluloid print (Bollmer 2015: 66–7).

Fuller's description of software's materiality is particularly attuned to ways that software is always enmeshed within dynamic assemblages, focusing not only upon properties of the software but also upon its affordances and capacities which are actualized through interconnections with other entities, providing a discursive framework which parallels an ecological methodology. Ecology is the study of interactions and transferences of energy between entities rather than entities in themselves, so software studies' stated aim 'to map a rich seam of conjunctions in which the speed and rationality, or slowness an irrationality, of computation meets with its ostensible outsiders (users, cultures, aesthetics)' (Fuller 2008: 5) closely corresponds to the relational and ethological emphases of media ecology.

While these aspects of software studies inform the analyses contained in this chapter, where software studies and media ecology differ, at least on some accounts, regards the status accorded to software with regard to contemporary culture. Manovich argues that not only does software add a

[1]For a detailed explication of the functioning of HDDs see Kirschenbaum (2008)

new dimension to culture but 'our contemporary society can be characterized as a *software society* and our culture can be justifiably called a *software culture* – because today software plays a central role in shaping both the material elements and many of the immaterial structures which together make up culture' (Manovich 2008a: 15 emphasis in original). The danger of ascribing centrality to any feature of the massively complex globalized networks of hardware, software, content, humans, natural resources, techniques, knowledges, legal, political and social structures that collectively comprise 'culture' or 'society' is that this immediately relegates other areas to the margins. While software is important to contemporary spaces – particularly the urban and domestic spaces which Rob Kitchin and Martin Dodge (2011) describe as Code/Spaces, whereby spaces are functionally dependent upon automated software systems – there are questions to be asked about the abstraction of software and code from the technocultural ecology in which it is always situated.

A useful counterpoint here is Castells's (1996: 29) genealogy of contemporary technoculture, which is predicated around the convergence of microelectronics, optoelectronics, telecommunications, biogenetics and cultural factors. This meshwork of technological evolution thus forms a digital ecology which is not structured around a single central point, be it software, microelectronics, information or another entity, but which is instead approached as an entangled assemblage. Although software plays a crucial role in contemporary societies, this role is a relational one which is entirely dependent on a series of other, equally critical areas, such as reliable sources of electrical energy, silicon, rare earths and other essential materials for digital infrastructures.

Declaring the centrality of software in computational assemblages risks positioning the 'creative', 'cognitive' or 'immaterial' mode of labour associated with programming (and by extension certain modes of content creation) as the central site for producing value within digital assemblages. This move relegates the 'physical', 'material', and increasingly automated practices of hardware production, which as we shall see in the following chapter are often predicated upon highly exploitative labour practices and environmentally harmful activities, to a peripheral or marginal position. This type of separation between valuable cognitive labour and devalued physical tasks seemingly replicates a division of labour in which the creative class (Florida 2002) of the urban developed world are lionized as intellectual, agile and digitally articulate, in glaring contrast to those whose physical labour is increasingly devalued by the growing presence of an industrial reserve force of the unemployed, and whose opportunities for employment are increasingly squeezed through the proliferation of automated technologies. Media ecology's commitment to social and environmental justice requires that such value systems are made visible and challenged, rather than relegated to a marginal position within a so-called software society.

Media ecology therefore stresses entanglement within the context of the networks of energy and matter, software and hardware, humans and technology, which comprise contemporary technocultural structures, rather than presenting software as the central element of these structures: the epistemological consequences of entanglement are that we cannot separate particular aspects of a technocultural milieu, either declaring code to be of central importance or studying its capacities in isolation from dynamic entanglements across multiple scales. This means not solely studying software but mapping assemblages of software, hardware, content and culture, and foregrounding the material politics involved.

Contesting the claim that contemporary society can be described as software culture or a software society does not, however, denote that software is not integral to contemporary technocultural systems. Most audio, visual, literary and other forms of mediated content are today predicated upon the use of digital publishing tools which afford content creation, distribution and modification in ways that were unthinkable with previous technocultural assemblages. Elsewhere, our economies, commerce, transport, legal and welfare infrastructures rely heavily upon software to provide automated or semi-automated processes for their continued ability to function. Indeed, the automated trading systems analysed in Chapter 1 delivers one exemplar. Equally, as Kitchin and Dodge demonstrate, contemporary urban spaces from airports to supermarkets would effectively fail to function without software (although of course they would also fail were they to be without electricity or wired/wireless network connectivity, indeed with no electricity at all they would be less functional than with a software fault). Given the proliferation of digital technologies within contemporary society, and that all such technologies require various forms of software in order to operate, it seems reasonable to agree with the contention of software studies scholars that software forms an area whose importance currently exceeds the amount of attention commonly bestowed upon its study.

Free, open and closed

Although the materiality of software has largely been under-explored, the mode of production associated with free and open source software has received substantial attention. Both free and open source software refer to ways in which software is produced and licensed, and this licensing affects how the software can subsequently be modified and distributed. While the terms ‘free software’ and ‘open source software’ are frequently used interchangeably, and there is significant overlap between them, particularly in their practical applications, the two terms reflect diverging philosophical standpoints on software production and distribution. Although the blanket terms ‘FOSS’ (Free and Open Source Software) and ‘FLOSS’ (Free, Libre and

Open Source Software) are commonly used, the philosophical incongruences between the free and open source software movements are worth exploring in order to comprehend the political dimensions of these debates within coding communities.

With roots in the 1970s computer hacker community, the free software movement was launched by Richard Stallman in 1983 with the development of the GNU (Gnu's not Unix) operating system (Stallman 1983). Once development was underway, Stallman founded the non-profit Free Software Foundation (FSF) in 1985 to maintain the GNU General Public License (GPL), a legally robust way of licensing free software which remains one of the most popular ways of licensing FOSS projects. The FSF also publishes the Free Software Definition (FSD), which provides a periodically updated definition of free software. The FSD outlines four freedoms which are necessary for software to be free software. The definition of 'free' being used is not gratis (free of financial cost), but free as in freedom, or as the FSD describes it, '"Free software" is a matter of liberty, not price. To understand the concept, you should think of "free" as in "free speech", not as in "free beer"' (FSF 2011).

The four freedoms required by the FSD are (1) the freedom to run the program for any purpose, (2) the freedom to study and modify the program (with access to the source code being a necessary precondition for this freedom), (3) the freedom to redistribute copies of the program, and (4) the freedom to distribute modified copies of the software. These freedoms do not prohibit corporate usage of free software or preclude parties from charging money for free software; in fact, both practices are explicitly encouraged as valid uses of free software. The freedom of any user to redistribute copies of the software does, however, place practical limitations on the potential for charging significant fees for free software, impeding the type of artificial scarcity engineered by monopolistic control over the distribution of products whose actual economic cost to copy and share (among those with the requisite hardware) is minimal.

The free software movement describes itself as adopting a moralistic approach to software that is designed to address the 'social problem' (Stallman 2003) of proprietary software. The term 'moralistic' is applied to denote a stable series of cultural judgements about what is right or wrong: the freedoms designated by the FSD are understood as positive values, whereas the encroachment upon these freedoms found within proprietary software is prescribed as problematic behaviour.

The open source movement emerged from the free software movement, with a group departing from the FSF and forming the Open Source Initiative (OSI) in 1998. Eric Raymond, who along with Bruce Perens founded the OSI, argued that moving from free to open source software was less attributable to divergent conceptual thinking than to terminological and public-relations-related problems pertaining to fears and suspicions that the

term 'free software' engendered among corporate users (Raymond 1998). Raymond contends that these concerns partially arose through ambiguities pertaining to different usages of the term 'free' and cites the fact that much of the FSF's literature begins by emphasizing their utilization of the term to demarcate freedom rather than gratis as evidence to support this. Consequently, Raymond employed the term 'open source' as an (allegedly) ideologically neutral alternative to free software. The OSI maintain the Open Source Definition (OSD)[2], which contains ten clauses, which extend beyond providing access to source code. Like the FSD, for a licence to comply with the OSD it must allow free redistribution of the software and its code, and permit modifications to the original program. Other clauses include statements that the licence must not discriminate against persons, groups or fields of endeavour (explicitly denoting that the licence cannot prohibit the use of open source software in businesses), that the licence must be technology neutral and must not restrict other software.

Comparing the details of the respective definitions of open source and free software, what becomes striking are the similarities between them; their differences lie not in what the terms refer to but in how they approach the same production process. According to Stallman (2007):

> Nearly all open source software is free software. The two terms describe almost the same category of software, but they stand for views based on fundamentally different values. Open source is a development methodology; free software is a social movement. For the free software movement, free software is an ethical imperative, because only free software respects the users' freedom. By contrast, the philosophy of open source considers issues in terms of how to make software 'better' – in a practical sense only. … For the free software movement, however, nonfree software is a social problem, and the solution is to stop using it and move to free software.

The philosophical schism between the approaches to free and open source software – with one side approaching the field from a moralistic position pertaining to freedom and the other pursuing the practical benefits of a commons-based production model – is somewhat reflected in wider discourses pertaining to commons-based peer-to-peer production.

The terms 'commons' and 'commonwealth' refer to assets which are communally managed and which create value which nourishes the community at large, rather than private interests. Unlike privately owned commodities, or centrally administered public services, commons are typically managed by the community that uses and produces them. Commons-based peer

[2]Available online at http://opensource.org/docs/osd

production refers to the creation of commonwealth by a distributed network of peers, voluntarily self-aggregating participants who are accorded equal status. That these peers are able to be geographically distributed is often highlighted as a key departure from earlier forms of commons that were place based.

The open source approach to commons is exemplified by authors such as Yochai Benkler (2005; 2006) and Lawrence Lessig (2001), who both self-identify as liberal capitalists, but present strong cases regarding the advantageous nature of commons-based peer production, both in the specific case of software and within other particular areas of contemporary technoculture. Benkler (2005: 175/176) contends that certain affordances specific to twenty-first-century digital culture makes peer production a successful strategy:

> Peer production is emerging as an important mode of information production because of four attributes of the pervasively networked information economy. First, the object of production – information – is quirky as an object of economic analysis, in that it is purely nonrival and its primary nonhuman input is the same public good as its output – information. Second, the physical capital costs of information production have declined dramatically with the introduction of cheap processor-based computer networks. Third, the primary human input – creative talent – is highly variable, more so than traditional labour, and certainly more so than many material resources usually central to production. Moreover, the individuals who are the 'input' possess better information than anyone else about the variability and suitability of their talents and level of motivation and focus at a given moment to given production tasks. Fourth and finally, communication and information exchange across space and time are much cheaper and more efficient than ever before, which permits the coordination of widely distributed potential sources of creative effort and the aggregation of actual distributed effort into usable end products.

There exists a range of scholarship that explores the use of commons-based economic systems in tribal societies (Strathern 2005; Seeger 2005) and premodern Europe (Boyle 2005; Runge and Defresco 2006), highlighting pre-capitalist commonwealth-based alternatives to market production and delineating that commons-based production is not a historically novel method of production. Equally, the work of feminist geographers J. K. Gibson-Graham (2006) productively illustrates the manner through which commons-based economic activities are dispersed throughout advanced capitalist economies, with examples ranging from domestic work and gift-giving to gleaning, poaching and theft. Benkler's thesis, however, is that several specific affordances of contemporary technoculture creates opportunities

for commons-based production to occur through geographically dispersed, distributed networks of self-aggregating peers, which, he argues, in certain conditions, provides a more economically efficient model than market-based production, and that this is particularly true in cases involving information.

This approach is based not on an overarching critique of capitalist social or ecological relations but on a utilitarian position surrounding economic efficiency, although we should note that Benkler does note several positive cultural externalities associated with commons-based peer production. As with the open source development model, Benkler's position encourages corporate capitalism to adopt commons-based peer production within certain realms, under the rationale of competitive cost advantage, a position which has become increasingly popular within the techno-capitalist business literature (e.g. Davenport and Beck 2002; Tapscott and Williams 2008; Leadbeater 2008). This position is not post- or anti-capitalist; primarily limiting itself to economic efficiency, it does not engage with contemporary crises of capitalism; instead, it looks to reform the neoliberal fetishization of competition and free markets by including commons under certain conditions where it proves economically competitive.

This reformist liberal–capitalist position can be juxtaposed with the more revolutionary claims associated with common-based production advanced by theorists such as Bernard Stiegler and Michel Bauwens. Stiegler contends that by the twenty-first century, capitalism has become intrinsically and systemically focused upon short-term financial flows, and consequently is thoroughly incapable of presenting useful solutions to problems such as climate change or creating economies free of dangerous economic speculation. Addressing this toxic short-termism, Stiegler contends that digital technoculture forms a new pharmacological context, in which there exists tendencies towards both an ecologically catastrophic short-termism and an alternative possible mobilization towards an economy of contribution, which Stiegler posits as a non-market mode of organization predicated on a model analogous to that of commons-based peer-to-peer production.

Free software is the exemplar that Stiegler provides as presenting an immanent alternative to consumer capitalism and Anthropocenic ecocide:

> The software industry and its digital networks will eventually cause associated techno-geographical milieus of a new kind to appear, enabling human geography to interface with the technical system, to make it function and, especially, make it evolve, thanks to this interfacing: collaborative technologies and free license software rest precisely on the valorization of such associated human milieus, which also constitute techno-geographical spaces for the formation of positive externalities. (Stiegler 2010a: 128/9)

Commons-based peer production is celebrated not only for its economic efficiency here but for creating technocultural structures which embrace cooperation. Stiegler terms these 'associated milieus', which he contrasts with 'dissociated milieus', technological systems within which producers and consumers are treated as separate entities. Stiegler argues that dissociated milieus lead to a process of proletarianization, whereby consumers lose the knowledge of how to produce culture, which becomes grammatized or embodied within technical apparatuses. Consequently, Stiegler contends that commons-based peer production creates positive externalities: beneficial extra-economic values which derive from the process of communal care.

In place of the perspective which contends that growth is understood solely along quantifiable monetary terms, Stiegler (2010a: 208) proposes a broader understanding whereby 'a pathway to genuine growth must be refound, a growth running counter to the misgrowth that consumerism has become, and a growth which would consist in a renaissance of desire. Such a rebirth would be achieved by implementing an economy of contribution, an economy for which "to economize" means "to take care."' This position aligns with ecophilosophy and ecological economics, insofar as it emphasizes that socioeconomic systems of valuation require a reorientation away from monetary value and towards qualities such as environmental sustainability and personal well-being. What is pertinent to this chapter is that, in Stiegler's analysis, it is the affordances of sociotechnical assemblages to produce distributed commons-based peer production which enables this type of economy of contribution. While this mode of production has been primarily visible in areas such as free software, Stiegler asserts that it can become the basis for a post-capitalist socioeconomic model.

The potential benefits of the widespread adoption of commons-based peer production are central to the work of Michel Bauwens, the founder of the P2P Foundation. Bauwens examines distributed peer-to-peer (P2P) networks as an alternative mode of production to both the market and the state, predicated upon the voluntary self-aggregation of individuals who control their own means of production, as well as having a commons-orientated output (Bauwens 2009). FOSS is cited within Bauwens's writings as a prime example of P2P production, with FOSS projects such as Apache, Linux and Mozilla Firefox presenting prominent examples of successful P2P systems.

Bauwens explores the material and cultural prerequisites for P2P systems to flourish, drawing similar conclusions to Benkler and Lessig about the centrality of digital-networked computational systems to the viability of P2P, while also exploring ways that a hybrid economy exists whereby P2P networks are partially dependent on capitalist markets – through P2P workers' current needs for a wage supported outside of their P2P activities – and capitalist markets are increasingly dependent on P2P networks as an

external source of value which can be appropriated into monetary value. However, Bauwens departs from Benkler and Lessig's positions by positing P2P as an alternative socioeconomic model to that of the market:

> This still nascent P2P movement … is fast becoming the equivalent of the socialist movement in the industrial age. It stands as a permanent alternative to the status quo, and the expression of the growth of a new social force: the knowledge workers. In fact, the aim of peer-to-peer theory is to give a theoretical underpinning to the transformative practices of these movements. It is an attempt to create a radical understanding that a new kind of society, based on the centrality of the Commons, and within a reformed market and state, is in the realm of human possibility. (Bauwens 2006)

Considering alternative systems which could support an economy heavily dependent on a P2P mode of production, Bauwens (2006) suggests that a universal basic income (UBI) could provide an economic base which then empowers individuals to contribute value via P2P networks. This position has in recent years gained traction across a range of left-wing thinkers and organizations including Stiegler (2010a); Maurizio Lazzarato (2004); Michael Hardt and Antonio Negri (2000, 2009) and Nick Srnicek and Alex Williams (2015).

Proponents of UBI contend that enabling universal access to a basic wage, alongside the provision of health care and education, would allow innovation and creativity to flourish by removing the compulsion to work to make ends meet, while reducing the current threat of precarity which is likely to be reinforced by increasing levels of automation. Furthermore, a UBI would require a reappraisal of renumeration for labour. Today, jobs that are deeply unpleasant, dirty, dangerous or demeaning – such as cleaning toilets – are currently often poorly paid due to the compulsion for people to work to make ends meet. If those basic needs were met by a UBI, finding people willing to perform those tasks would require significant financial incentivization. Alternatively, that financial incentive could spur the development of technologies to automate those unpleasant tasks, something that is unlikely to occur in the current socioeconomic environment, precisely because they are so poorly paid.

It must be noted, however, that such claims go beyond those made by the free software movement, which campaigns around and develops software, rather than the broader socioeconomic issues advocated by Bauwens and Stiegler. Stallman's own political position can best be described as libertarian, and the FSF has always stated that free software has commercial potential. However, the dissociation of the open source movement from the free software movement can be understood as partially resulting from free software's connections with radical social movements and the desire on

the part of liberal–capitalist advocates of open source software to distance their work from anti-capitalist connotations in order to provide more corporate-friendly platforms. Indeed, among anti-capitalist tech-activist communities, projects are typically framed by the rhetoric of free software, while corporate projects tend to ensconce themselves in the language of open source.

The differences surrounding the open source and free software movements demonstrate the diverse range of views which are broadly supportive of commons-based peer production. These range from avowed capitalists and corporations innovating around affordances particular to the network society, to anti-capitalist activists contending that these formations provide a glimpse of a hyper-productive economic mode with intrinsic drives towards an alternative model of organization based upon cooperation rather than competition. In relation to these debates, the media ecological approach I wish to develop is situated towards the anti-capitalist end of the spectrum, contending that sociotechnical assemblages must be re-orientated away from GDP as the sole source of value, towards promoting broader conceptions of growth and wealth as the enhancement of ecological systems.

Hyper-productive digital networks do not, however, inherently address ethical or ecological problems. As we saw in the previous chapter with regard to viral marketing, astroturfing and blogging, often those best situated to benefit from technological innovations are existing elites, so pre-existing inequalities can be widened rather than narrowed, and this is certainly the case when analysing how corporations such as Google, Microsoft and IBM have leveraged open source software to enhance profitability. As we shall see, community-led development can mean that corporations effectively benefit from the unpaid labour of volunteers. Despite this, if we are to take seriously the claims advanced by Stiegler and Bauwens that commons-based peer production forms a nascent alternative mode of social organization and economic production, providing potential tools for social and ecological liberation within control societies, a detailed exploration of various practices, actions and forms pertaining to FOSS, as the paradigmatic example of this activity is important in grasping salient features, affordances and affects related to this mode of production.

Whereas debates surrounding the discourses and practices of FOSS and software studies present one scale for examining the ethics and agencies of software, I now turn to numerous examples which explore a range of scales within the software ecosystem. These cases treat software as being operative across numerous registers, ranging from the microscopic materialities of firmware or specific device drivers, through to the development and distribution of networking protocols, social media algorithms and search engines. They will develop an analysis of variable deployments of openness across an ecology of software, alongside examining the agencies and technocultural politics associated with various software.

Jailbreaking iPhones and Magic Lanterns

The term 'firmware' describes the lowest level of software, usually consisting of relatively small programs or data structures which enable device functionality, without which the hardware device in question would be completely non-operational. Firmware is present throughout the range of microelectronics present in contemporary technoculture. While the term has become somewhat fluid as the technologies involved with firmware have evolved, the loose demarcation between software and firmware references both the level at which the code operates and the fact that originally firmware was encoded in read only memory (ROM) on discrete hardware modules. Updating firmware therefore initially required users to physically alter the machine, plugging and unplugging the respective firmware-containing modules into the device.

Semiconductor-based programmable read only memory (PROM) chips were eventually superseded by erasable programmable ROM (EPROM) chips in which memory could be erased through sustained exposure to strong ultraviolet light, which in turn were replaced by electrically erasable ROM (EEPROM). Most modern devices contain flash memory, a modern form of EEPROM first introduced by Intel in 1988 (Tal 2002) which permits up to 1,000,000 erase/rewrite cycles. This entails that modern firmware can be regularly updated by manufacturers in order to add functionality, remove bugs or improve performance. Firmware may initially appear to be a utilitarian set of instructions designed to enable the underlying capabilities of hardware devices; however, firmware has significant impacts on the affordances of these devices, revealing struggles pertaining to power, control and agency surrounding firmware access and modification.

Firmware's agential affordances are illustrated by the open source Magic Lantern firmware that was originally designed for the Canon 5D Mark II (5DMII) and subsequently deployed on other Canon DSLRs capable of shooting video. Upon release on 19 November 2008, the 5DMII generated significant interest from videographers due to the inclusion of a high-definition video mode. Although the camera was primarily designed and marketed by Canon as a photographic camera, the 5DMII had several unique features for a video camera priced around £2500, largely deriving from the camera's full-frame 35mm sensor, which dwarfed the sensors in video cameras which existed in 2008 at a similar or higher price point. Commonly used professional video cameras in 2009, such as the Sony Z1 and Panasonic HVX200, used 1/3-inch sensors, the higher-end Sony EX3 used a 2/3 inch sensor and even the Red One – a professional digital cinema camera used for feature films such as Peter Jackson's *King Kong* and costing over ten times the price of a 5DMII – used a Super 35mm sensor (whose size is similar to an APS-C sensor; see Figure 4.1).

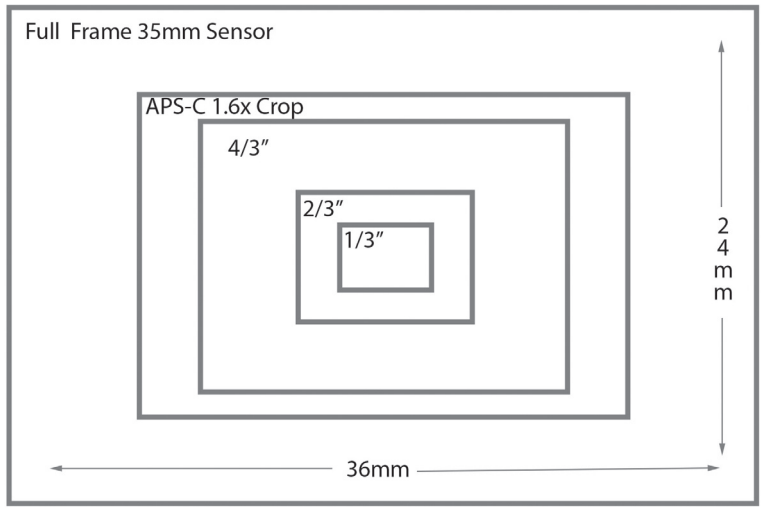

FIGURE 4.1 *Video camera sensor size comparison.*

Cameras containing larger sensors feature enhanced low-light performance, as the greater surface area allows more light to fall upon each individual pixel. Another capacity of larger sensor sizes, which is seen as highly desirable by cinematographers, is that they provide a shallower depth of field (DOF) at a given aperture. Consequently, cameras with large sensors afford film-makers a greater degree of control over DOF, allowing the creation of aesthetics traditionally associated with high-budget 35mm film productions, whereas deep DOFs are historically aligned with low-budget or amateur video or 8mm productions. Additionally, the 5DMII had an interchangeable lens mount, allowing a huge range of optics to be mounted to the camera, whereas in 2008 most camcorder featured fixed zoom lenses. These jack-of-all-trades optics are designed for versatility, but interchangeable lens systems allow the use of specialized lenses such as tilt-shift, macro and wide-aperture fixed focal length lenses.

Despite these advantages, there were also significant drawbacks when comparing the 5DMII to professional video cameras. Upon release, the camera did not allow alterations of the lens aperture while in video mode; adjustments had to be performed by exiting video mode, resetting the aperture and then re-entering video mode.[3] The camera would only record video at 30 frames per second, meaning that it could not be used for broadcast material in Europe, where the PAL standard requires 25 frames per second,

[3]This was changed by a firmware update from May 2009 (Canon 2009).

and it could not shoot 24 frames per second – the speed of film cameras.[4] Furthermore the 5DMII lacked a number of features ubiquitously found on professional video cameras, such as manual audio gain control, audio levels and zebras.[5] Although the 5DMII's hardware was able to implement these features, the Canon firmware which shipped with the camera did not enable them.

Following the 5DMII's release, a group of open source programmers decided to investigate the potential of modifying the firmware to add functionality to the cameras. The result was the open source Magic Lantern software whose first public release was in June 2009. The initial release included features such as manual aperture control, zebras, manual gain control and audio levels, and over time Magic Lantern has expanded to include features such as focus peaking, variable bit rate recording, full HD output via the cameras HDMI output (the Canon firmware only supports 640 × 480), assignable white balance values in kelvin and an intervalometer. The addition of this functionality greatly improves the versatility and utility of the 5DMII as a video camera.

Magic Lantern is installed through a straightforward process detailed on the Magic Lantern website and subsequently illustrated by online videos. Users begin by downloading the software and a firmware update from the Magic Lantern website, and then load the firmware onto a memory card which is placed into the camera. The user then navigates through camera menus, selecting an option to update their firmware – a process congruent to installing official firmware updates. Once the modified firmware has been installed, the user must then make the selected memory card bootable, which can be achieved using a software tool with a GUI linked from the website. Once this has been achieved, the Magic Lantern software can be loaded onto the memory card, which when placed into the camera with the modified firmware will boot the software. This particular practice means that if the memory card in the camera does not contain the software, or is not bootable, then the camera functions as though it was unmodified.

The Magic Lantern group have successfully reverse engineered versions of the firmware to add similar functionality as to that achieved for the 5DMII on subsequently released Canon DSLRs such as the 5D Mark III, 6D, 7D, 600D and 70D. Additionally, as of 2012, Magic Lantern added capabilities for RAW video recording on numerous Canon DSLRs. Whereas the default video capture from Canon DSLRs records compressed 8-bit video using the h264 codec (either with IPB or with intraframe compression), Magic

[4]Both 24 and 25 frames per second recording capabilities were added by Canon in a firmware update in March 2010.

[5]Zebras provide a cinematographer with visual feedback indicating the overexposed areas of an image.

Lantern adds an option to capture a stream of 14-bit RAW images, which retain the full level of data recorded by the sensor. The file size for RAW video capture is thus far larger than for h264 and the extra detail and sharpness in these images significantly increase the quality of the recorded images. Consequently, Magic Lantern RAW video has been enthusiastically adopted by independent film-makers.

The example of Magic Lantern highlights that firmware is not a neutral, utilitarian set of instructions which simply allows hardware to function but represents a method for controlling particular kinds of functionality. Access to firmware becomes crucial to grasping the affective potentials of devices, what they are capable of doing and which actors are afforded the capacity to explore and modify these boundaries. Interestingly, when a photography blogger contacted Canon to ask whether installing Magic Lantern would void his camera warranty (Tirosh 2013), the response he received advised that while any damage caused through the alteration of the firmware would not be covered by the warranty, damage from other sources (such as buttons failing) on cameras running modified firmware would be replaced under the Canon warranty.

This position, where Canon are happy for customers to customize their devices but will not be held responsible for damage which occurs through the process of modification contrasts sharply with the behaviour of certain other companies faced with open source developers attempting to enable features on their devices. A prime example of this is Apple's reactions to iOS jailbreaking, the process of gaining root access to a device running Apple's iOS operating system which is found on iPhones and iPads. Attaining root access enables users to remove numerous limitations and restrictions built into the software, including allowing the installation of software from sources other than the official Apple App Store, customizing the user interface, setting different default applications for specific tasks and various other ways of customizing functionality which is prevented by iOS. Prior to iOS version 4.0, the Apple software also prevented devices from multitasking, another feature which was enabled by jailbreaking iOS devices.

The ability to download applications from outside of the official Apple App Store allows users to decide which applications they wish to run, rather than relying on the applications deemed appropriate by the hardware manufacturer, whose policies over application censorship have been criticized in numerous cases. In December 2009, Apple rejected an app created by Pulitzer Prize-winning satirist Mark Fiore on the grounds that it contains satirical content which violates 'Section 3.3.14 from the iPhone Developer Program License Agreement which states: Applications may be rejected if they contain content or materials of any kind (text, graphics, images, photographs, sounds, etc.) that in Apple's reasonable judgement may be found objectionable, for example, materials that may be considered obscene, pornographic, or defamatory' (Singel 2010). The same section of

Apple's guidelines was cited in the removal of an application from the German tabloid newspaper *Bild*, deciding that it contained overly sexual material for the Apple platform, leading to claims of censorship from *Bild*'s publisher, Springer (Gebauer and Patalong 2010). Apple has also been criticized over decisions to ban an application from WikiLeaks (Helft 2010) and to prevent charity and non-profit organizations from providing applications which allow users to donate to their organizations (Strom 2010).

To circumnavigate restrictions put in place by Apple, users can choose to jailbreak their device. While accurate numbers of jailbroken devices are hard to source, in 2013 over seven million devices installed the Evasi0n jailbreaking tool within its first week of public release (Greenberg 2013), denoting that significant numbers of iPhone users override the restrictions put in place by Apple. Apple's response to jailbreaking has been attempts to prevent it through technical and legal means. iOS jailbreaking relies on the user utilizing one of several known firmware exploits which allows the user to attain root access to the device. An exploit can be broadly defined as taking advantage of vulnerabilities in the device's firmware, affording the user the elevated privileges associated with a super-user or root account. The term 'root' references the file system on Unix-style operating systems, whereby the root directory is the top-level system directory, so root access refers to a user having privileges to access all areas of the system and to set access permissions for other users.

Jailbreaking usually requires users to enter the device firmware update mode on their device, which is achieved by turning the device off, connecting it via USB to a computer with iTunes running and then holding down the home and power buttons for ten seconds, before releasing the power button while continuing to hold down the home button. If this procedure is correctly applied, the user receives a message that iTunes has detected a phone in recovery mode. Device firmware update mode allows jailbreaking software such as RedSn0w to install firmware onto the iOS device, as the firmware and OS are not loaded by devices booted into this mode, which is intended to recover devices when the firmware or OS has been corrupted and requires reinstalling. Once connected to the jailbreak software, the device has the modified firmware applied, allowing the user to install a modified OS.

The process of jailbreaking devices is enabled by the existence of online how-to guides and instructional videos, which provide step-by-step instructions for jailbreaking. As the act potentially results in permanently rendering the device inoperable if incorrectly applied, provision and straightforward access to clear instruction is crucial to jailbreaking. Dozens of YouTube tutorials delineate how to jailbreak various versions of iOS, with the most popular tutorials having over a million views each. Not only is the networked infrastructure of the web the means for disseminating jailbreaking software, but broadband internet capable of streaming video becomes crucial for its adoption. Here we see a way in which entanglement

between scales of content, software and hardware is made visible: digital content is used to instruct users how to jailbreak hardware by means of installing customized software. Without the web, users would lack both access to the jailbreaking software and the knowledge of how to execute the jailbreaking process.

To combat these exploits, Apple frequently releases firmware updates closing vulnerabilities used by the jailbreaking community. After each exploit is closed, the jailbreaking community finds new vulnerabilities to continue jailbreaking devices. Apple also stops signing old firmware versions in order to prevent jailbreakers downgrading their firmware to earlier versions which had been successfully jailbroken and have released iOS firmware updates such as version iOS 4.02 for the iPhone and 3.2.2 for the iPad which add no new functionality (Patel 2010), but do close known jailbreaking exploits, demonstrating Apple's commitment to preventing jailbreaking. Consequently, jailbreaking iOS devices is a cyclical process whereby products are released, exploits are found, implemented, published and subsequently patched by new firmware releases, which in turn leads to the search for novel firmware exploits.

In addition to utilizing technical means attempting to prevent iOS jailbreaking, Apple have sought to criminalize the act itself. In 2008, Apple submitted materials to the US Library of Congress Copyright Office, requesting that the circumnavigation of restrictions built into mobile telephony devices be reviewed under the Digital Millennium Copyright Act (DMCA). Apple argued that explicitly exempting jailbreaking from DMCA, which was originally designed to prevent circumvention of copyright controls commonly known as digital rights management (DRM) would 'destroy the technological protection of Apple's key copyrighted computer programs in the iPhone device itself and of copyrighted content owned by Apple that plays on the iPhone, resulting in copyright infringement, potential damage to the device and other potential harmful physical effects, adverse effects on the functioning of the device, and breach of contract' (Apple 2008). In 2010, the US Library of Congress Copyright Office dismissed Apple's arguments, ruling that jailbreaking was a private decision for individuals, who were free to decide which applications they wished to run on hardware they had purchased and that this was covered under existing legislation around the fair use of products (Albanesius 2010). Although Apple were ultimately unsuccessful in their efforts to render jailbreaking illegal, they continue to deploy technical measures attempting to prevent jailbreaking and maintain that jailbreaking voids any product warranty (Satriano and Shields 2010).

This case presents an example of a multinational corporation having a conflict of interest with a significant minority of its customers: while Apple prevent users from utilizing features their devices are capable of – notably downloading applications from locations other than the official Apple App Store, from which Apple take 30 per cent of any monetary transactions – a

fraction of Apple's customers seek the freedom to use the applications they wish and to download them from their location of choice. This conflict of interest has seen the creation of tools which provide users with root access to their devices, and Apple's response has been attempts to criminalize their customers and to prevent jailbreaking through technical means.

This conflict of interest highlights what is at stake with regard to controlling access to firmware. Firmware enables or denies access to various elements of device functionality, delimiting particular possibilities of the device/user assemblage. Firmware, then, becomes a terrain of conflict for competing groups who lay claim to ownership of devices and desire the agency associated with ownership to designate how devices can be utilized. Consequently, we can understand that firmware relates to both power relations and agencies within media ecologies: how parties can or cannot connect to, alter and modify firmware affects agential capacities regarding ways that user/device assemblages function, and conflicts over controlling access to these connections illustrate differential power relations between actors. Furthermore, the persistence of jailbreaking over a protracted temporal duration denotes the inability of Apple to entirely control their own code, evidencing one way that it possesses its own agencies and affordances.

Responses to firmware/product hacking have differed widely, with the two examples outlined here demonstrating this via the contrast between Canon's statement that they will repair modified devices under warranty (so long as firmware modification has not caused the fault) and Apple's attempts to criminalize their customers. This divergence can largely be explained by the economic aspects of each case. Magic Lantern adds value to Canon's customers, providing them with enhanced functionality, but Canon itself stands to lose nothing through users modifying hardware they have already purchased. Magic Lantern effectively enhances the value of Canon's products, while Canon themselves invest no time, energy or capital in this process, and are under no obligation to support users whose hardware encounters problems from these modifications. By contrast, while iOS functionality is also enhanced through jailbreaking, the ability for users to escape the walled garden of Apple's App Store and instead use alternatives such as Cydia to download applications entails that Apple loses revenue. The negative economic connotations for the manufacturer presented by jailbreaking can thus be understood as a primary motivation for Apple's stance.

This account of firmware and product hacking produces productive homologies with accounts of computer game modding practices, which have long been seen as key indicators of paradigmatic changes to media culture in the early twenty-first century:

> Game modifications do suggest that the era of media as software will produce new legal relationships between consumers and producers. However, these relationships are not the precondition for a utopian

> democratization of creativity – they still exist within the prevailing economic nexus. Game modders provide the industry with free research and development of new ideas and sometimes whole new titles. … The mod community now provides a reliable source of labour for the industry, with very low or no training investment. (Dovey and Kennedy 2006: 134)

While game publishers have gone to great lengths to attract modding communities, modding practices are viewed as highly attractive so long as value is added to the existing commercial framework laid out by the software developers: 'The point at which modding becomes competition rather than brand development and viral marketing is very carefully policed' (Dovey and Kennedy 2006: 134). This closely corresponds to Apple's behaviour surrounding iOS jailbreaking, as the ability of jailbroken devices to download apps outside of the official App Store represents a challenge to the monopoly system Apple otherwise operates.

Consequently, we can suggest that open source communities bear some semblance to game modding communities, both of which see 'consumers' taking increasingly active roles in shaping the development of media platforms. While there are divergent reactions in specific cases, these predominantly arise from potential threats or boosts to profitability. Notably, these heterogeneous responses demonstrate that a one-size-fits-all approach to understanding firmware/product hacking would prove overly reductive and that according to the economic specificities of the situation, corporate actors may embrace or vehemently reject open source modifications to devices.

Drivers, antifeatures and DRM

An operating system (OS) is the software that controls numerous crucial functions of a computational device: resource (hardware) management, interfacing the core system with connected hardware via device drivers, disk access, file systems, user interface (commonly a graphical user interface) and networking protocols, while also acting as an intermediary between higher-level software applications and the system's hardware. The section of the OS which deals with resource management is the kernel. The kernel manages hardware resources such as the CPU, GPU, RAM and any input/output (I/O) devices, such as disk drives, displays, printers and input devices, and allows other software applications to run by allocating system resources among them. The kernel communicates with hardware via a combination of firmware and device drivers: software whose function is communicating between the hardware and OS, allowing the OS to manage the device and allocate its functionality to higher-level applications. While inter-device communication and allocating resources may sound like a utilitarian task,

there are instances where the types of agency inherent to these functionally crucial but often unseen forms of software make themselves visible.

This is exemplified by implementations of proprietary binary drivers for graphics cards under the free/open source GNU/Linux OS.[6] Device drivers are OS specific, and different OSs utilize divergent models for independent hardware producers to create device drivers. The Microsoft Windows model sees Microsoft publish a stable set of Application Binary Interface (ABI) calls which provide hardware vendors with a selection of services that are made available to device drivers by the OS. The ABI effectively decouples OS and driver development, as Microsoft maintains the closed-source OS and the published ABI, while the hardware producer maintains the closed-source device driver, with the ABI presenting the stable interface between repositories of proprietary software. One negative aspect of this model is that Microsoft has at times altered the ABI between successive Windows releases, entailing that hardware producers must rewrite their drivers to be compatible with the new ABI. This led to widespread problems with Windows Vista as many vendors had not rewritten their drivers when the OS was released, leading to users being unable to access peripheral devices (Montalbano 2008).[7]

Within Linux, the preferred approach is for hardware producers to provide open source drivers which are subject to a public peer-review process, before being accepted into the mainline kernel for the OS. Once drivers are accepted, they are maintained by developers working on the OS, so drivers continue to work with future releases: 'The key strength of this approach from the user's viewpoint is that, in happy contrast with proprietary operating systems like Windows Vista, once a device is working on a given version of Linux support continues through all future versions. In Linux, hardware support only gets better; it never gets worse' (Kohn 2008). From the hardware producer's perspective, this model is beneficial, as once a driver is accepted into the mainline kernel, they do not update or rewrite the driver.

The difficulty with the Linux model arises when vendors provide closed-source drivers (as they would do with Windows or OSX). As the community does not maintain the driver, it must be updated by the hardware vendor alongside each kernel update, leading to compatibility issues. Within the sphere of graphics card drivers, this has been the strategy pursued by

[6]The OS derives from Stallman's initial call for the GNU operating system; however, this project was completed with the Linux kernel developed by Linus Torvalds. Subsequently, the OS has commonly become known as Linux, although FSF materials always refer to it as GNU/Linux. From here on, I will use the term Linux, as this will be the name recognized by most readers.

[7]Subsequent to the Windows XP/Vista fiasco, Microsoft has implemented a backwards compatibility mode for device drives to ensure that hardware devices do not fail to function when upgrading OS.

Nvidia, whereas Intel and ATI (the other two major players in the graphics card industry) have both released open source drivers. Linux users with Nvidia graphics cards have experienced significant difficulties, with the driver regularly being recorded in the top 15 oopses (Bottomley 2009) – deviations from the correct kernel behaviour which produce an error log. While many experienced Linux users consequently choose to purchase Intel or ATI graphics cards, Linux Foundation technical advisory board chair James Bottomley (2009) contends,

> Most of the reported oopses are coming from less experienced or even novice Linux users. The problem here is that these people quickly get frustrated with the problems which they will ascribe to Linux in general, not the problem binary driver in particular. Even worse, they may report the problem to a Linux forum only to be told that it's a binary driver issue and can't be fixed, thus leaving the reporter with few options to try a working Linux system beyond an expensive graphics hardware replacement. These users aren't likely to continue their experiment with Linux; nor will they recommend it to their friends. In fact, they're probably turned off Linux for a considerable period (if not for life). This last is an illustration of the active harm binary modules do to the Linux ecosystem: Linux gets classified as unusable because of a problem in a binary module which no open source developer can fix.

This highlights the impact which device drivers can have on user experience, while also demonstrating some of the unplanned affordances of software: Nvidia have not conspired to create oopses for customers opting to use Linux. While the relatively small market share of personal computers running Linux[8] may entail that the company expends less resources on driver implementation than on its Windows counterpart, Nvidia still attempt to create a stable device driver. However, issues that arise surrounding system stability have widespread ramifications for users, in some cases rendering hardware unusable with a particular OS. This not only foregrounds the different affordances of open and closed models of software creation but also highlights one way that unintended impacts arise from software usage, denoting the presence of a form of nonhuman agency.

The solution Bottomley and Kohn provide – hardware producers writing open source drivers which can be integrated into the mainline Linux kernel – does not itself eradicate bugs in drivers or incompatibilities introduced by kernel updates. By opening problems up to the Linux development

[8]Among servers, or other computational devices such as networked attached storage and smart TVs where Linux market share is significantly higher, dedicated graphics cards tend not to be used.

community, however, they allow a large networked community to investigate and correct problems. Opening access to the driver's source code entails that user and development communities are no longer beholden to an external entity to resolve issues but are empowered to directly intervene and address issues. This approach utilizes the increase in connectivity afforded by the contemporary networked media ecosystem to crowdsource solutions to compatibility issues, demonstrating a practical instantiation of the open source mantra known as Linus's Law: 'Given a large enough beta-tester and co-developer base, almost every problem will be characterized quickly and the fix obvious to someone'. Or, less formally, "Given enough eyeballs, all bugs are shallow"' (Raymond 1999: 30).

It must, however, be emphasized that this strategy is not guaranteed to reveal errors or exploitable vulnerabilities in code, particularly when the codebase grows over a prolonged temporal duration. This is well illustrated by the 2014 Heartbleed security issue found in the OpenSSL cryptographic library, a widely used open source implementation of the transport layer security and secure sockets layer protocols that are designed to provide secure connections across computational networks. Heartbleed has been described as 'a serious vulnerability. Some might argue that it is the worst vulnerability found (at least in terms of its potential impact) since commercial traffic began to flow on the internet' (Steinberg 2014), with over half a million servers affected, including high-profile companies such as Pinterest, Amazon Web Services, SoundCloud and Wikipedia. Although the exploit was patched as soon as it was discovered, prior to public disclosure the vulnerability could have been used for up to two years to obtain passwords and other sensitive data, such as the 4.5 million patients' health records which were obtained from Community Health Services, the second largest for-profit hospital chain in the United States (Frizell 2014). That said, the episode around Heartbleed, which revealed the underfunded and understaffed process around OpenSSL development has subsequently led to significant improvements in its maintenance, precisely because of its interrogatability as an open source project.

Although questions of compatibility surrounding how differing devices connect and communicate with one another are common to a vast array of technological systems, answers have tended to be framed within the context of political economy, and specifically by approaches to competition and regulation undertaken by corporate and governmental actors. What the Linux community offers is an alternative model predicated upon utilizing distributed networks of self-aggregating peers to examine openly published standards. The result is that the open source community provides a workable alternative to developmental methodologies based upon intellectual property, enabling co-creatively designed systems to provide long-term driver support. This open source methodology presents an example of how peer-to-peer systems enabled by the material infrastructure of the network

society can intervene into processes which have erstwhile been dominated by multinational corporations.

Allowing individuals with technical competencies and access to networked digital computers to participate in the development of tools and technologies crucial to the functioning of a technocultural milieu in this way exemplifies how the collaborative practices of peer-to-peer systems challenge previous models based upon the separation of producers and consumers. Stiegler foregrounds this as a critical distinction between the contemporary technological ensemble and those of industrial society: 'The internet age is an age of hypomnesis constituting itself as an *associated* technical milieu. It marks the end of the era of dissociated milieus – the escape from milieus that separate the functions of producers and consumers, deprive both of their knowledge, and consequently strip their capacity to participate in the socialization of the world through its transformation' (Stiegler 2010b: 83). Stiegler argues that associated milieus built upon networked digital technologies afford the construction of an economy predicated on contribution to the commons, rather than the communal loss of knowledge associated with a producer/consumer dichotomy. Whereas for Stiegler the dissociated milieu of industrial culture is characterized by knowledge being displaced into technology or elites, the associated milieu of contemporary media ecologies allows an alternative system based upon cooperation and contribution to supplant the proletarianization of neoliberalism.

This example differs from firmware/product hacking, as it involves the creation of systems which function as competition to existing proprietary OSs, which arise from a peer-to-peer developmental methodology. As we have seen, advocates such as Stiegler and Bauwens argue that this mode of production points beyond the hypercompetitive market-dominated model of neoliberalism, towards a post-capitalist alternative which provides social benefits through positive externalities based upon the formation of associated milieus. We should, however, remind ourselves that FOSS is also proposed as a hyper-efficient developmental methodology which forms 'mutually reinforcing relationships with market-based organizations' (Benkler 2006: 123), rather than an alternative socioeconomic system. Indeed, the degree to which multibillion-dollar corporate entities such as IBM, Google and Amazon leverage Linux-based systems and contribute to Linux development – allowing them to co-design the open source systems they benefit from – should give pause for thought when considering claims that FOSS gestures towards a departure from contemporary modes of capitalism.

Another set of differences between FOSS and proprietary software which manifest at the level of the OS are antifeatures: 'functionality that a technology developer will charge users to *not* include' (Mako-Hill 2007). This is distinct from the traditional process of charging for features which enhance functionality or user experience, which logically derives from a labour theory of value, whereby as coding features takes time, labour

and resources on the part of the programming team, users effectively pay for the labour time of the coders. Antifeatures invert this logic, with customers paying programmers not to include features designed to inhibit functionality; in these cases, the customer pays more money for less labour as the features in question are restrictive or malicious. Antifeatures are frequently employed within digital rights management (DRM) systems, software which prevents certain usages of digital content. DRM has proven a contentious topic, with proponents claiming that DRM provides essential security for copyright holders while opponents contend that DRM systems go beyond the scope of copyright laws in preventing users from accessing content they have purchased, inhibiting fair uses of products.[9]

Windows Vista provides an example of an OS whose DRM implementation received heavy criticism. The Protected Video Path DRM which debuted in Vista and has been included within more recent versions of Windows constantly monitors user activity in order to police the outputs of certain types of digital media designated as 'premium content', primarily high-definition video, whose digital transmission is encrypted by Windows in an attempt to prevent the content from being copied and shared. In order to achieve this, the OS has to expend resources both monitoring the content and providing the encryption, and this was one of the reasons why Vista's minimum recommended systems specification of a 1GHz processor and a gigabyte of RAM far exceeded its predecessor, Windows XP, which recommends a 300 MHz processor and 128 megabytes of RAM. DRM within Vista disables hardware devices that do not include approved digital content protection facilities. For example, the Sony/Phillips Digital Interface Format (S/PDIF) high quality audio output contains no digital content protection and is disabled by Vista when the OS detects that a system is playing premium content (Gutmann 2007). DRM technologies built into Windows Vista not only impede the performance of hardware but additionally inhibit user freedom with regard to digital media content; making copies for personal use is considered fair use by copyright law but disallowed by Vista's draconian DRM.

Similar complaints regarding DRM have been levelled at devices such as the Apple iPad and Nintendo 3DS. Like other iOS devices, the iPad uses DRM to prevent users downloading applications which have not been ratified by Apple and has consequently been criticized for being the most locked-down general-purpose computing device available (Anderson 2010, Defective by Design 2010). The Nintendo 3DS is a mobile gaming device that wirelessly transmits information about the user's activity to the manufacturer, gives the manufacturer a royalty-free licence to use any content created by the

[9]My usage of the term 'fair use' here technically refers to US legislation, but is intended to include related legal constructs such as UK laws pertaining to 'fair dealing'.

user (the device includes a camera, so Nintendo claim the right to use any pictures you take with your device) and scans the system for any software modification, which if detected can lead to the manufacturer remotely rendering the system permanently unusable (Defective by Design 2011).

Antifeatures are a phenomenon exclusively restricted to proprietary software. The act of adding malicious code to FOSS programs in order to limit functionality would simply lead to members of the FOSS community forking the project and creating a branch with the antifeatures removed from the code base. This highlights one of the key differences between the philosophies of open and proprietary software: whereas proprietary software is created to generate profits, which can include deliberately sabotaging the functionality of some versions of the software with antifeatures, FOSS is based around communal innovation attempting to create the best possible software solution. While FOSS may include numerous different versions of a particular form of software – such as the many different implementations of Linux – each version is designed to afford users different useful features, not to include malicious code designed to hamper user experience. There is a crucial distinction, then, in the value systems evident within the respective developmental modes: proprietary software reflects an ethic whereby economic profits are the primary imperative, echoing the neoliberal position whereby GDP is the sole determinant of wealth, whereas within FOSS economic benefits are seen as supplementary to the primary goal of creating platforms which enable various forms of value to flourish, arguably positing an alternative value system which resonates with the ecological ethic outlined in Chapter 2 whereby creating connections and allowing systems to grow in various directions and dimensions supplants economic determinism.

Formats and protocols

The file formats, codecs and protocols[10] which comprise the outputs and standards used by applications and networks can again be either open or closed. While there is no prescriptive definition of an open format analogous to the FSD, open file formats are generally understood as publicly published specifications for storing data that are usually maintained by a standards organization. Open formats are thus available for implementation by anyone using either proprietary or free/open software, whereas closed formats involve methodologies for data storage which are the intellectual property of the entity who maintains legal ownership (via copyright or patent) of the file format. This gives the owner exclusive control over the

[10]For a comprehensive examination of the role protocols play within networked technoculture, see Galloway 2004.

format, entailing that other software cannot be compatible unless it has been licensed or successfully reverse engineered. Proprietary software can produce formats which are either open or closed, FOSS exclusively produces open formats.

Notable examples of open file formats include the Joint Photographic Experts Group's (JPEG) lossy compression format for digital photography and images, which is maintained by the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC); the WebM audio/video format for use with HTML5, which is developed by Google, the Portable Document Format (PDF), which was initially designed as a closed format by Adobe but was subsequently published as an open standard in 2008 and is now maintained by the ISO, and the Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS) used to author and style pages on the World Wide Web, which are maintained by the World Wide Web Consortium (W3C) and the ISO.

HTML and CSS present particularly pertinent examples when discussing the merits of open formats, as the design and construction of the web around exclusively open formats, standards and protocols was a key choice in shaping its character as an informational network. Discussing computer networks which existed before the web, Tim Berners-Lee, the British engineer and computer scientist generally credited with inventing the web, argues,

> In 1980, the world still suffered from incompatible networks, incompatible disk formats, incompatible data formats, and incompatible character-encoding schemes. This made any attempt to transfer information between systems daunting and impractical. This was frustrating because people were increasingly using computers to handle information, a large amount of important information was already stored in computers, and many of the computers were networked. However, these systems in use, including those that were proprietary and those that physicists wrote for their own use, were incompatible. (Berners-Lee 1996)

One of the primary ways that Berners-Lee sought to address these incompatibilities was through employing open formats and protocols for the web. Utilizing standards which did not rely on proprietary methodologies enabled users on any computational platform to engage with the web. Indeed, this openness, which Berners-Lee describes as a primary design principle of universality, is ascribed as being of central importance to the web's utility and popularity.

This reveals the importance of the structural design of platforms and the way in which openness can be pivotal to the success of a platform: 'People seem to think the Web is some sort of piece of nature, and if it starts

to wither, well, that's just one of those unfortunate things we can't help. Not so. We create the Web, by designing computer protocols and software. … We choose what properties we want it to have and not have' (Berners-Lee 2010). It is important to restate that contrary to Berners-Lee's usage, here, within an ecological framework, 'we' refers not only to the humans involved in design but to a sociotechnical assemblage incorporating multiple nonhuman actors. People may aspire for the web to have terabit/second connections; however, if the physical carrying capacity of the global networks of fibre-optic cables or the end-user networking devices and protocols do not support these desires, then the actual system presents a negotiation between agencies, desires and capabilities within the system as a whole. The open protocols of the web additionally provide a useful reminder that technology does not evolve according to a teleological pathway; the web arose from particular decisions, constraints and actions; it was not and is not the only possible outcome.

Bearing in mind the centrality of open protocols to the successes of the web, we should note that the development of the latest set of standards for the web, HTML5, has been marked by an increasing volume of corporate involvement in the drafting of the standard (Daubs and Manzarolle 2015), with Apple and Google contributing thirty-seven representatives to the HTML working group between them. The consequences of this can be seen in the incorporation of DRM protocols into the HTML5 standard via the Encrypted Media Extension (EME) specification, a move which has sparked significant controversy. Proponents of EME claim that HTML5 requires DRM to maintain the open web as a viable alternative to both the walled gardens of iOS and Android apps, and the closed-proprietary web-based usage of systems such as Adobe Flash (Meyer 2013). Opponents of the incorporation of DRM into the HTML5 standard, such as the EFF, who in 2013 filed a formal objection to the proposal and in 2017 resigned from the body who maintain web standards – the W3C – over EME's adoption, contend that it 'will shut out open source developers and competition, throw away interoperability, and lock in legacy business models. This is the opposite of the fair use model that gave birth to the Web' (EFF 2013). Cory Doctrow (2013) has highlighted that EME violates the W3C's own policies, which requires that standards are not burdened by patents and that the inclusion of DRM is thus fundamentally incompatible with the principles of openness and inclusion which underpinned the formation of the web and W3C. Consequently, Daubs and Manzarolle (2015) surmise that while HTML5 has been heralded in some areas of the technology press as an antidote to the proprietary duopoly of Apple and Google, 'the proposed inclusion of DRM protocols suggest HTML5 apps will be just as limiting and closed as their native counterparts on iOS and Android devices. HTML5 may provide new technical capabilities, but only insofar as these capabilities

link back to forms of accumulation and commoditization of creative labour characteristic of app-centric media.'

The case of HTML5 and EME demonstrates that the protocols and standards which underpin the web are still developing and that present moves around their commercialization depart from the openness upon which the web was originally built. Far from being utilitarian and neutral tools, or a fundamental part of the nature of networked telecommunications, these standards are an ongoing site of struggle in which activists from organizations such as the EFF and FSF contest the increasing corporatization and enclosure of digital networks. Within this space, the ideology of openness, which was a guiding principle for the initial development of the web, has been eroded over time through the incorporation of corporate and commercial interests, with debates over DRM and HTML5 elucidating one area where open protocols are being enclosed at the behest of multibillion-dollar technology corporations.

Crawling the web

One of the defining aspects of contemporary computational technologies is their ability to communicate with other computers over networks. While this is partially predicated on a global assemblage of hardware, software also plays a critical role, with shared protocols enabling networking and various forms of software utilizing networking capabilities. Forms of software pivotal to networking include the device drivers for network cards and their interactions with the OS, which itself will include networking protocols such as TCP-IP (transmission control protocol/internet protocol), FTP (file transfer protocol) and SSH (secure shell). As we have seen, the openness of these protocols has been crucial to how networked computing and the web have evolved, allowing devices to connect with one another and exchange data irrespective of their hardware platform. Today, a multitude of applications depend upon networking capabilities, and many websites employ numerous forms of software to accomplish a broad spectrum of activities pivotal to the functioning of networked media ecologies.

The algorithms and programmes that underpin search engine software present a useful example that illustrates some of the agential and political issues embedded within networking software. Search engines are a key form of software, as their results direct traffic around the web, determining what sources we are shown for specific queries, thereby constructing what users tend to imagine the web to be. A search engine is predicated upon an index of web pages, an enormous database detailing what pages exist and the key information they contain, which is obtained by web crawlers, pieces of automated software which create the index by following hyperlinks and continuously reporting the results of the crawl back to the database.

This immediately implicates a degree of machinic agency, as not all web pages are indexable; it is estimated that between 40 and 70 per cent of pages are indexed by major search engines (Gull and Signorini 2005). While this cover virtually all preferentially attached sites that do not require a login, vast numbers of pages are rendered invisible at any given time by search engines. Although accurately mapping a dynamic system such as the web is impossible due to its constant mutation, the ways that crawlers index the web are not neutral but depend upon how crawlers are programmed. In addition to material hidden on the darknet behind a dynamic .onion address (Gehl 2014), search engines do not typically crawl certain types of content, such as sites built with Adobe Flash or Microsoft Silverlight. Other issues which can affect the indexing behaviour of crawlers include web pages using frames, temporary faults with the site's server during the index, temporary faults with the crawler during indexing, the page requiring a login or the page being dynamically generated. In each of these cases, the alleged objectivity and neutrality of the indexing process is shown to in fact be partial and contextually dependent on forms of agency pertaining to the crawler itself, the technologies used to generate the web page and the way that their respective capacities interact during the indexing process.

A further issue that contradicts the notion of algorithmic neutrality is the manner in which search engines produce their results. Google's search engine famously utilized the PageRank system, with Lawrence Page and Sergey Brin describing the algorithm in 1998 as 'a method for rating Web pages objectively and mechanically, effectively measuring the human interest and attention devoted to them' (Page and Brin 1998: 1). The PageRank algorithm was thus designed to provide a universal, objective ranking system; however, due to the unequal diffusion of web connectivity allied to the attractor of preferential attachment, results frequently presented pages from the United States as disproportionately relevant to search terms (Vaughan and Thelwell 2004; Van Couvering 2009: 261). Consequently, Page and Brin's claims pertaining to PageRank's objectivity are dubious at best. That this bias skewed relevance in search terms towards geographical regions with pre-existing economic and informational privileges evidences that far from being neutral and objective agents, algorithms possess forms of agency and that these do not necessarily stem from their design: Google did not intend to design an algorithm which favoured US-based results, consequently reinforcing existing hierarchies surrounding material wealth and access to cutting edge technologies, but this is how PageRank acted.

Consequently, Google updated the PageRank algorithm to present users with data that factored local geography into results, so users from other countries would not receive US-biased search results. In order to achieve this, the search engine's software has to log the Internet Protocol (IP) address of the user, allowing them to be geographically identified. By storing the results of search terms attributable to unique IP addresses, search engine operators

are able to compile complex profiles of users' online activities, which has become a valuable commodity, allowing the search engine operators to profile user types, and then use this data to produce highly targeted, user-specific advertising. While Google had been implementing forms of personalized search results for users signed into Google accounts since 2005 (Kamvar 2005), in December 2009 Google extended their personalized search results to include users who were not account holders or logged in to services: 'This addition enables us to customize search results for you based upon 180 days of search activity linked to an anonymous cookie in your browser' (Horling and Kulick 2009).

Current search results from Google are far from the objective and universal reproduction of knowledge which Page and Brin originally sought to produce. They involve the implementation of complex personalization algorithms which modulate search results dependent on the user's previous behaviour. The practice of personal algorithmic filtering is not exclusive to Google's search engine; other websites such as Facebook, YouTube and Amazon use similar forms of algorithmic filtering to present personalized material. Eli Pariser (2011) contends that these practices create filter bubbles, in which the web becomes an echo chamber, whereby users are provided information which acts to support and reinforce confirmation biases, while failing to challenge their preconceptions. danah boyd (2009) describes this as the 'psychological equivalent of obesity', whereby companies which have a financial interest in capturing attention achieve this through presenting the informational equivalent of fast food: celebrity gossip, sports and sexualized imagery. The popularity of this digital junk food with certain user groups leads personalization algorithms to subsequently filter out alternative search results which present more serious discursive frameworks.

When considering the agencies of software, what is notable here is that these functions are performed by algorithms, which essentially become the new gatekeepers of information. Whereas in the mass media age professional journalists acted as the filter through which information had to pass in order to reach the public, this role is now accomplished by software. 'Search engines construct net reality. They are not just technical tools in the hand of the user. They have a significant impact on the image users have of web content and its patterns of relevance' (Schultz, Held and Laudiene 2005: 1422). Consequently, an analysis of the emerging online practices of gatekeeping via algorithmic filtering requires an investigation of 'the politics of code' (Goode 2009: 1303), considering the nonhuman agencies embedded in every layer of the software ecology, alongside exploring the connections between human and nonhuman elements of the complex techno-social assemblages within which contemporary software is situated.

Paralleling other cases explored within this chapter, the FOSS community has responded to perceived threats to digital freedoms, this time to online privacy and anonymity via the array of personal information held by

Google, creating technical systems enabling the circumvention of Google's data mining strategies. Three such systems are Startpage, Duck Duck Go and Tor. Startpage is a search engine which applies a proxy system to utilize Google's search results without the user having to directly engage with Google, thus allowing anonymized search while using the Google system. Instead of travelling directly to Google, which could identify the user based on their IP address and browser cookie, the request is sent via the startpage.com proxy server, whose identity Google associates with the request. The proxy then retrieves the search results and forwards them to the user. The system uses a number of proxies and each successive request from a user is passed onto different servers, entailing that Google is unable to identify a single user as the originator of the agglomeration of search terms, so they are unable to build a dataset of terms associated with a single user, which is key to their statistical profiling techniques. This method also entails that Google cannot provide personally filtered search results, as they cannot access a personal search history with which to enact filters relevant to the user's previous interactions with the search engine.

Whereas Startpage offers an alternative search facility which leverages Google's results to provide a privacy-oriented search engine, Duck Duck Go provides an alternative search engine to Google which has marketed itself as an option for users who are concerned about privacy. Duck Duck Go does not track the activity of users and thus is designed to avoid the issue of creating filter bubbles based upon personalized search results and is designed to prevent search histories becoming valuable data for marketing companies. Espousing a cyberlibertarian ethic which resonates with early discourses of online freedom, Duck Duck Go does not store any information about users' IP addresses or user agent (the web browser/OS and other data about the machine accessing the server) in order to provide an anonymous mode of search.

Whereas Startpage and Duck Duck Go both specifically focus upon search, Tor – an acronym of The Onion Router, a reference to the layered structure of the vegetable – is a broader privacy-related project which can be deployed to similar effect with regard to anonymous web searches. The system behind Tor was originally developed by the US Naval Research Laboratory for protecting governmental communications (Tor 2011a) but has been developed into widely used FOSS tools for anonymous web browsing. Tor functions by connecting users to a distributed peer-to-peer network, and all internet traffic is routed via this network. The pathway data is channelled through regularly changes, entailing that requests and traffic are not traceable to the originator, so they remain anonymous and therefore impervious to personalized filtering algorithms. Although the final node in the network that the request is routed through, which is known as an exist node, can be readily identified, this does not allow the pathway back through the Tor network to be traced.

The advantage of using Tor over other anonymizing tools is that the user's entire internet traffic is anonymized, not just search queries, meaning that Tor has far broader utility in online activism. For example, Tor was used widely during the uprising against the Mubarak regime in Egypt during the Arab Spring of 2011 when the government attempted to cut the protesters' channels of communication by ordering ISPs to cut off internet access to Egyptians. Whereas some ISPs revoked their Border Gate Protocol routes, rendering connections via Tor impossible, other ISPs such as Noor and Etisalat only implemented IP filtering; software filters enabled to prevent Egyptians communicating online by redirecting any traffic associated with an Egyptian IP address. One of the responses by those inside Egypt was to utilize the Tor network to anonymize their IP addresses and therefore bypass the filtering restrictions constructed by ISPs (Ioerror 2011). This led to a huge spike in the traffic within the Tor network, resulting in Twitter users across the world requesting that politically sympathetic users set up additional Tor relay nodes to accommodate the extra traffic (Finley 2011).

Startpage, Duck Duck Go and Tor demonstrate that the FOSS community have created various tools to contest issues surrounding privacy and anonymity on the web, and that these solutions are capable of circumnavigating numerous issues, such as Google's data retention and personalized search filters. It must be noted, however, that the usage of these FOSS hacktivist tools is miniscule in comparison to Google's overall traffic; as of 2018, Startpage has around 5.5 million searches per day and Duck Duck Go receives over 20 million daily queries, while Tor has over 2 million daily users. While these numbers sound impressive in isolation, they are dwarfed by the 3.5 billion search queries which Google receives daily. There becomes a significant risk when foregrounding such activist/privacy-led alternatives, that we lose sight of the overwhelming scale of corporate dominance.

Services such as Duck Duck Go, Tor and Startpage can easily become ways for a technologically literate, ethically concerned elite to escape the issues of Google's corporate dataveillance and filter bubbles while building alternative bubbles of their own in which their techno-social networks employ an array of privacy enhancing tools but do little to effect broader social change. That is not to say these tools cannot be useful for activists who wish to maintain private and secure communications in their ongoing attempts to organize a range of activities but that the key is trying to mobilize wider networks, rather than simply bolstering one's own online privacy. Put another way, media ecology advocates using these technologies to promote the formation of communities whose actions are geared towards solidarity and sustainability, not just individual freedoms.

While these examples only scratch the surface of debates surrounding the ethics and politics of internet privacy, anonymity, data mining and filtering, they do elucidate key features of these debates, notably the demarcation

between commercial entities whose economic viability is predicated upon selling targeted advertising based on the possession of a vast quantities of data and FOSS/hacktivist communities who are concerned with protecting privacy and anonymity. In light of the Snowden revelations, we should note that many of the long-recommended security practices advocated by hacktivists, such as using Tor and PGP,[11] have largely been validated as ways of maintaining anonymity or encrypting data (Taffel 2015). Understanding debates over user privacy – what information is being harvested by whom, for what purpose and with what degree of transparency – becomes crucial when exploring the ethics of network driven software. In this sense, finding ways of providing users with feedback about the digital footprints they leave is an important task (Pasquale 2015). The current situation sees the majority of internet users unaware of the information contained about their IP address and user agent allied with the ways that this data is used by predicative systems of corporate and state dataveillance, so finding ways of making these processes visible may be one avenue by which activists can productively engage with issues surrounding data security and privacy.

The European Union's General Data Protection Regulation (GDPR), which came into effect in May 2018, is one prominent way that these issues have been approached through multinational regulation. The wide-ranging legislation is designed around the concept of data protection by design and default, whereby businesses that handle personal data must build systems that are designed to provide safeguards to protect data, such as using the highest-possible privacy settings by default. GDPR includes clauses that include the ability to challenge automated decision-making systems, a right to erasure of personal data, a right to access of copies of personal data that is held and a requirement for informed consent to be provided before businesses can collect and process data. GDPR also has significant penalties for non-compliance; parties who violate GDPR can be fined up to €20 million or 4 per cent of annual worldwide turnover, whichever is greater. In the case of major digital platforms such as Google and Facebook, this amounts to several billion euros per year.

On the surface, this would appear to be a significant milestone in regional regulatory action that contests poorly understood issues surrounding data harvesting and extraction. There have, however, been significant concerns raised about where GDPR places the burden of responsibility in many of these instances. Trawling through lists of data firms and cookies, obtaining rationales for specific automated decisions or copies of data to inspect, all falls squarely upon the shoulders of individual data subjects. As Adam Greenfield (2017: 251) notes, the underlying logic is 'thoroughly consonant

[11]PGP (pretty good privacy) is a public key cryptography standard which is used to send encrypted emails within a web of trust.

with the neoliberal practice of governmentality which tends to individualize hazards and recasts them as issues of personal responsibility or moral failure rather than structural and systemic issues'. Resonating with the previous chapter's focus on the poverty of time within a commodified economy of attention, it is then unsurprising that for many people, the reaction to GDPR's rollout has been dominated by anxiety. Every website and digital platform simultaneously required users to read through lengthy end-user licence agreements and check or uncheck boxes for each of the third parties that data was previously shared with. This process was made particularly time-consuming and tedious by many sites breaching the regulations by not defaulting to the most stringent privacy settings and refusing to include an untick all option, so users had to manually click on a seemingly endless list of boxes to opt out of sharing data with third parties.

Consequently, Max Schrems, an Austrian data activist has filed complaints about how Facebook, WhatsApp, Instagram and Google have implemented GDPR compliance, arguing that these companies are in clear breach of the spirit and letter of the regulation; their new terms of service are a form of 'forced consent', where users either accept them wholesale or stop using the service. It will be interesting to see how this develops, as the filing can potentially lead to multibillion-euro fines for each entity. While GDPR's neoliberal mode of governmentality should be foregrounded as an issue that limits its efficacy, especially for time-poor subjects who are often those most vulnerable, it does still have the potential to mitigate some of the worst elements of data and algorithmic opacity, especially if authorities decide to impose heavy financial penalties upon corporations who breach its guidelines.

Conflicts and agency in code and design

This chapter has examined entanglements within ecologies of software, exploring how disputes and struggles over ethics, agency and power occur within these technocultural assemblages. Approaching software through an ecological framework entails that 'no piece of software is a singular entity' (Yuill 2008: 67), software is always dependent upon a multiplicity of other forms of software, protocols, hardware and social structures; it functions as part of dynamic technocultural assemblages that collectively evolve through intra-actions, rather than as isolated individual commodities. Within these assemblages, network effects see particular forms crystallize into platforms, well-established large entities which exert selection pressures that draw new actors into their basin of attraction. As we saw with the example of HTML5 and EME, the ongoing corporatization and enclosure of digital spaces within what has been described as 'platform capitalism' should be a serious concern for proponents of social and environmental justice.

In this chapter, there have been two tensions which have dominated proceedings. The first of these is between open and closed systems of software, whereby there are ongoing struggles over agential, political and ethical dimensions of software development and maintenance. It would be wrong, however, to present this as a binary opposition, where openness is understood to effectively mean good and necessarily point towards a post-capitalist future. For example, product hacking presents instances where companies such as Canon have allowed user communities to customize and enhance products, as this behaviour effectively increases product value with no necessary capital outlay from the manufacturer. In cases such as iOS jailbreaking though, where economic models are challenged by alternatives generated by distributed peer-to-peer networks, we see the deployment of various legal and technical measures attempting to preserve profitability. Outside of a company's key economic interests, however, they may choose to deploy FOSS to a significant degree, such as Google's embrace of FOSS outside of its search engine, in software including the Android OS and Chrome web browser.

In some ways, this denotes the variable affordances of FOSS, highlighting the differences between anti-/post-capitalist and free software advocates on the one hand and proponents of efficiency and open source on the other. Numerous cases explored within this chapter demonstrate that while open approaches may provide beneficial outcomes, FOSS can simply present a hyper-efficient model of production for corporations, for whom increased efficiency denotes increased profitability. This competitive advantage has nothing to do with the potential ecological benefits of commons-based peer production, instead demonstrating how powerful economic actors can exploit the free labour of precarious workers. Arguments surrounding economic efficiency are far removed from claims that FOSS are emblematic of an associated milieu and the economy of contribution, whereby contributing to culture is linked to taking care of the community and moving beyond a politics of competition, austerity and precarity.

The pharmacological context of technics must again be emphasized. To foreground this, I have attempted to outline how open systems are leveraged in different ways within technocultural assemblages with divergent political and social outcomes. The spaces and practices which are deterritorialized by the affordances of a new technocultural milieu are subsequently reterritorialized and colonized by powerful actors seeking to exploit these developments to enhance their own positions. Just as in the previous chapter we saw that networked digital ecologies afforded the formation of new modes of communication and participation alongside the creation of novel modes of hierarchy, we can understand that the affordances of open source have had a similar effect, both challenging previous economic dogmas regarding the efficiencies of markets and positing commons-led alternatives,

while simultaneously allowing powerful economic actors to leverage crowdsourced, precarious labour to enhance their economic standing and inflict further defeats on organized labour movements.

We have also seen conflicts between corporate actors and heterogeneous FOSS communities relating to issues surrounding intellectual property and privacy. These issues raise questions surrounding which actors have agency to modify, alter, enhance and hack devices. In cases such as the creation software-enforced monopolies such as the Apple App Store, or the insertion of DRM into web standards such as HTML5, we see corporations attempting to dictate the range of acceptable usages of digital assemblages largely based on economic outcomes. By contrast, FOSS and hacker groups contend that having purchased hardware or software, users are within their rights to utilize these materials as they see fit, not as the manufacture instructs. Examining network-based software such as search engines, browsers and social networking software additionally reveals tensions pertaining to user privacy, whereby FOSS groups question current practices surrounding data mining, profiling users and leveraging user's personal data for profit and/or corporate/governmental surveillance. However, as cases such as Magic Lantern and Android development denote, when companies see functionality added to their devices at no economic cost to themselves, they are likely to embrace open source communities.

Openness alone is not sufficient to realize an ecologically inflected post-capitalist economy, as is evidenced by the various enthusiastic corporate adoptions of open source. Here my thinking resembles some of the recent discussions which have been conducted through the P2P foundation, which outline sustainability, openness and solidarity as the three fundamental building blocks of a commons-based alternative economy. Transparency, openness and collaboration are thus understood as being beneficial when their aims are aligned with social solidarity and ecological resilience, rather than being a positive thing in and of themselves. The key here is the relational context of openness, so that it becomes more than just a way of magnifying existing inequalities, enabling corporate reterritorialization and enclosure or assisting individuals in enhancing their own situation while leaving broader power structures unaffected.

The second major tension which runs throughout this chapter relates to distributions of agency throughout the techno-social assemblages of the network society. In numerous places, the agencies of software have been foregrounded, examining ways that software develops along trajectories unforeseen by those responsible for creating it. Examples of this nonhuman agency explored in this chapter include the presence of glitches, bugs and exploitable loopholes in code, the material consequences of algorithmic informational gatekeepers, and the inability of companies to control their own code. Consequently, we see that software possesses forms of agency, rendering an ecological account of software distinct from humanist accounts

of technology, whereby technologies become neutral, agency-less tools in the hands of human subjects. Forms of nonhuman agency differ from those associated with human actors, but nonetheless they clearly set limits and define spaces of potentiality. In particular, the ability of software to automate tasks, such as crawling the web or filtering particular types of search results or social media streams, and to take decisions based upon machine learning from past behaviours demonstrates the agential mode which Mackenzie (2006: 8) describes as 'secondary agency', one which is differentiated from that of both humans and other nonliving entities.

Nonhuman agencies contrast with certain ways that agency is discussed with regard to design at various points throughout this chapter; designers are portrayed as being able to significantly determine aspects of systemic development through their choices, particularly with regard to openness and freedom within computational systems. An ecological conception of software design requires a reorientation of the designer; whereas social constructivist accounts would place the human agent – the subject capable of free will, creativity and innovation – as the designer, an ecological account emphasizes that software design is never undertaken solely by humans. Rather than individual designers, contemporary software design requires assemblages of humans, computers (themselves assemblages of various components composed of a multitude of elements), networks of fibre optics, modems, internet exchange points, input devices, scripting languages, protocols and syntaxes alongside the existing software ecology, all of which influence and constrain what is and is not possible.

In other words, it is not the human designer who wields agency in the design process, but the entire designing assemblage whose agencies are mobilized. Indeed, the agency of the human designer only exists precisely because of the complex array of interconnections with the nonhuman nodes of the assemblage: without the pre-existing work that has gone into collectively evolving an advanced informational environment the human capacity to design software would resemble that of our cave-dwelling ancestors. As such we cannot understand technical evolution without exploring both the cultural and technical conditions which afford the design of software, hardware and mediated content. My argument here is that doing so requires a fundamental rejection of the atomized individualism of neoliberalism, instead foregrounding the collective entanglement of assemblages. The following chapter continues this theme, through an exploration of the political ecology of digital hardware.

5

Materiality and digital infrastructures

The language employed to describe digital media includes numerous terms that conceal the materiality of technology. The term 'virtual' gestures towards the somehow not quite there, an ethereal spectre which grasps at but never quite reaches reality. While there is a more concrete definition of the term 'virtualization', which specifically refers to the software-generated simulation of one computational platform by another, the commonplace notion of digital technology as relating to virtual spaces, virtual communities and virtual reality is a discursive practice that obfuscates the complex and often poorly understood materiality of microelectronics. Similarly, the now unfashionable contrast between cyberspace and actual space effectively masks the underlying materiality of global networks of computational technologies, optoelectronics, cellular networks and global positioning satellites which enables the creation of the novel spatial engagements associated with a pervasive digital technoculture.

Immaterial labour is frequently proclaimed to be the paradigmatic mode of labour associated with digital technologies; we may quite reasonably ask if it would it be possible to posit a concept further removed from matter or materiality? Whereas Maurizio Lazzarato's (1996) original essay bearing that title features some incisive analysis regarding post-Fordism and the neoliberal economy, including a delineation of various material practices and structures that have transformed labour practices, the connotation that working with digital technologies involves a departure from materiality is quite understandably how many have interpreted the trope. The recent designation of vast server farms providing data storage and computational processing power for ultra-portable thin client devices such as smartphones and tablets via networks of undersea and underground fibre optics and 4G cellular networks as 'cloud computing' denotes the continuation of this trend, with the employment of a descriptor which evokes nebulous floating

vapour, rather than the witches' brew of toxic chemicals, heavy metals and plastics found within microelectronics. The notion of the cloud, then, continues the history of discursively situating digital technologies as some form of quasi-magical departure from material reality.

This encourages us to conceive of these technologies as disposable commodities, 'smart' isolated objects that appear as if from nowhere to be bought and swiftly discarded, rather than encouraging an engagement with the material flows of metals, minerals, plastics, energy, labour and waste, and the political economies and ecologies from which these commodities are produced and through which they circulate. A central contention of media ecology is that when considering the ethical and political affordances and impacts of media systems, we must not only address the final communicational outputs designed to be read by humans – the content of media – but also additionally explore the architectures of software and hardware which were necessary to produce and distribute that content. From this perspective, the material impacts of media infrastructures cannot be separated from the cultural connotations of content.[1] Whereas the previous two chapters have explored the scales of content and software, this chapter investigates concerns centring on computational and communicational hardware.

The flows of matter and energy which transform ores, earths and fossil fuels into assemblages of digital microelectronics involves a multiplicity of materials and actants; producing a smartphone requires around seventy of the eighty-four stable (non-radioactive) elements (Rohig 2015). Ores mined in one country will often be processed into pure metals and minerals elsewhere, before being shipped to new locations for processing into alloys, transformation into components, assembly into devices, and packaging and branding, before travelling to the country where the device will be sold, used and discarded. Having been thrown away, electronic waste – or e-waste as it is commonly known – is commonly sent around the world once again for disassembly and processing, as specific valuable materials contained within devices are recovered and sold for reuse. Each stage in the life cycle of microelectronics is entwined with ethical imperatives regarding social and environmental justice, and this chapter aims to delineate many of these concerns. Alongside these issues, the chapter foregrounds interventions into systems designed to either limit detrimental impacts or promote positive alternatives to current methods. Analysing these interventions form a

[1]One question raised by discussing the material impacts of hardware is whether the term 'impact' is itself too molar, suggesting pre-formed entities which collide with one another, rather than a process of assembling. My usage of impact here is homologous to thinking about affect, how particular entities connect with and transform the affective capacities of one another, with positive impacts being ones which enhance the capacities of assemblages and negative ones being those which diminish them. Impacts, then, are ways of describing the evolution of dynamic assemblages, rather than the percussive encounters of stable subject/objects.

crucial part of an ecological approach, which, following the schizoanalytic methodology employed by Deleuze and Guattari, must go beyond the destructive task of critique which highlights negative impacts associated with current practices, suggesting lines of flight that posit potential bifurcations into more equitable and resilient ways of living.

Structurally, the chapter breaks up the life cycle of electronic goods into a series of chronological stages: product design, extracting and processing raw materials, manufacture, usage, and recycling/disposal. Although these sections could be depicted as a strictly linear succession of events, from the inception of the product's design and the unearthing of the necessary raw materials for its manufacture, through to the disposal or recycling of the hardware, these stages are in fact heavily dependent upon one another. Consequently, when seeking to intervene in the systemic processes involved in the production cycle, there are frequently strategies applied within one stage which create changes elsewhere in the life cycle, rather than simply affecting localized changes to a particular stage.

This is especially true of the design stage. As Jim Puckett (2006: 226) states while examining the effects of dumping e-waste in Asia, 'True solutions to our toxics crisis lie not in recycling wastes downstream, rather in eliminating them through "green design" upstream.' By designing products which reduce or eliminate toxic materials from their construction, which are built to last, modular and designed to be easily and safely recycled, ecologically inflected design has an important role to play in creating safe, socially beneficial and ecologically sustainable digital technologies. While we should raise a note of caution surrounding design-centric 'solutionism', which can provide a depoliticized, technocratic approach to problems which can never be extracted from power relations, this chapter explores design-based strategies last, as strategies surrounding design frequently apply to transforming the entire structure of the life cycle of microelectronics, rather than simply impacting one constituent stage. Focusing on design, then, allows a second scale surrounding hardware to be addressed. Whereas the previous examples deal with particular phases within the life cycle of microelectronics, design additionally affords an overview of the flows comprising the entire process, raising a series of additional problems.

Blood coltan and rare earths

The 'raw' materials for microelectronics are the various ores, fossil fuels and earths that typically are found beneath the surface of the Earth. Consequently, in order to access these substances, they must be extracted from the planet. This removal of vast quantities of matter can logically be understood as one of the first steps in the life cycle of microelectronics. Considering processes of extraction connects the 'virtual' reality of digital networks to not only the

geology and geography of the earth but also the globalized flows of energy, human labour and matter, that compose the twenty-first-century mining and processing industries. The scale of these flows is immense, with large-scale mining operations moving over 500,000 tonnes of rock on a daily basis. These industries undoubtedly produce beneficial effects, providing materials crucial to creating and powering contemporary infrastructures, while conferring employment opportunities and associated material wealth upon communities. Without the benefits of the extraction industries, contemporary society would be dramatically altered; however, the processes of extraction used to obtain materials vary widely, and in many instances, incur various social and environmental costs.

For example, open-cast mining which is frequently employed to extract elements such as copper and zinc involves stripping away the topmost layers of earth to reveal the ores below – a process which necessarily involves the destruction of whichever habitat previously occupied the site. Furthermore, mining operations can produce adverse effects including the contamination of local groundwater and erosion, such as in Tar Creek, Oklahoma, where local lead and zinc mines left the area so badly polluted and at risk of structural subsidence that the Environmental Protection Agency (EPA) ordered an evacuation, declaring the town uninhabitable and enacting a buyout of citizens in the area (Oklahoma Department of Environmental Quality 2006; Roosevelt 2004).

The diversity of materials required for microelectronics is a consequence of the specific properties of those materials. For example, lanthanides, commonly referred to as rare earth elements (REE), create the strongest type of permanent magnets: 'Small, lightweight, high-strength REE magnets have allowed miniaturization of numerous electrical and electronic components used in appliances, audio and video equipment, computers, automobiles, communications systems, and military gear. Many recent technological innovations already taken for granted (for example, miniaturized multi-gigabyte portable disk drives and DVD drives) would not be possible without REE magnets' (US Geological Survey 2005). Despite the connotation of their name, REE are not uncommon elements; however, they are extremely difficult to extract and refine as they tend to be found in very low concentrations, alongside one another (their similar atomic structure makes separation a difficult task), in sites also containing radioactive elements. Consequently, the production of each tonne of REE additionally produces a tonne of radioactive waste water and 10,000 to 12,000 cubic metres of waste gas (NASA 2012). The tailings pond at Bayan Obo, China's largest REE plant,[2] holds around 180 million tonnes of toxic waste from the mine. Since 2009,

[2]China produces around 85 per cent of these strategically valuable materials, and this has caused geopolitical concerns over their future availability. For more see Taffel 2016b.

the human population that previously dwelt in the area has been relocated by the government due to high incidences of cancers and growth defects arising from proximity to the plant (Kaiman 2014).

From an eco-ethical perspective, these cases prompt us to ask questions about digital microelectronics as the extraction of materials used to create digital infrastructures causes serious harms to human and other biotic communities. To what extent can we justify damages to these ecological systems based on the socioeconomic benefits that digital culture brings? Can the economic benefits of mining be seen to compensate for social impacts? What kind of status do we afford the nonhumans whose ecosystems are damaged by these activities, and how can we evaluate nonhuman costs in relation to social benefits?

A further example that brings the stakes of digital materiality into a sharper political and ethical focus while also foregrounding the historical and enduring colonial dynamics of extraction is the procurement of coltan ore for the extraction of tantalum. Tantalum is primarily used as a powder inside capacitors (Cunningham 2002), due to its volumetric efficiency – a crucial quality for technologies such as mobile phones and laptops where size is a paramount design concern – and durability, as unlike electrolytic capacitors, tantalum capacitors do not lose capacitance over time. The usage of tantalum capacitors within mobile phones and associated portable computing platforms has been important for reducing the size of these devices in the twenty-first century, which is a significant factor with regard to their growth in functionality and popularity. While tantalum is mined in Australia, Brazil and China, controversy arises from the coltan[3] industry in the Democratic Republic of Congo (DRC). Whereas in 2006 the DRC produced just 2 per cent of global tantalum supplies (US Geological Survey 2007), by 2016 this had risen to around 40 per cent, entailing the DRC had become the single largest national source of tantalum (US Geological Survey 2017).[4]

According to the International Rescue Committee (2008), a decade of international and civil conflict in the DRC resulted in approximately 5.4 million deaths, the majority of cases being indirect deaths resulting from treatable diseases, which flourished following the collapse of the economy and healthcare system, with children under the age of five accounting for

[3]Coltan is a contraction of columbium-tantalum, the tantalum bearing ore found in the DRC. Columbium is an alternative name for the element niobium which has similar physical and chemical properties to tantalum.

[4]While many online activist campaigns claim that 80 per cent of the world's tantalum/coltan is derived from the DRC, and such claims have made their way into the academic literature (e.g. Meikle 2016: xiii), the source of this dubious figure is untraceable, and potentially refers to the particular tantalum bearing ore mined in central Africa, rather than global tantalum production.

nearly half these deaths. While this conflict raged, exports of coltan from the DRC continued, notably including those from mines controlled by armed militias whose continued military activity is financed by coltan and other conflict minerals such as tin and tungsten. Additionally, the neighbouring states of Rwanda and Uganda, neither of which have significant domestic tantalum reserves (Anderson 2008), began exporting coltan, having exploited Congolese reserves while their armed forces controlled parts of the DRC, with Ugandan coltan exports increasing from 2.5 tonnes before the war in 1997, to 70 tonnes by 1999 (Essick 2001). President Kagame of Rwanda described the war in the DRC as self-financing (Hara 2002) chiefly due to mineral exploitation, with the Rwandan army having seized over $62 million worth of coltan from the DRC in 1999 alone.

The war in the DRC was instigated by a multitude of factors including the legacies of racial segregation and the ensuing preferential treatment of certain groups by European colonial regimes, the Mobutu dictatorship which was overthrown in 1997, and an influx of refugees from Rwanda, a significant minority of which were implicated in the Rwandan genocide of 1994. As Michael Nest (2011: 76) explains,

> While political and strategic factors were important at the start of the conflict, all armed groups turned to revenue raising activities to finance their costly military campaigns. As the conflict wore on, economic interests became a major reason to continue fighting. … the Congo war became a conflict in which economic agendas became just as important as other agendas, and at times more important than other interests.

Consequently, conflict minerals such as coltan have been essential to both the international and enduring civil conflict within the DRC.

In addition to the human costs of the conflict, there are numerous environmental issues associated with coltan mining in the DRC. The Okapi Wildlife Reserve, a world heritage site, suffered incursions from thousands of artisanal coltan miners, who decimated the animal population after staff were evacuated (Essick 2001; United Nations Environment Programme 2008). Illegal mining camps in national parks have also led to miners hunting endangered species such as Grauer's mountain gorilla (Taylor and Goldsmith 2002: 421) and elephants (UN 2001) as food. Miners hunt these animals due to a lack of alternative food sources; given the choice between bushmeat from endangered species and starvation, it is hard to blame miners for feeding themselves. Starvation here is linked to land use change surrounding the conversion of agricultural land into artisanal coltan mines:

> In Numbi in Kalehe the massive destruction of former grazing land is catastrophic. Soil which has been used for unplanned prospection and artisanal coltan mining is no longer usable for agriculture. Entire hills

> and valleys have been turned into giant craters, turning the landscape of the region into an expanse of naked earth, at the bottom of which flow rivers and streams which were diverted for the requirements of coltan mining. (Tegera 2001: 20)

This exhibits one way that social and environmental ecological impacts form an entangled meshwork, with social malaise resulting in environmental issues, which feeds back into further social issues, particularly when ecosystems are damaged through deforestation and soil erosion, which prevents any future return to agricultural activities.

Primarily due to the activities of NGOs such as Raise Hope for Congo, Global Witness, Amnesty International and Action Mondiale Pour le Congo (Global Action for the Congo), who used the tantalum-containing microelectronics devices whose production they sought to alter to create social media campaigns, online petitions and documentary films, the ethical issues surrounding the usage of Congolese conflict minerals has received considerable media attention. Consequently, numerous electronics companies have sought to publicly distance themselves from tantalum originating from central African nations; however, the complexity of the global tantalum trade, whereby coltan mined in the DRC passes through at least ten intermediaries between extraction and consumption (Essick 2001; Ma 2009), entails minimal transparency and accountability. Each transaction represents another avenue for plausible deniability on the part of the new owner, and consequently it can be extremely difficult for electronics companies to distinguish whether or not they are using conflict-related tantalum. One strategy advocated by NGOs which would assist transparency is for electronics corporations to publish their supply chain; however, corporations have been adamant that such activity would adversely affect their ability to obtain competitive price advantages, highlighting a tension between ethically motivated action and the pursuit of economic profit.

The mediated attention surrounding mineral extraction from the DRC also translated into lobbying pressure seeking to enact legislation entailing that action was legally mandated, rather than merely an option for corporations. The outcome of this action was section 1502 of the Dodd-Frank Wall Street Reform and Consumer Protection Act (commonly referred to as the Dodd-Frank Act), a wide-ranging post-recession US law which introduced a series of modifications to financial regulations in the United States. Section 1502 specifically dealt with issues surrounding the procurement of Congolese conflict minerals and explicitly requires American companies to take steps to determine whether their products contain minerals from the DRC or neighbouring nations. President Obama signed the law into effect in July 2010, and in August 2012 the Securities and Exchange Commission (SEC) published the rules and regulations which companies had to adhere to with

regard to their efforts to trace minerals. In an attempt to avoid regulation, the National Association of Manufacturers, Chamber of Commerce of the United States and Business Roundtable filed a lawsuit against the SEC contending that section 1502 was a transgression of the first amendment of the US constitution; however, this case was dismissed in July 2013 (US District Court 2013).

Despite the intention for section 1502 to improve the situation in DRC by reducing the availability of funds to militias, the impacts of the bill have been heavily criticized. By requiring that Congolese tantalum be certified as conflict-free, major electronics corporations simply turned away from purchasing Congolese tantalum, tin and tungsten, with reports that even before SEC reporting was introduced, legal exports of tantalum from the DRC fell by over 90 per cent (Drajem, Hamilton and Kavanagh 2011). While this was accompanied by an increase of 25 per cent in illegally smuggled tantalum, the net result was that thousands of artisanal miners who had previously survived on a meagre income from legitimate mining operations were no longer able to obtain revenue from their labour, entailing that the effect of this legislation had been to inflict further suffering on Congolese citizens while boosting the black market trade in smuggling minerals out of the DRC (Dizole 2011; Aronson 2011). Western lawmakers were accused of over-simplifying the complex process of mineral procurement and detrimentally impacting upon the livelihoods of the people they sought to assist. Because of the globalized production process, it was simply easier for corporations to purchase materials from other sources, thereby avoiding the criticisms associated with using conflict minerals and the additional cost of certification.[5]

An alternative approach to mineral procurement has been undertaken by Fairphone, a company which originated from a Netherlands-based NGO, the Fairphone Foundation, which was established to research and campaign around ethical microelectronics. The Fairphone project evolved because its members felt that making a commercial product which embodied the values of the foundation expounded the best way to verify the viability of alternative methods of producing microelectronics. The first Fairphone was a smartphone featuring a capacitive touchscreen which runs a version of Android. The company crowdfunded the production costs of the phone, using an online advertising campaign that informed potential customers that production would be economically viable once 5,000 Fairphone orders had been placed, illustrating that in the twenty-first century, in order to produce ethical hardware, an assemblage involving software and content

[5]In February 2017, President Trump announced a suspension of Dodd-Frank section 1502. This was described as the right decision for the wrong reasons (Stoop, Verpoorten and van der Windt 2018).

are essential components. In 2014 an initial production run of 25,000 Fairphones was ordered and the first phones were delivered to customers.

Fairphone sources materials from partner institutions based in the DRC, such as tantalum from the Katanga-based Solutions for Hope initiative (Ballester 2013) and tin from the Kivu-based conflict-free tin initiative (van Abel 2013). These local initiatives certify particular mines as being conflict-free, and tag all minerals leaving these mines, meaning that they remain traceable and thus can bring economic benefits to Congolese miners and associated workers without funding warlords and militias. Consequently, Fairphone can be understood as a venture which leveraged ecologies of content and code to impact upon the production of microelectronics in ways which sought to produce outcomes that demonstrably improved the lives of those involved in producing the materials necessary to construct the devices.

While the project highlights that a more ethical microelectronics production model is possible, 25,000 Fairphones contrast with a broader industry which saw 1.4 billion smartphones sold in 2015 (Gartner 2016). Fairphone therefore involves a tiny fraction of devices being produced in a more ethically responsible fashion. Recalling the critique of ethical consumerism that was advanced in Chapter 2, ethical consumerism alone cannot provide answers to issues around the ecological impacts of microelectronics manufacture; it merely represents the abdication of regulatory governmental practices by devolving ethical responsibility onto the individual, and Fairphone could be seen as indicative of this. Ethical microelectronics could simply become a lifestyle choice practised by a tiny minority of consumers, creating minimal disturbance to mainstream corporate practices while exemplifying the central mantra of neoliberal consumer culture, the right of the atomized individual to choose.

Furthermore, a combination of economies of scale and the speed of upgrade culture within smartphone production created issues with Fairphone's attempts to produce a device that is repairable and has long-term support. In July 2017, just three and a half years after the original Fairphone launched, the company discontinued support. The annual upgrade cycle of smartphone components meant that by 2017 numerous suppliers no longer produced the parts used by Fairphone, and due to the small scale of the company it was not economically feasible to manufacture new batches of components. Despite the best intentions of the company, the speeds and structures of the broader industrial microelectronics ecology prohibited the device being supported for as long as less-ethically designed smartphones such as the iPhone or Samsung Galaxy devices. The Fairphone, then, is no panacea for issues surrounding microelectronics. However, by highlighting the potential for product design and mineral procurement to productively engage with artisanal mining communities, it delineates a less reductive and damaging way forward than the Dodd-Frank section 1502.

Examining the relationships between digital culture and the extraction industries illustrates that microelectronics have severe consequences for people and other living systems and that digital infrastructures are entangled with the flows of materials, energy and finance that comprise contemporary globalized capitalism. While digital culture has often been presented as a dematerialized postmodern public sphere or as an associated milieu allowing commons-based peer-to-peer alternatives to emerge, the technologies that currently support the network society are heavily implicated in the exploitative, inequitable and unsustainable dynamics of global supply chains. Within these networks, however, not all flows are equal, especially when considering their social and environmental implications. Digital technoculture is part of the exploitative history of colonialist and capitalist social relations. In the case of coltan, we see how the legacy of colonialism influences current practices and how colonial practices of exploitation are echoed in the digital age.

While issues surrounding the procurement of the materials necessary to construct the contemporary digital media ecology are reported within NGO and activist circles, supranational institutions such as the United Nations, and industrial and political discourses, they have largely been absent within discussions of media and/or mediation that concentrate on discourse as language and meanings that are tied to content. My argument here follows recent developments in critical infrastructure studies in suggesting that when approaching digital media as material systems, it is crucial to include analyses of the flows of matter and energy, the assemblages of minerals, metals, human labour and toxic by-products, that are necessary for the production of digitally mediated content. While this suggests a decentring of the social constructivist focus upon content and information, it by no means requires replacing this with a formalism which relegates the importance of content. Indeed, as we see when approaching assemblages such as the Fairphone, content, software and hardware are not discrete domains which can be understood in isolation but form entangled ecologies which coexist and co-evolve as dynamic meshworks.

Virtual? sweatshops

Once the raw materials for the production of ICT hardware have been extracted from the Earth and refined into elements and alloys, the next step in their reconfiguration into iPhones and ultrabooks is the manufacturing process. By the early twenty-first century, microelectronics production had shifted away from being primarily conducted by corporations who brand and sell products, towards a globalized model where ‘manufacturing is no

longer considered a core competency for market control' (Luthje 2006: 22). Brand-name electronics companies are now largely fabrication-free entities which outsource manufacturing to vast complexes in low-cost, newly industrializing countries in Asia, Latin America and Eastern Europe.[6] Although this shift in industrial microelectronics production can be understood as part of the ongoing processes of globalization, situating manufacturing in this way provides a useful counterpoint to claims that information technologies are post-industrial or dematerialized.

The transition to a globalized industry based on subcontracting has been accompanied by marked decreases in wages and safety conditions, alongside increased environmental damage caused by companies externalizing costs onto local ecosystems (Price 2010). Indeed, the lack of adequate environmental or labour-related regulations are reasons why regions provide attractive locations, as the financial cost of adhering to stricter environmental and labour laws reduces profitability. Perhaps unsurprisingly, the industry has aggressively sought to resist regulation from governments and unionization or similar forms of collectivized worker representation. The levels of environmental damage caused by ICT manufacture can be grasped by considering the twenty-nine sites around Silicon Valley designated as Superfund priority locations by the US Environmental Protection Agency, the highest concentration of seriously contaminated areas within the United States (Gabrys 2011: 1). These sites arose due to chemicals used in microelectronics manufacturing seeping out from underground tanks into local ecosystems, poisoning soils and water supplies and creating a toxic legacy which will remain hazardous to biotic systems for decades.

The most prominent examples of labour rights abuses in ICT manufacturing pertain to Foxconn, the world's largest manufacturer of electronics components, and the Longhua Science and Technology Park situated in Shenzhen, China, which employs between 300,000 and 400,000 workers in conditions that have seen them labelled as iSlaves (Qiu 2016). The 2006 scandal began with an exposé in the British *Mail on Sunday* newspaper (Joseph 2006) which revealed that workers manufacturing iPods laboured for twelve to fifteen hours a day, earning £54 per month, with half that figure deducted by the company for food and accommodation. Inside the on-site accommodation, one-hundred workers occupied each dormitory and visitors were forbidden. These conditions, and the labour cost of manufacturing an iPod nano – £4.20 – were contrasted with the retail price in the United Kingdom of up to £179. The controversy provided widespread media coverage (Frost and Burnett 2007) which concerned

[6]However, there are exceptions to this, such as Sony and Samsung, both of whom not only manufacture their own devices but produce components for many competitors, with Samsung producing screens for Apple, and Sony manufacturing most cameras found in smartphones.

Apple, prompting the company to launch an audit of labour conditions at the plant. This found violations of local labour laws or Apple's corporate code of conduct pertaining to the number of hours undertaken by workers, as the limit of sixty hours of work per week 'was exceeded thirty-five percent of the time and employees worked more than six consecutive days twenty-five percent of the time' (Apple 2006); the amount of living space inside dormitories; methods of reporting overtime; dispute processes for workers whose overtime had been underpaid; and ways that management disciplined workers. Apple subsequently pledged to remedy these infractions via a press release; however, as the 2010 scandal denotes, many of the violations of local labour laws and Apple's corporate code of conduct were not rectified.

The subsequent scandal surrounding Foxconn in 2010 was prompted by the actions of fourteen employees who committed suicide between January and May 2010. These acts were committed by young migrant workers, who like the majority of microelectronics labourers in China had left agricultural home towns for manufacturing centres such as Shenzhen to find better-paid work.[7] Confronted with the reality of working excessively long hours, while living in crowded dormitories under a fiercely disciplinary regime, these workers aged between eighteen and twenty-five jumped to their deaths to escape the misery of manufacturing the material infrastructure of the attention economy. Unlike the 2006 scandal, the 2010 controversy focused primarily upon Foxconn rather than Apple or other contractors (Blanchard 2010; Hille 2010), although academic criticism traced accountability back through the networks of production, arguing that 'leading international brands have adopted unethical purchasing practices, resulting in substandard conditions in their global electronics supply chains' (Chan and Pun 2010). Companies like Apple typically sign exclusive contracts with subcontractors to manufacture the entire stock of new product lines, which the contract stipulates must be available by a certain date. The penalties for not fulfilling the specified quota of devices by the deadline are severe, so the subcontractor typically enacts extremely high levels of compulsory overtime in order to fulfil the contract.

In response to the adverse publicity generated by the scandal, Foxconn announced a series of measures designed to improve worker morale and halt the suicides. The basic rate of pay was increased from 900 to 1200 yuan in June, and then from 1200 to 2000 yuan in October 2010 (Blanchard 2010), the number of compulsory overtime hours was reduced (SACOM 2010), and workers were asked to sign pledges that they would not kill

[7]While historically this labour was largely undertaken by women, by 2011 64 per cent of Foxconn employees were male, partially as a result of female infanticide in China, meaning that there are fewer young women available as workers (Chan, Pun and Selden 2013).

themselves. The wage increase announced in June can be largely attributed to a rise in the legal minimum wage in Shenzhen to 1100 yuan, meaning that Foxconn's wages remained just above statutory minimum levels (SACOM 2010); however, the subsequent rise to almost double the legal minimum wage suggests that under the scrutiny of sustained international attention, Foxconn felt forced to act before the negative coverage translated into contractor action.

One noteworthy aspect of this case which parallels the actions of NGOs campaigning around Congolese conflict minerals is that the mobilization of mediated attention which was partially successful in addressing concerns revolved around the usage of various digital technologies whose conditions of production were the issue at hand. This point invokes Stiegler's argument that technics constitutes a pharmacological situation, whereby contemporary technologies are simultaneously poisonous and represent the remedy to their own toxicity. Examining the material impacts of these technologies is revealing here, as what could otherwise appear to be a metaphor referring to the toxification of subjectivity is realized in a strikingly literal way through the exposure of workers to poisonous materials commonplace throughout the life cycle of microelectronics.

Although Stiegler does not explicitly engage with the ecological costs of digital media technologies, the notion of replacing the current mode of production and the separation of producers and consumers which frequently sees negative social and ecological impacts of technologies borne by people and ecosystems far removed from sites of consumption does present a potential alternative. Indeed, Stiegler's focus on an economy of contribution as a system predicated upon inclusive systems of care and the formation of positive externalities can be seen as a remedy to the current tendencies towards separation between producers in Congolese coltan mines and Chinese sweatshops and consumers spatially and affectively removed from the impacts of the production process. Examining the globalized ecologies at play here reveals the production of negative externalities which impact upon vulnerable people and ecosystems by a system designed around economic growth rather than ecological well-being. However, it must be emphasized that the disparities of wealth and associated communicative power within an information society entail that often those human and nonhuman actors who bear the brunt of these negative externalities are unable to mobilize attentional flows via social media networks.

The impacts of using media technologies to campaign for changing the conditions under which media technologies are produced also demonstrates why the symbolic and material aspects of technology cannot be effectively separated into disparate realms. Symbolic communication is never immaterial, as it performatively shapes material processes and actors; in this example the production of media and attention affects the labour conditions under which tools necessary for mediated communication are

produced, forming a feedback loop whereby semiotic and material systems are symbiotically entangled.

Powering digital culture

Stating that microelectronics require electricity to power them borders upon tautology, but electricity has to be generated, which within the contemporary cultural context predominantly requires the combustion of fossil fuels, entailing the release of carbon dioxide and other greenhouse gases into the atmosphere thus contributing to anthropogenic climate change, alongside the localized ecological costs of fossil-fuel extraction, which were dramatically highlighted by events surrounding the BP-owned Deepwater Horizon oil rig in 2010 which saw 4.9 million barrels of oil spilt into the Gulf of Mexico (US Coast Guard 2011: 33). The energy requirements of powering ICTs is substantial and rapidly rising, presenting questions surrounding the ethical and political status of these technologies. Explicating the scope of these issues is required in order to better comprehend what is at stake: by paying attention to the problems posed, we can begin to consider the ethical problematics and formulate programmes designed to remedy issues.

The global ICT industry was responsible for approximately 14 per cent of global electricity in 2014, and this is expected to grow substantially due to the expansion of the Internet of things and server infrastructure, with a worst-case scenario that ICT could require half of all electricity by 2030 (Andrae and Edler 2015). The energy requirements of ICTs are not limited to powering products, as manufacturing microelectronics hardware requires high volumes of energy. Producing a 174-gram iPhone X requires around 500 kilogrammes of raw materials – so less than 1 per cent of the overall material required is present in the final device – and is responsible for the emission of approximately 80 kilogrammes of greenhouse gases. Manufacturing a 2018 iMac Pro desktop computer releases over 1700 kilograms of CO_2e[8]. For computers and smartphones, the vast majority of life cycle energy costs pertains to production with the remainder split between transportation and customer usage. While we think about the energy footprint of these devices in terms of our actions of plugging them in to charge their batteries or powering them via mains electricity, this is a small fraction of the total energy required.[9] This is because of the complexity of manufacturing processes and

[8]CO_2e denotes an atmospheric forcing equivalent to an amount of CO_2. The release of other greenhouse gases are factored into such equations to provide an overall atmospheric forcing.

[9]There are, however, spectacularly wasteful practices surrounding the electricity usage of ICT, notably the mining of the cryptocurrency Bitcoin. Bitcoins are produced through 'mining', which involves solving a complex mathematical problem to validate each new section of the blockchain ledger, requiring billions of calculations to be performed. The Bitcoin network

the variety of materials required but also results from the highly limited lifespan of media hardware within the cultural context of upgrade culture.

While microelectronics manufacturers have trumpeted claims regarding improvements in carbon efficiency per transistor within the manufacturing process, the overall increase in transistors used typically negates these efficiency savings. This is an example of Jevons paradox, whereby any increases in efficiency are negated by increased demand for and consumption of that resource. Similarly, the production of devices which require less power to operate does not negate the costs of producing these devices in the first place or the proliferation of networked microelectronics devices. Whereas in the 1990s a household may have owned a single desktop computer, they are now likely to possess numerous laptops, tablets, smartphones and other 'smart' devices such as televisions, fitness tracking bands, internet radios, smartwatches and networked attached storage devices.

The rapid pace of contemporary technological change entails that obsolescence is often perceived before devices fail to function. For example, research synthesizing analyses of computer lifespans (IVF 2007; Hoang et al. 2008) calculates that the average life of a laptop is between two and half and four years, with desktops lasting only slightly longer. Although most computers function beyond these durations, users upgrade to newer, more powerful machines, a process which is frequently driven by the introduction of newer versions of software, which demand higher system specifications, resulting in consumers perceiving their hardware to be obsolescent. This is especially relevant for tablets and laptops, as upgrading hardware often requires considerable technical expertise, meaning that when one key component (such as the CPU or graphics card) does not meet the owner's requirements, the entire system requires replacement, partially explaining why laptops have shorter lifespans than desktops. The difficulty in upgrading components additionally entails that if a key component fails and the system is outside of warranty, the entire system is usually replaced.

Perceived obsolescence is also an issue with mobile phones, which are commonly sold on twenty-four-month contracts, at the end of which the consumer is offered a new contract, with another free phone as an incentive. Consequently, the average life cycle of a phone in the United States, European Union and China is between seventeen and twenty-one months (Balde et al. 2017: 21). Despite the old phone still functioning adequately, it is either thrown away or left in a drawer to gather dust. In 2009, 141 million

self-adjusts the complexity of these calculations, so that new blocks are on average created once every 10 minutes. Due to the value of Bitcoin, which in December 2017 reached over US $19,000, astronomical amounts of computational power are expended by Bitcoin miners performing this task. Consequently, it is estimated that in 2018 electricity usage associated with Bitcoin was over 73 TWh, higher than that of entire nation-states such as Ireland and Austria (de Vries 2018).

mobile phones were disposed of in the United States alone, only twelve million of which were recycled (US EPA 2011). The vast majority of these devices remain functional, but the economic and cultural imperatives of networked capitalism and upgrade culture entail that they are perceived as obsolete. Advertising constantly bombards us with messages that frequently upgrading our digital devices will make our lives more efficient, enjoyable and entertaining. Given the ecological costs of producing these devices, the practice of discarding functional hardware must instead be understood as ecologically unsustainable and ethically dubious.

Examining the life cycle energy costs of ICTs proves useful in delineating that the vast majority of energy is spent producing hardware, partially due to the limited lifespan of these technologies. Bearing this in mind, it is unsurprising that extending the lifespan of hardware is among the most promising approaches to mitigating energy costs associated with microelectronics. By simply not discarding functional devices, consumers can significantly reduce the ecological footprint of their technology. However, as illustrated by the example of mobile phones – where models are annually replaced and each revision is declared to be a revolutionary innovation – the corporations producing these technologies are eager for consumption to speed up rather than slow down, deploying a combination of perceived and planned obsolescence in order to reduce product lifespans, which increases ecological costs but raises short-term profitability.

This highlights the divergence between corporate imperatives driven by economic profitability and the ecological epistemology presented by Bateson. The unit of survival for corporations is the individual company, which competes with rival corporations, viewing social and environmental commons as assets to be appropriated and exploited, or an othered outside onto which ecological costs can be externalized in the quest for profitability. By contrast, Bateson's epistemology calls for the implementation of economic models which value wider ecological contexts within which the corporation is embedded. In the ever-intensifying battle between corporate actors for consumer attention and economic growth, broader notions of ecological growth are marginalized, allowing the type of destructive short-termism criticized by Stiegler to flourish. Indeed, from the longer term, ecological perspective, such behaviour is ultimately self-defeating, as individual purposive systems that quarrel with their own ecology inevitably harm their own futures. Contributing to global ecological crises such as anthropogenic climate change will eventually prove detrimental to corporate profitability; however, the short-term structural directives of market valuations effectively prevent corporations from taking ecologically effective action.

It must, however, be emphasized that critique which solely focuses upon the energy costs associated with individual laptops, smartphones or tablets, merely repeats the misidentification of the individual object as the relevant scale for analysis. When using modern computing systems, we are very

rarely exclusively engaged with the individual microelectronics device with which we have immediate bodily contact; a vast array of cloud data storage and processing, fibre-optic cables, 4G cellular towers, Wi-Fi access points, GPS satellites and other hardware provide the infrastructure necessary for networked, mobile and pervasive computing. Indeed, the trend seen over recent years, whereby desktop computers sales have significantly declined, whereas devices such as tablets, smartphones and ultrabooks have become increasingly popular, is dependent on most storage and processor-intensive computation being located elsewhere, while the end user accesses these resources through ultra-portable thin client devices. Although this situation provides the illusion of small, smart, green information technologies, the reality is very different when we consider the magnitude of the back-end infrastructure necessary for this arrangement, but which is often out of sight and out of mind. Cubitt, Hassan and Volkmer (2011) highlight this situation through a discussion of the energy costs and ecological impacts of the gargantuan server farms built by Google to host the data uploaded to sites such as YouTube, Google Docs, Gmail and Google Drive. These facilities draw over 100 megawatts each, and Google is only one of the major players in server farms and cloud computing, alongside companies such as Amazon, Dropbox and Microsoft.

While Cubitt et al. argue that data servers are likely to be the sector within information and communications technologies with the most rapid increase in carbon emissions over the coming years, this claim is disputed by material from the Centre for Energy Efficient Telecommunications (CEET) at the University of Melbourne, whose 2013 report entitled 'The Power of the Wireless Cloud', contends that much of the focus upon the environmental impact of data servers has failed to acknowledge the rapidly growing energy costs of wireless access networks. Especially with regard to the introduction of the Internet of things, whereby an array of devices from fridges to watches, televisions to traffic lights are becoming wirelessly connected to the internet, CEET (2013: 3) estimates,

> By 2015, [the] wireless cloud will consume up to 43 TWh, compared to only 9.2 TWh in 2012, an increase of 460%. This is an increase in carbon footprint from 6 megatonnes of CO_2 in 2012 to up to 30 megatonnes of CO_2 in 2015, the equivalent of adding 4.9 million cars to the roads. Up to 90% of this consumption is attributable to wireless access network technologies, data centres account for only 9%.

What we see from the work of Cubitt et al and CEET is that the environmental impacts of information technologies reach far beyond the devices we see, touch and think of as contributing to 'our' individual carbon footprint. Indeed, the vast assemblages of hardware required to construct today's digital world can be conceptualized as resembling an iceberg; the

hardware we are directly in contact with is just the tip of the technocultural infrastructure, with the vast majority residing out of sight. This demonstrates the importance of making the often-imperceptible assemblages of hardware become visible, which means adopting a stance which explicitly combats the fuzzy notions of immateriality, virtuality and informationalization which often accompany discourses of cloud computing.

An important point which arises from this material is that proprietary strategies which rely on exclusivity and restriction of access are only likely to compound the environmental costs of the wireless cloud. When mobile telephony providers install access points which only benefit the users of their network, what we see is the replication of infrastructure, which multiplies the environmental impact of networking technologies. Such replication is not, however, a technical necessity, and open-access digital resources can provide examples whereby communally accessible resources are far more efficiently stored than was previously possible. In order to access a print copy of *Encyclopaedia Britannica*, an individual typically had to own the text, which entailed a substantial economic outlay, alongside the environmental costs associated with sourcing and bleaching the paper, inks and printing machinery. Similarly, Encarta, the Microsoft-published encyclopaedia for computers, required each individual user to purchase the CD-ROMs on which the data was stored. By contrast, no single end user is required to download the entire Wikipedia, nor would this be desirable even if this wasn't rendered impossible by Wikipedia's dynamic and metamorphic nature. The status of the project as open content entails that rather than replicating data, it can be stored centrally (or at least in a polycentric way across several mirrors located across the globe) and accessed by hundreds of millions of users, rather than requiring each individual to possess their own copy of the ecologically costly artefact.

Questions over data storage, then, not merely are instrumental and neutral but contain political affordances which are connected to the sociocultural usages of these technologies, with models based upon openness at the levels of content and software, resulting in hardware platforms which could significantly reduce the environmental impacts of hardware systems, in contrast to those based upon exclusivity and competitive individualism. Again, what we see here emphasizes that when we think about the impacts of digital technology, hardware is fundamentally inseparable from thinking about software and content, further strengthening the case for thinking about them as entangled, rather than interconnected phenomena.

The global trade in e-waste

Once digital devices reach the end of their useful life, through either damage or obsolescence, they must be disposed of, but safely disposing of

microelectronics is not straightforward, as devices contain numerous toxic materials. The multiplicity of materials within microelectronic devices typically include acetone, lithium, hydrochloric acid, benzene, arsenic and plastics that contain phthalates and brominated flame retardants, all of which are hazardous to humans and other living system. Until their usage within consumer microelectronics was banned in 2006 under the European Union's Restriction of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) directive, lead, mercury, cadmium, hexavalent chromium and polyvinyl bromides were also ubiquitously utilized within ICTs. Consequently, e-waste accounts for 'forty percent of all lead, seventy percent of the heavy metals and a significant proportion of the pollutants in US dumps' (Byster and Smith 2006: 210). In 2016, 44.7 million metric tonnes of e-waste were generated globally (Balde et al. 2017: 38). Consequently, both the toxicity and volume of e-waste present further examples of hidden ecological harms associated with digital technologies.

As with other Anthropocenic environmental issues, e-waste production is highly heterogeneous, with nation-states such as the United States, United Kingdom and Australia generating over 20 kilograms per inhabitant per annum, whereas the continental average for Africa is under 2 kilograms per inhabitant annually. Currently, wealthier nations send large volumes of toxic e-waste to poorer countries, where they are manually treated, with few safeguards in place to protect the health and safety of workers or local environments. This externalization of environmental harm from rich nations to poorer ones has been the subject of various campaigns since the turn of the century, and while these have had some successes, in 2016, it was still found that around 40 per cent of e-waste sent for recycling in the United States was illegally shipped to the developing world for 'recycling' (Hopson and Puckett 2016). We should note how the rhetoric of recycling and associated connotations of environmental concern and sustainability have been co-opted into a system that breaks international law to externalize ecological costs onto impoverished people. These flows of toxic waste denote another level at which digital colonialism operates; whereas raw materials and data are extracted from the global poor to enrich global elites, toxic waste is then sent back to impoverished areas.

Under the Basel Convention, adopted in 1989 and amended in 1994, it is illegal for most OECD nations to export hazardous waste and for non-OECD countries to receive it (although the treaty was not ratified by the United States almost all developing countries have done so, entailing that it illegal to ship e-waste to those places). More recently, the European Union's Waste Electrical and Electronics Equipment (WEEE) directive requires all e-waste within the European Union to be recycled at local facilities and that retailers must allow consumers to return old electronics products when purchasing replacements. While the WEEE directive and Basel Convention exist to prevent a global trade in e-waste, these laws are routinely

circumvented through waste management companies shipping e-waste labelled as working, second-hand goods for sale in non-OECD countries: 'In Lagos, while there is a legitimate robust market and ability to repair and refurbish old electronic equipment including computers, monitors, TVs and cell phones, the local experts complain that of the estimated 500 forty-foot containers shipped to Lagos each month, as much as seventy-five percent of the imports are "junk" and are not economically repairable' (BAN 2005). Part of the difficulty results from the vast global flows of material through major shipping routes. Effectively policing the movement of e-waste would require significant investment in port authorities, who would have to not only check whether these devices were functional but be sufficiently knowledgeable to adjudicate whether faults were easily repairable.

Once e-waste arrives in processing centres, it is manually disassembled, with valuable materials such as copper, gold and silver gathered for re-sale. The techniques employed to recover valuable materials by artisanal e-waste recyclers in developing nations would typically be illegal in developed nations where many of these devices were used, as they poison workers and local ecosystems. For example, wires are often burnt, melting the plastic casing to revealing the valuable copper contained inside. As the insulating plastics often contain PVC and brominated flame retardants, the smoke emitted contains organically persistent and highly toxic compounds such as brominated and chlorinated furans and dioxins. Acid baths are used to recover the gold used in pins which connect silicon chips to circuit boards, with the corrosive leftover products of nitric and hydrochloric acids mixed with the dissolved remnants of the components routinely finding their way into local water tables, rendering the water undrinkable. CRT monitors have the lead-laden glass cracked open so that the valuable copper yoke can be removed, resulting in lead leaching into the ground and water table.

Consequently, when the Basel Action Network tested water from the river in Guiyu, China, a major e-waste processing area, they found it contained lead levels 190 times higher than the maximum level safe for human consumption prescribed by the World Health Organization (BAN and STVC 2002: 24). Subsequent research has found elevated levels of lead in the blood of children of Guiyu (Guo et al. 2014). As lead poisoning in children is associated with impaired cognitive development, dealing with toxic high-tech trash serious damages the health and future available to these people. Soil from Agbogbloshie, Ghana, another major e-waste processing area presented similar findings, with lead levels being over 100 times the background level, alongside elevated levels of cadmium, antimony, phthalates and chlorinated dioxins (Greenpeace 2008). Most of the 215,000 tonnes of e-waste in Ghana comes from Europe and North America (Itai et al. 2014).

Workers in e-waste processing zones frequently include children, sometimes as young as five years old (Greenpeace 2008). Wages are often

in the region of US$1.50 a day (Roman and Puckett 2002: 2). 'Workers and the general public are completely unaware of the hazards of the materials that are being processed and the toxins they contain. There is no proper regulatory authority to oversee or control the pollution, nor the occupational exposures to the toxins in the waste. Because of the general poverty people are forced to work in these hazardous conditions' (BAN and STVC 2002: 26). The global trade in e-waste involves affluent countries externalizing ecological costs onto the peoples and ecosystems in impoverished areas of the world. In this way, the material architecture of the attention economy detrimentally impacts upon the digital have-nots, as vast quantities of hazardous materials are sent across the world to be manually 'recycled' by people who do not comprehend the harms to themselves, their communities or local ecosystems wrought by their actions. Consequently, both drawing attention to this inequitable situation and finding ways of enforcing existing legislation which renders exporting e-waste illegal become crucial tasks if the inequities and ecological harms currently caused by e-waste are to be addressed.

One strategy widely championed as an effective method for dealing with problems caused by e-waste is extended producer responsibility (EPR) (Raphael and Smith 2006; Huisman and Magalini 2007) allied with legislation mandating EPR schemes. EPR is designed to make producers responsible for the disposal of devices, requiring that companies take products back once they break or become obsolete, or that they pay another company to undertake local recycling, thereby avoiding the exportation of toxic material to areas where it will be manually disassembled. EPR requires producers to internalize ecological costs, ideally leading to producers redesigning hardware so that many of the current hazards are eliminated through sustainable design:

> Rather than seeking remedies at the end of a product's life, we need a new political and economic infrastructure to support the development of products that are safe and sustainable throughout their life-cycle. This policy must prevent pollution and waste rather than just controlling it. Just controlling waste, which has been the approach society has relied on since the Industrial Revolution, is no longer adequate or acceptable. (EPR Working Group 2003: 1)

The European Union sought to implement a comprehensive system enforcing EPR through the WEEE directive, which was passed into law in 2003, requiring that by August 2005 all companies which supplied electronic equipment within the European Union were to establish programmes to collect and safely recycle e-waste.

Before implementation, the WEEE directive was widely lauded as an excellent piece of legislation; in practice, however, less than 40 per cent of end-of-life EEE is being returned and treated under these schemes, leaving substantial room for improvement (Balde et al. 2017). One report into the

efficacy of the WEEE directive concludes, 'Increasing consumer awareness is a necessity for an eco-efficient WEEE implementation with maximized environmental results (collect more) and increased costs efficiency (treat better)' (Huisman et al. 2008). This foregrounds the role that mediated communications can play in publicizing existing schemes by raising awareness of their existence. Without effective publicity (i.e. media content) leading to an informed populace, the WEEE directive will continue to make only a fraction of its potential impact. Without effective communication and molecular activity, the molar strategy of international legislation does not necessarily realize its aims. What we see here is not an argument for either molar or molecular strategies, for regulation or activism; eco-effective outcomes are most likely to arise from actions which combine these approaches, exemplifying the synthetic logic of the AND proposed by Deleuze and Guattari.

A further problem with the WEEE directive is that the existing global trade in e-waste masquerading as functional second-hand goods still functions, presenting companies an avenue that avoids paying for WEEE processing. An investigation into e-waste being illegally shipped to Nigeria found that 29 per cent came from the European Union (Odeyingbo, Nnorom and Deubzer 2018: 8), despite this breaching both the WEEE directive and Basel Convention. Again, this highlights the weaknesses of unenforced molar strategies; in this case, the risk/reward scenario for companies surrounding the cost of legally processing e-waste and the risk of being detected while shipping defunct items as second-hand goods frequently sees laws broken. While a total system of surveillance and control over global flows of matter is not economically viable, this does suggest that significantly increasing penalties for those found exporting hazardous materials such as e-waste may alter the risk/reward calculation.

Linear and cyclical models of production

Alongside the WEEE directive, the European Union passed the Restriction on the Use of Hazardous Substances in Electrical and Electronics Equipment (RoHS) directive, which focused upon eliminating several of the most harmful substances which were previously ubiquitously used within microelectronics manufacturing: mercury, hexavalent chromium, lead, polybrominated biphenyls and polybrominated diphenyl ether – making it illegal for new devices to contain more than trace amounts of these substances.[10] RoHS has proved a highly effective piece of legislation because it targets design; banning the usage of toxic materials entails that issues relating to toxicity do

[10]In 2015 RoHS was amended to include four additional substances, all of which are phthalates, organic compounds that are used as plasticizers.

not exist later within a product's life cycle. Design, then, potentially becomes a crucial point in the life cycle for the implementation of ecologically beneficial alternatives to current practices.

A first major issue with the current design process is the structure of the 'life cycle' of microelectronics produced under the logic of industrialism. Currently, this proceeds as a near-linear chain of events which begins with product design and extracting raw materials, and ends with disposal. A limited amount of down-cycling occurs during e-waste processing whereby certain valuable resources are extracted from used products for reuse. This process is realistically described as down-cycling rather than recycling as only parts of the product are re-used, and these typically create materials of lower quality than the original. This does not form a cyclical process where 'waste' becomes resources for next-generation materials, it merely extends the limited lifespan of certain parts of these products.

The near-linear progression from design to the dump that is characteristic of current industrial processes contrasts sharply with cyclical processes found within ecology and life sciences, which are sustainable and resilient. In these cases, 'waste' becomes 'food', outputs become inputs for the next iteration of the process, meaning that these systems can run continuously for millennia without accumulating problematic stockpiles of 'waste' material. Below are simplified diagrams of the nitrogen cycle (Figure 5.1), an example of a sustainable process and the industrial model of production (Figure 5.2).

Whereas every stage within the nitrogen cycle is infinitely repeatable with no identifiable beginning or end point, the industrial production model inexorably leads towards landfill or incineration, with the outputs not being recoverable into fresh resources for the next generation of products. Problems with this mode of design are compounded by the incorporation of substances which are toxic to organic systems; not only is there an accumulation of waste material, but this stockpile is hazardous to life.

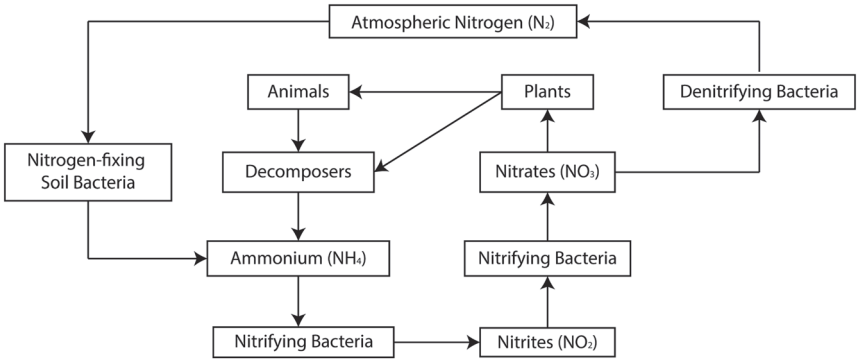

FIGURE 5.1 *The nitrogen cycle.*

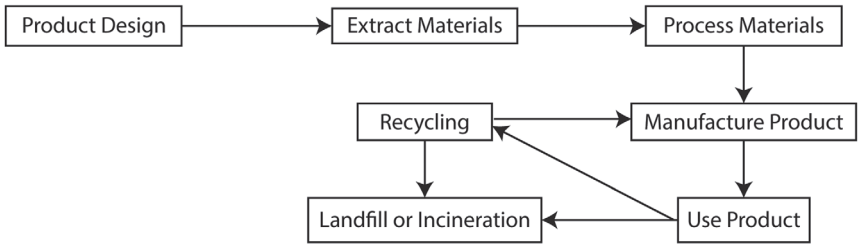

FIGURE 5.2 *Industrial production model.*

The nitrogen cycle includes multiple feedback loops, a systemic arrangement that builds systemic resilience as it allows for a certain amount of slippage within the system to be absorbed without the entire process collapsing. This stands in contrast to the model of the linear production cycle which is streamlined for efficiency, leaving as little redundancy as possible. In ecological and evolutionary systems, 'the key is flexibility, not admirable precision' (Gould 1996: 44). Ecological and biological systems are resilient precisely because they incorporate redundancy, affording flexibility in an uncertain and changing world, whereas this redundancy is conspicuously absent from the optimized, efficient linear production models of just-in-time capitalism. While this presents a somewhat crude and reductive approach to approaching cyclical processes within ecological systems, we can juxtapose the geological durations of the nitrogen cycle, which was relatively stable for two billion years (until the onset of the Anthropocene), with the two centuries of industrial civilization, which has produced multiple concurrent Anthropocenic ecological crises.

Problems regarding the linearity of industrial design are addressed by the cradle-to-cradle movement and related concepts of zero waste and the circular economy. Founded by Michael Braungart, an industrial chemist, and William McDonough, an architect, the cradle-to-cradle movement explicitly seeks to remodel the entire system of industrial manufacture according to cyclical processes. Braungart and McDonough argue that the linear cradle-to-grave model which has dominated design and production since the industrial revolution is extremely wasteful:

> More than ninety percent of materials extracted to make durable goods in the United States become waste almost immediately. Sometimes the product scarcely lasts longer. It is often cheaper to buy a new version of even the most expensive appliance than to track down someone to repair the original item. … What most people see in their garbage cans is only the tip of a material iceberg: the product itself contains on average only five percent of the raw materials involved in making and delivering it. (Braungart and McDonough 2009: 27)

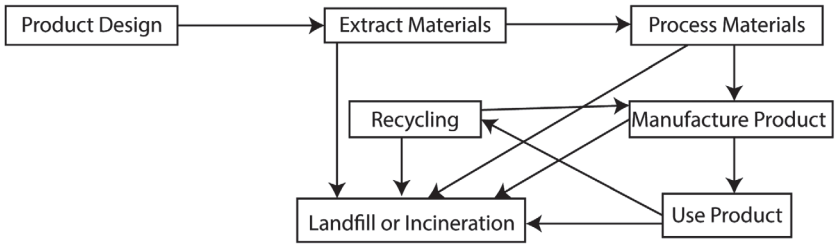

FIGURE 5.3 *Revised industrial production process.*

Indeed, bearing this in mind, it is worth revising our notion of the industrial production model (Figure 5.3) to account for the fact that waste is generated at every stage throughout the process. This is particularly evident when dealing with portable microelectronics such as a smartphone where, as we have seen, over 99 per cent of waste is generated in production, rather than in end-of-life disposal.

Consequently, Braungart and McDonough contend that design and manufacturing require re-orientating towards an ethos of eco-effectiveness; whereby the logic of economies of scale and the widespread deployment of toxic materials are supplanted by designs where every material employed is entirely recoverable and reusable. This reorientation of production stands in contradistinction to contemporary environmental approaches that portray humanity as inevitably destructive towards natural systems, proposing that such approaches stem from erroneous epistemological premises which accept the linear model of industrial production as the only valid system of production. Consequently, environmentalist actions are delimited in scope to lessening inevitable harm(s) perpetuated by human actions, rather than transforming the logic of production to generate positive environmental contributions. The cradle-to-cradle approach therefore proposes a process of industrial re-evolution:

> Our products and processes can be most deeply effective when they most resemble the natural world. … Natural systems take from their environment but they also give something back. The cherry tree drops its blossoms and leaves while it cycles water and makes oxygen; the ant community redistributes nutrients throughout the soil. We can follow their cue to create a more inspiring engagement – a partnership with nature. We can build factories whose products and by-products nourish the ecosystem with biodegradable materials instead of dumping, burning or burying them. (Braungart and McDonough 2009: 155/156)

The cradle-to-cradle movement has enjoyed several notable successes in implementing this type of change to specific industrial processes, particularly

within the textile industry. Working with Victor-Innovex, a Quebec-based fabric producer, Braungart and McDonough developed eco-intelligent polyester, a fabric designed to be completely recyclable and which avoids many of the toxic materials traditionally used in polyester production. For example, antimony, a catalyst regularly used in polyester fabrication, is a carcinogen and is poisonous to various human organs including the heart, lungs and skin. Conventional methods of recycling polyester involve a high-temperature process releasing antimony-trioxide into the air. McDonough and Braungart's design replaced antimony with a titanium and silica-based catalyst which lacks the toxicity of antimony. Furthermore, McDonough and Braungart (2002a) 'analysed all the dyes and auxiliaries Victor used in the manufacture of polyester, trimming a list of fifty-seven chemicals to fifteen. Of those, several were replaced with more environmentally sound chemicals'. Utilizing innovative green design to replace toxic materials from industrial processes points to an example of how implementing ethics via design can create ecologically beneficial alternatives to certain current practices.

The restoration of Ford's Rouge River manufacturing complex in Dearborn Michigan is another case where Braungart and McDonough's principles have been applied. While transforming an ageing 1,000-acre industrial site into a modern complex, featuring a living roof, improved insulation and the utilization of natural skylights (McDonough and Braungart 2002b) can all be understood as positive environmental contributions, McDonough and Braungart's contentions that this demonstrates Ford's commitment to environmentally sound production, with the possibility of cradle-to-cradle style automobile manufacturing in the future, seems hopelessly naive when considering that the complex is used to manufacture 14 mile-per-gallon F150 trucks. Similarly, Coca-Cola promote their green credentials for incorporating cradle-to-cradle carpeting in their Pemberton Place site in Atlanta, United States; however, the company has been subject to an ongoing boycott from human rights campaigners in relation to numerous incidents across the corporation's globalized workforce. Incidents cited by activists include financing the murder of trade union leaders by right-wing paramilitaries in South America (Killer Coke 2010a), firing workers for attempting to unionize at numerous plants across several continents, and the overexploitation and pollution of groundwater in India (Killer Coke 2010b). While the complexities of globalized capitalism entail that all companies are implicated in exploitative practices – such as those delineated throughout the course of this chapter – not all actors within these networks are ethical equals; not all corporations stand accused of hiring paramilitaries to execute workers for attempting to unionize.

Heralding companies such as Ford and Coca-Cola as harbingers of an eco-effective re-evolution is problematic, insofar as despite conducting beneficial actions in particular areas of environmental policy, these corporations

frequently breach labour rights or create environmental degradation elsewhere. Presenting their vision of a sustainable social ecology, Braungart and McDonough present a triangular diagram with the points representing ecology (by which they meant environmental ethics), economy and equity. However, their uncritical support for corporations whose actions towards their workforce and environmental impacts are so deeply inequitable undercuts their vision of a future which is not merely sustainable but claims to encourage positive growth across ecology, equitability and economy.

Recalling the model of the three ecologies, effective ecological action is not just aimed at the environment but is designed to create beneficial conditions for social and psychological relations, not sweatshop labour, union busting and gas-guzzling motor vehicles. Providing positive public relations for corporations to present themselves as ethically concerned businesses, despite their dubious human rights and environmental justice practices, merely creates positive brand associations that corporations are often more concerned about than underlying ethical concerns (Klein 2000; Peretti 2006). Although the cradle-to-cradle movement presents useful ideas with regard to removing toxic and non-biodegradable substances from product design, their overarching vision for a positive future is seriously tarnished by an uncritical celebration of corporations whose labour and environmental justice records are severely problematic.

Beyond planned obsolescence

Alongside issues surrounding the cradle-to-grave life cycle of microelectronics, a second major problem surrounding the overall structure of microelectronics life cycles relates to planned obsolescence. The idea was initially proposed by Bernard London, who in 1932 argued that a major factor perpetuating economic depression in the United States was that citizens were increasingly repairing and reusing goods and products, extending their lifespans. London argued that this created a lack of consumer spending, supressing economic growth and recovery. To combat this, London proposed:

> I would have the Government assign a lease of life to shoes and homes and machines, to all products of manufacture, mining and agriculture, when they are first created, and they would be sold and used within the term of their existence definitely known by the consumer. After the allotted time had expired, these things would be legally 'dead' and would be controlled by the duly appointed governmental agency and destroyed if there is widespread unemployment. New products would constantly be pouring forth from the factories and marketplaces, to take the place of the obsolete, and the wheels of industry would be kept going and employment regularized and assured for the masses. (London 1932)

While London's plans for a centrally mandated form of planned obsolescence never materialized, many digital devices incorporate elements of planned obsolescence into their design.

Devices such as the Apple iPhone, iPad and Google Pixel devices feature non-removable lithium-ion batteries, whose performance degrades over time; most Li-ion batteries deliver around 500 full charge/discharge cycles (Buchmann 2008), entailing that these batteries typically last between two and four years. Eventually, the battery will hold only a fraction of its original capacitance, denoting that for portable devices such as smartphones and watches, the battery is essentially useless. While manufacturers could design products with removable batteries, so that once the limited lifespan of the battery expires it could simply be replaced, products such as the iPhone are deliberately designed so that users cannot easily achieve this, with the use of nonstandard screw threads and the battery being held in place by strong adhesive. In some cases, it is possible for consumers to send devices back to the manufacturer to have batteries replaced; however, the monetary cost is often substantial, for example, replacing an iPhone battery in this manner costs £45 to £79. By contrast, replacement batteries for the LG G4, a smartphone featuring a removable battery, costs around £10. Additionally, the practice of telecommunication providers giving away 'free' phones with new contracts is further designed to make discarding old but functional phones an attractive option for consumers, combining planned and perceived obsolescence.

Designing products that require replacement every few years – once the supplied battery fails to hold an adequate charge – makes economic sense for the companies involved, as if products have relatively short lifespans, consumers will purchase new hardware regularly, rather than simply replacing the inexpensive battery and continuing to use older devices. Indeed, from the perspective of upgrade culture, if consumers were not prepared to regularly invest in new hardware, then electronics corporations would become less profitable and begin to slow down the R&D process and product cycle to adjust to consumer demand. If this occurred, the price, as opposed to the ecological cost, of these items would likely rise, as the rate of consumption presents a feedback loop which drives R&D and keeps prices down, in turn driving further consumption. From an ecological perspective, however, it makes little sense for people to discard functional hardware because a solitary, cheap-to-manufacture, and potentially easy-to-replace component no longer works adequately. As we have seen, the short lifespan of consumer electronics is a significant contributor to the extremely high energy costs, so one effective strategy for reducing these costs is extending product lifespans. This again returns us to ethology and the politics of speed in digital capitalism; curbing the destructive velocity of consumption becomes key to ecologically beneficial outcomes.

A useful example showcasing how networked digital technologies enabled productive engagements with planned obsolescence is provided

by iFixit, a website and online community which provides a communally generated repository of repair guides. As of 2017, the site lists over thirty thousand repair manuals featuring devices from tablets to toasters. Each guide is available as a HTML webpage, via an iOS and Android application, or as a downloadable PDF file. In each case, the contents are released under a Creative Commons 3.0 Attribution, Non-commercial, Share Alike licence, meaning that anyone can reproduce, remix and republish the content, so long as the resulting works are issued under the same licence, the derivative works attribute the original source material as coming from iFixit, and those remixed works are not sold. In addition to repair manuals, the iFixit site features a space for community members to ask questions, allowing new and less technically adept members to draw upon the broader community's expertise, with the site containing around 110,000 of these questions and a YouTube page with video repair guides and device disassembly guides which have over fifty million views.

iFixit additionally maintains a blog which provides a manifesto arguing why repairing devices is ecologically and socially beneficial. These arguments include explorations of issues surrounding e-waste and ethical mineral procurement, alongside individual factors such as consumer freedoms and cost savings, and social issues such as the creation of local jobs. These issues are outlined in Figure 5.4, the Self-Repair Manifesto, and the iFixit blog explores each point in detail, using source material from NGOs such as the Basel Action Network and the Institute of Electrical and Electronics Engineers to substantiate the claims being advanced.

It is worth noting the homology which exists between the triumvirate of levels at which iFixit claims that repairing electronics presents positive outcomes, which are identified as the individual, society and environment, and the three ecologies outlined by Bateson and Guattari as mind, society and environment. While there is clear overlap among the categories of society and environment, it is worth highlighting the discrepancy between the enclosed and atomized notion of the individual consumer, and the distributed and connectionist conception of the mind which Bateson forcefully argues is immanent outside of the body. Indeed, for Bateson (1972: 468), the reduction of the mind to the level of the individual represents a fundamental epistemological pathology which has serious evolutionary repercussions for (post)modern humans:

> As you arrogate all mind to yourself, you will see the world around you as mindless and therefore not entitled to moral or ethical consideration. The environment will seem to be yours to exploit. Your survival unit will be you and your folks or conspecifics against the environment of other social units, other races and the brutes and vegetables. If this is your estimate of your relation to nature and you have an advanced technology, your likelihood of survival will be that of a snowball in hell.

FIGURE 5.4 *Repair Manifesto: source iFixit.com. CC BY-NC-SA 3.0.*

For Bateson, then, the three ecologies cannot be reduced to individual, society and environment, as there are no enclosed and bounded individuals. Indeed, this alteration entails that rather than an entangled meshwork, there are three relatively autonomous domains, which we can comprehend as being interconnected, but which are discrete and separable, marking a critical departure from an ecological onto-epistemology.

iFixit could, however, be seen as making an important intervention around Stiegler's argument that digital mnemotechnics – exteriorized technologies which comprise a crucial element of human memory – can form associated milieus which resist the communal loss of knowledge which Stiegler, following Marx but departing from conventional Marxist readings, terms 'proletarianization'. Whereas most Marxist accounts of proletarianization focus upon the transition of the rural peasantry into the urban working class, Stiegler contends that what underpins this transformation is the relationship between the worker and the product of their labour. Whereas the rural agricultural worker understood the production processes surrounding the growth of crops and their conversion into saleable goods, the urban factory worker is merely one cog in the factory machine, and so becomes alienated from the product of their labour as each worker is deprived of knowledge regarding the process of production. Stiegler argues that this knowledge becomes externalized within the machinery of the factory, which effectively becomes an exteriorized form of technocultural memory.

The emphasis on the externalization of memory denotes the continuity between Bateson and Stielger's schemata of the distributed nature of being. Where Stiegler goes beyond Bateson, however, is in his detailed delineation of the ways in which mnemotechnics entail that collective memories become subject to forms of biopolitical control, exercised by the elements within a social ecology which have control over the means of mnemotechnical production. Whereas the centralized structure of the mass media led to an industrialization of memory and the formation of a dissociated milieu in which production and consumption remained distinct activities, whereby production was only accessible for a tiny socioeconomic elite, Stiegler (2010b: 83 emphasis in original) contends that contemporary digital technologies point towards a pivotal change in this dynamic as digital technologies enable the collaborative construction of communal knowledge and memory. Here the Self-Repair Manifesto's point that repair 'makes consumers into contributors' would appear to be emblematic of Stiegler's arguments surrounding an economy of contribution and the formation of collectivized forms of exterior memory.

However, as we have seen, the digital age far from guarantees the end of the separation between producers and consumers, especially when we look beyond content towards systems of software and hardware. Indeed, when comparing the reparability of devices, the move towards ultra-portable thin client devices such as tablets and smartphones, sealed units designed not to be disassembled by end users, demonstrates a further loss of knowledge when we consider our understandings of, and ability to maintain, the mnemotechnical devices which accompany us through life. Viewed in this way, digital technologies may not present the end of the era of dissociated milieus as Stiegler suggests but their intensification. Alternatively, while sites

like iFixit may enable a technologically literate elite to repair their devices, this could become another minority lifestyle choice, whereby a handful of geeks can feel good about their ethical repair-based activities, but the vast majority of humans simply keep consuming black-boxed devices at an increasing pace.

iFixit does, however, demonstrate that there are ways of combatting attempts to remove the communal knowledge to maintain and repair microelectronics hardware which involve leveraging the cooperative and communicative affordances of networked digital technologies. We again see the merit in Stiegler's demarcation of technology as pharmakon, simultaneously poison and cure, as the technologies whose design veers towards planned obsolescence and a raft of negative consequences that permeate across the three ecologies are also the means by which a distributed community is able to collaboratively produce a common resource which addresses issues surrounding planned obsolescence and proletarianization. Such a pharmacological approach precludes Stiegler's position from becoming a simple claim for the revolutionary positive effects of digital technologies, as, while he clearly acknowledges the potential formation of associated milieus which produce an economy of contribution and an ethic of care, this must always be contrasted with the toxic reterritorializations which accompany such possibilities.

An alternative, though related, method for redressing the problematics associated with planned obsolescence is found in the open-source hardware (OSH) movement. Also referred to as open hardware and open design, the OSH movement is based around the principles of free and open-source software. A working definition of OSH, derived from the Open Source Initiative's definition of open-source software explicates that 'Open Source Hardware is a term for tangible artefacts – machines, devices, or other physical things – whose design has been released to the public in such a way that anyone can make, modify, distribute, and use those things' (OSHW 2011). A crucial point regarding OSH, then, is that the blueprints for making hardware are freely and publicly available, with the licence granting users the freedom to utilize and alter designs.

The emphasis on design is paramount, because by opening up the way products are made to innovation over distributed networks of users via the internet, OSH implements a methodology of creating rivalrous, physical objects along similar lines to those by which non-rival FOSS are created. Importantly, this signifies a shift in the form of production where peer production presents an alternative to market-based production. Goods are described as rivalrous assets if their material embodiment prevents them from being simultaneously used by multiple parties. For example, if I am using your digital camera, then you cannot simultaneously be using the same device elsewhere. Consequently, we can be conceptualized as rivals

to use the device, whose distribution is governed by scarcity. By contrast, informational goods, such as ideas, languages and affects, tend to be non-rival, insofar as any number of people can simultaneously access words and thoughts without the originals being depleted.

Crucially, the advent of networked digital computers with vast amounts of storage space altered the status of certain kinds of information from rivalrous to non-rival goods, so long as certain preconditions are met (Benkler 2006: 85–6). Whereas copying a vinyl record to an audio cassette tape entailed degrading the quality of information, copying music between computers produces duplicates that are indiscernible from the original, at virtually zero cost, due to the proliferation of high-capacity digital storage devices. The materiality of computational technology does not, however, equate to immateriality; the specific material capacities of digital computers afford lossless copying and storing vast quantities of data on ever-smaller devices. Furthermore, the networked nature of twenty-first-century computing technologies afford the ability to share information across massive distributed peer-to-peer networks, entailing that information can be shared among millions of peers rather than relying upon face-to-face interaction.

While the internet provides a relatively straightforward method of copying and distributing various forms of content and software, this mode of digital translation does not initially appear to apply to hardware; physical objects such as washing machines, computers and cars remain rival resources, which cannot be translated into binary code. Until the early part of the twenty-first century, this difference was perceived as sufficiently critical to prevent the emergence of an open hardware movement paralleling the FOSS movement:

> Because copying hardware is so hard, the question of whether we're allowed to do it is not vitally important. I see no social imperative for free hardware designs like the imperative for free software. Freedom to copy software is an important right because it is easy now – any computer user can do it. Freedom to copy hardware is not as important, because copying hardware is hard to do. Present-day chip and board fabrication technology resembles the printing press. Copying hardware is as difficult as copying books was in the age of the printing press, or more so. So the ethical issue of copying hardware is more like the ethical issue of copying books 50 years ago, than like the issue of copying software today. (Stallman 1999)

Where OSH intervenes is not the physical act of copying hardware, but the process of designing hardware. By making the blueprints for various types of device openly available for anyone with a networked digital computer to peruse, download, examine and modify, OSH presents an alternative to the

'manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years' (Von Hippel 2005: 1).

One device developed subsequent to Stallman's contention that OSH is untenable with contemporary technologies, and whose popularity and versatility suggests otherwise, is the Arduino. Launched in 2005, Arduino is an open-source, electronic microcontroller which consists of a CPU, memory, circuit board and inputs/outputs whose precise specifications depend on the particular kit. Arduinos are programmed via a Universal Serial Bus (USB) port, which is connected to a personal computer, using the Arduino programming language, which is based upon Wiring, an open-source programming framework for microcontrollers. The low cost of the board – about $35 for a basic Arduino branded kit[11] – ensures that economic barriers to entry are minimal for individuals who already have access to a computer and network connection. The hardware designs are issued under a Creative Commons licence, and the software used to interface with the device is issued under an open-source GPL licence.

The growing Arduino community has used the versatile microcontroller for projects from robotics to electronic textiles, controlling art installations to creating inexpensive MIDI outputs for accordions. Looking just at Arduino user-community-developed innovations with a specific focus on environmental themes, there are numerous systems whose designs are now available for others to use or modify. These include Open Energy Monitor, a project aiming to develop open-source systems for energy monitoring, control and analysis, alongside tools designed to increase energy efficiency and promote the usage of distributed renewable micro-generation. Like many FOSS projects, a large OSH project such as the Open Energy Monitor brings together a geographically distributed group of developers, who can allocate tasks in a modular fashion, allowing tasks to be divided among the distributed community (Benkler 2006; Holland, O'Donnell and Bennett 2010). The Open Energy Monitor project itself consists of a modular array of sensors, displays, microcomputers (which act as data servers) and EmonCMS, a custom-built open-source content management system which logs, processes and visualizes the data collected by the Open Energy Monitor system.

Gardenbot is another Arduino-based project that aims to affect environmental sustainability. Users embed sensors in their garden, enabling Gardenbot to 'show you charts of the conditions in your garden – so you can see the world the way your plants see it' (Freuh 2010). This highlights that sensor systems can make nonhuman perspectives visible in ways that are designed to mobilize practices of caring for nonhumans. By making

[11]But as an OSH device there are community-designed alternatives based on the original schematic which can be found for or less.

the perspective of plants tangible, we can act in ways designed to enhance their well-being. There exist numerous other Arduino-based systems geared towards building environmentally conscious technology, such as self-powering systems to enable solar panels to track sunlight, systems to increase battery life through monitoring sleep/standby functions, systems for monitoring water usage to help reduce unnecessary water wastage, and self-watering gardening systems which sense when soil is dry and then irrigates arid areas. The diverse range and scope of peer-produced commons-based hardware projects emanating from the nascent but growing Arduino community demonstrates the viability of OSH projects.

Utilizing low-cost technology alongside open design and licensing, these projects provide ecologically beneficial, user-generated systems available to anyone with the requisite technicity, whose designs are freely available for others to innovate with and build upon. Advocates have suggested that the OSH movement therefore presents a possible starting point for an alternative to industrial hardware production. Whereas profit-driven corporations have an economic imperative to produce goods designed to become rapidly obsolescent, OSH can be designed in a modular manner, geared towards extending the duration of usage, user/producers are not typically interested in having to regularly replace hardware. These differences are part of what Bauwens (2009) describes as the positive externalities of commons-based peer production, which contrasts sharply with the negative externalities of late-capitalist production, whereby, as we have seen, detrimental effects are frequently externalized onto workers or the environment.

An important difference between FOSS and OSH remains the fact that whereas FOSS is generally available for no economic cost OSH requires users to purchase the materials to assemble the hardware.[12] It should be noted, however, that in manufacture-centric production systems, the end user pays for the cost of materials, in addition to the intellectual endeavour in designing and patenting the product. Additionally, many OSH projects, such as the Open Source Washing Machine – an OSH project which uses an Arduino to create a low-cost, low-energy washing machine for people currently unable to afford a commercial device – are designed to use recycled or low-cost, readily availability materials in order to prevent the cost of materials from becoming prohibitive. However, current practices, where users purchase the materials for assembly, do present material barriers to participation in OSH communities in addition to the requirements of access to a networked computer.

One OSH project which sought to reduce or remove this material barrier to access is RepRap. Initiated by Adrian Bowyer of the University of Bath

[12]Or purchase a pre-built kit as with the example of the Arduino.

in 2005, RepRap – a contraction of (self)Replicating Rapid Prototyping machine – is an open-source device issued under the GPL licence, which aims to create a machine capable of constructing the necessary parts to produce a working copy of itself; a self-replicating machine. While self-replicating machines have been theorized since the early days of cybernetics (Von Neumann 1966), the RepRap project provides a practical example of an OSH project which not only is designed to generate replacement parts so the machine can repair itself, but could afford individuals and communities the capacity to manufacture a wide number of items, using either custom-made designs or pre-made open source patterns, including additional RepRap machines. Consequently, much of the hype surrounding RepRap and related 3D printing technologies has invoked the replicator found in Star Trek, a device capable of producing any desired object, which in its most utopian accounts can act as a panacea for material scarcity.

RepRap is built around an Arduino circuit board, and the device uses a process called Fused Filament Fabrication (FFF), a form of 3D printing, to manufacture objects from blueprints created using open-source CAD software. The FFF process involves printing an object using layers of thermoplastics, with the object being built up in three dimensions over a short period of time. The most commonly used materials for FFF are acrylonitrile butadiene styrene (ABS), a petroleum-derived plastic, and poly lactic acid (PLA), a biodegradable material produced from cornstarch or sugar cane. Although ABS has a higher melting point and tensile strength, PLA has the advantages of not being produced from fossil fuels or contributing to global crisis of non-biodegradable petroleum-derived plastics (Michaels 2013: 43). Immediately, we see that there are potentials pitfalls as well as positive outcomes associated with 3D printing. Depending upon the specific materials used, this can transform fossilized prehistoric life into 'disposable' objects that have afterlives measured in millennia, as they slowly degrade into microplastics that attract persistent organic pollutants, become ingested by organisms and which mimic hormones and so disrupt their endocrine systems. Which materials are employed matters when it comes to the ecological impacts of technologies.

The first 3D printers were produced in the 1980s; however, as recently as 2007, the cheapest commercial 3D printer cost over £12,500 (Sells 2009). The open source approach pioneered by RepRap was pivotal to the introduction of low-cost 3D printers, with the 2009 edition of RepRap, the Mendel, costing between just £400 and £500. Around this time, a number of affordable, consumer-orientated pre-assembled 3D printing kits were released, including the MakerBot and Ultimaker, both of which were inspired by the RepRap and whose designs were originally released under open source or Creative Commons licences. While purchasing standalone pre-built 3D printers has proved to be a far more popular route for making consumer-level 3D printers than RepRap's community-building

self-replicating machines, in 2018, the legacy of the RepRap's commons-orientated approach can be seen in top-selling 3D printers such as the Original Prusa i3 continuing to use open-source designs.

By re-inventing the manufacturing process as a system which could be almost infinitely customizable yet maintained from front rooms, RepRap and 3D printers provide a glimpse of an alternative model of production to centralized, manufacturer-centric systems that have dominated industrial production since the 1800s. This model that has been described as fully automated luxury communism (Frase 2016), whereby automation is able to increasingly replace the necessity of labour, thereby allowing humans to spend their time caring for others and the environment instead of working. While a distributed community of peers producing physical objects using self-replicating machines may sound like a utopian fantasy, RepRap and Arduino demonstrate that the contemporary technocultural milieu affords commons-based peer production of physical objects that potentially form a bifurcation from a model of industrial production. It would, however, provide an empirically dubious teleology to simply proscribe progression from an environmentally and socially destructive model of consumer capitalism to cybercommunism predicated upon commons-based peer production. If the OSH movement is to succeed in revolutionizing the model of production, it will do so via multiple pathways through dynamic complex social structures filled with uncertainty at every step. Indeed, Chris Anderson's (2012) depiction of the maker movement as a force which heralds a new industrial revolution predicated upon invention enabled by the affordances of networked computing, 3D printing technologies and entrepreneurial business models demonstrates one avenue through which the radical potential of OSH is currently being reterritorialized and reintegrated into neoliberal capitalism.

The degree of product customization and individualization of goods afforded by 3D printing technologies can be understood to embody the neoliberal celebration of unique individual consumers, and the maker movement enables the development of micro-entrepreneurial ventures which will potentially provide immense material gains for a miniscule elite comprised of well-educated, technologically adept, business savvy individuals. Equally, as Greenfield (2017) astutely notes, economies of scale currently produce consumer goods at such low prices, that it is hard to see 3D printers being able to economically compete with mass-produced products anytime soon. Additionally, the use of fossil-fuel-derived thermoplastics in some 3D printing contributes to ecological harms in very tangible ways that illustrate that this new design paradigm is not intrinsically environmentally benign. As we have seen elsewhere, we can envision futures whereby pharmacological elements of existing technocultural systems lead to collectivized, ecologically inflected notions of resilience and growth, while these same technologies simultaneously contain alternatives tendencies

which see atomized consumerism, overconsumption and the reduction of growth to economic profitability continue to dominate technocultural assemblages.

Externalized harms and feedback

Surveying the ecological impacts associated with the life cycle of microelectronics hardware reveals that far from being predicated upon dematerialization or virtuality, the networked digital economy is entangled with the globalized systems of contemporary capitalism. As we have seen, contemporaneous practices surrounding mining, factory labour and e-waste frequently involve the systemic externalization of harms onto communities and ecosystems in impoverished areas far from the affluent districts where digital technologies are predominantly used. Addressing the ecological costs of microelectronics requires a thoughtful consideration of the ethical questions raised by current practices. A liberal ethics based on the Rawlsian notion of justice and rights-based discourse would undoubtedly criticize contemporary labour practices that depend upon enormous material inequalities and which involve workers – frequently including children – poisoning themselves for scant financial recompense. However, as we saw in Chapter 2, deontological approaches are poorly situated to address the commensurability of benefits to humans and harms to nonhumans. Consequently, an ecological approach to ethics has been posited here as a way of approaching the ecological costs of microelectronics hardware.

Within this context, ethics moves from considering 'good' and 'bad' acts based upon essentialized morals to contingent and contextual truths which are actualized within material assemblages. This does not mean eschewing differences between good and bad acts, but relating ethics to ethology and the affective and material coupling between assemblages. Resultantly, an ecological ethics pertains to practical transformations, to ways that actions bring the dynamic relations constitutive of an ecological assemblage into composition with those of other beings and networks, with positive actions augmenting the agential and affective capabilities of actors, whereas negative actions reduce them. Undoubtedly, the deleterious practices we have encountered throughout the life cycle of digital technologies reduce the capabilities of differing forms and scales of actors, including individual workers poisoned by treating e-waste, local ecosystems ravaged by open-cast mining and the net contribution to climate change that arises from the energy costs of producing hardware and powering server farms and the Internet of things. Crucial to ecological ethics, then, is the move from focusing on human subjects to considering entangled relations between human and nonhuman actors.

When considering methods to address these problems via mobilizing political action, Guattari (2000: 120) contends,

> The ecological crisis can be traced to a more general crisis of the social, political and existential. The problem involves a type of revolution of mentalities whereby they cease investing in a certain kind of development, based on a productivism that has lost all human finality. Thus the issue returns with insistence: how do we change mentalities, how do we reinvent social practices that would give back to humanity – if it ever had it – a sense of responsibility, not only for its own survival, but equally for the future of all life on the planet, for animal and vegetable species, likewise for incorporeal species such as music, the arts, cinema, the relation with time, love and compassion for others, the feeling of fusion at the heart of cosmos?

This highlights the importance of altering mental ecologies via engaging with systems of distributed cognition. An ecological ethic, then, does not consider the material implications of digital media ecologies to be separate from economies of attention and modes of subjectivity, it contends that only by reconfiguring attention and subjectivity across multiple entangled scales can these issued be substantively addressed.

When searching for modes of activity to reduce these ecological harms, several promising avenues arise from mobilizing attention towards the current ecological costs of ICTs achieved by utilizing ICTs. The surge in global attention towards Foxconn and Apple regarding working conditions in Shenzhen led to concrete improvements to the lives of workers. Similarly, Huisman et al.'s (2008) claims that the WEEE directive's impact could be vastly enhanced by increasing consumer awareness demonstrate that communicative action that highlights the material impacts of microelectronics can be a useful strategy in mitigating certain ecological costs – so long as this goes beyond mere awareness raising to provide forms of collective action such as lobbying for legislative action or enacting boycotts. The examples of iFixit and Fairphone provide further evidence whereby the technologies which are currently associated with a range of detrimental practices and impacts are leveraged in order to provide novel outcomes that are designed to mitigate these impacts.

Citizen-led activism directed at raising awareness and altering corporate actions through voluntary corporate social responsibility ventures is, however, unlikely to ever rival the efficacy of enforceable national and international legislation, especially within the context of communicative capitalism. Indeed, devolving responsibility onto consumer groups and the conscience of corporations effectively abdicates collective democratic responsibility to the market. The success of the European Union's RoHS directive in removing many of the most toxic substances that were previously

ubiquitously found in digital devices demonstrates that large-scale collective actions enacted by states or groups of states that regulate entire industries rather than individual corporations can significantly address harmful practices by prohibiting them. This kind of large-scale collective action to protect human and nonhuman systems is essential to dealing with the globalized issues that have been the focus of this chapter; however, as Dodd-Frank 1502 and WEEE delineate, legislation must be capable of being enforced and supported by those it is designed to defend.

A further area where harms can be minimized surrounds innovation in the design process. Designing products that do not contain hazardous substances, which can be easily and safely recycled, which are built to last, and modular in composition, can substantially reduce ecological costs associated with the life cycle of ICTs. RoHS presents an example of design-orientated legislative change which has significantly impacted upon microelectronics production practices, having effectively eliminated the usage of some of the most toxic materials that were previously ubiquitous within digital devices. Design has particular utility insofar as it presents a way of not only addressing problematics which arise at the various component stages of microelectronics life cycles, but altering the structure of the process itself. That said, we should be wary of design-centric solutions, such as elements of the cradle-to-cradle approach, whereby the detrimental impacts of contemporary technoculture can simply be written off as a case of poor design, rather than anything to do with political structures, legislation and discourse. Here, focusing upon design becomes a way of cancelling attention to politics, asking us to explore social and ecological problems via a perspective drawn from engineering that problematically assigns itself a veil of political neutrality which disguises its technocratic ideology.

The cradle-to-cradle movement and OSH communities gesture towards potential future methods of creating hardware in ways which reduce or remedy many of the detrimental ecological impacts incurred by contemporary practices, particularly those surrounding planned and perceived obsolescence. Indeed, the shift from a consumer-based mass-manufacturing system to the distributed peer-to-peer architecture of OSH is one way of transitioning from a system of commodification to an economy of contribution. OSH provides a particularly pertinent example, as it provides evidence whereby the mode of distributed, peer-to-peer production which originated with free software and is claimed by information exceptionalists to relate solely to non-rival goods, is applied to rivalrous goods ranging from washing machines to 3D printers. Additionally, by providing open access to design-related data, OSH resists the struggle against the loss of communal knowledge of how to create and sustain sociotechnical systems which otherwise become the intellectual property of multinational corporations, whose economic interest is to produce information without knowledge: the contemporary situation

of information excess accompanied by a lack of awareness regarding the detrimental ecological impacts of digital infrastructures.

Both the formation of the peer-to-peer networks which comprise OSH communities and the strategies for utilizing networked digital telecommunications to garner attention and raise awareness of issues surrounding the ecological costs of ICTs, highlight the pharmacological context of contemporary technics, whereby the devices which ostensibly are the causes of these detrimental ecological impacts, simultaneously present the most promising pathways to alleviating these same problems. It is worth contrasting this picture, whereby activists utilize the very tools they are campaigning to change, with Audre Lorde's (1984: 112) famous statement that 'the master's tools will never dismantle the master's house. They may allow us temporarily to beat him at his own game, but they will never enable us to bring about genuine change.' Within the contemporary context, it becomes unclear as to how campaigns could effectively avoid using tools connected to the flows of matter and energy that comprise globalized capitalism. Even if such actions were viable, they would require segregating oneself to such a degree that the types of communicative and organizational strategies which are effective at reducing negative impacts would be impossible.

One of the central concepts explored within Chapter 2's delineation of an ecological onto-epistemology was the nonlinear impacts of feedback within complex systems. The examples explored within this chapter suggest that meaningful feedback regarding the ecological costs and ethical implications of current practices surrounding the life cycle of hardware are largely lacking from contemporary systems of digital media. Would people knowingly discard functional microelectronics if they realized the ecological costs involved in their production, energy usage and disposal? How would behaviour change if people better understood, or more directly felt, the impacts of their actions? While digital media systems have greatly enhanced systems of feedback and connectivity surrounding many facets of people's lives, particularly regarding informational flows, there exists a distinct lack of feedback and systemic understanding with regard to the material consequences of our mediated actions, of how these actions always go beyond 'virtuality' in connecting with multiple and complex flows of energy and matter deeply embedded in the systems of globalized capitalism. Part of this discrepancy in feedback, visibility and attention relates to the communicative capacity of the agents involved: whereas we receive an avalanche of information about celebrities, friends, co-workers and acquaintances that are preferentially connected within our social networks, impoverished workers, poisoned fish and carbon dioxide molecules all lack the capacity to garner attention.

6

Enacting change across digital media ecologies

This book has explored entanglement in contemporary digital media ecologies, focusing upon flows of energy, matter, information, data, code and attention. Doing so marks a departure from approaches that employ the term 'media ecology' as a metaphor, either to denote environmental concern or to examine the existence of a cultural ecology distinct from 'natural' ecology. The three preceding chapters have in turn explored content, software and hardware within media assemblages. The act of separating these areas echoes the approach to scale found within the science of ecology which explores flows of energy and matter within and between individuals, populations and communities, and the homologous approach to mental, social and environmental ecologies advocated by Bateson and Guattari.

This approach has allowed certain factors specific to each scale to be examined, as well as demarcating particular ways that information, code and hardware cannot be understood in isolation from one another. However, the danger is that this method could be taken as presenting content, code and hardware as autonomous phenomena that can be examined as discrete levels rather than entangled meshworks. Consequently, this concluding chapter begins by presenting two examples which draw together particular strands that have been explored individually over the course of the preceding three chapters. This is designed to further entrench the sense of inseparability across these apertures, before I move on to present some conclusions which assemble some common threads surrounding digital media ecologies.

Phone story

Phone Story is a game developed for use on touchscreen devices using the Android or iOS mobile platforms by Molleindustria, an Italian collective

of artists, programmers and designers who produce video games to foster critical perspectives on globalized capitalism:

> Games are an integral part of the global cultural industry, and they are in a strategic position in the ongoing processes of media convergence. These developments inhibit the political and artistic emancipation of this medium: every code line is written for the profit of a big corporation. … We can free videogames from the 'dictatorship of entertainment', using them instead to describe pressing social needs, and to express our feelings or ideas just as we do in other forms of art. (Molleindustria 2011)

Phone Story takes the player through a series of events that highlight ecological impacts associated with mobile phones. The initial scenario, focused on extraction, sees the player controlling armed militiamen at a coltan mine, tasked with coercing prisoner-of-war child labourers who exhibit weariness to continue working. Next, the player controls a mobile suicide-prevention net and is charged with catching workers jumping off the roof of an electronics factory. The third level sees players throwing phones to consumers, while the narration discusses the manufacture of desire, before the final encounter sees the player take on the role of impoverished e-waste workers, sorting materials into separate piles of circuit boards, copper wires, glass and screens, while the voice-over discusses the fact that the majority of mobile devices will end up being exported and dismantled in ways that are deleterious to worker health and local environments. If at any stage the player fails to complete the task in hand, they are greeted with a screen informing them: 'Don't pretend you are not complicit' in the actions they are being asked to perform.

The game is solely playable on mobile devices, thereby reminding users that they are implicated in the events experienced via the game world through their ownership and physical connection to a device whose problematic material construction is explicated in the content. This demonstrates a powerful way of implicating the user in events, exhibiting one way to realize the mode of politicized configuration outlined by Moulthrop, in which ludic action presents insights into complex contemporaneous globalized systems. The way in which the game – a form of software – uses a combination of narrative and ludic modes – what we conventionally term 'content' and 'form' – to reconfigure users' understanding surrounding the ecological costs of hardware and their subjective relationships with technological devices demonstrates how contemporary media experiences can tie together ethical and political concerns through indicating how users, content, software and hardware form media assemblages where social inequity and environmental degradation are rife. Indeed, what makes Phone Story a pertinent example is how it demonstrates entanglement across scales of content, software and hardware, making connections visible and tangible to the user, who is

situated within this assemblage through their complicity in the game world whose content depicts the real-world harms associated with the smartphone they are using to play the game.

Four days after its release, Apple banned Phone Story from their App Store, contending that the application breached four developer guidelines. Two transgressions pertained to objectionable content and depicting violence towards children. The fact that this objectionable content regards the production of the hardware used to play the game is irrelevant; in the highly controlled Apple App Store, there is no place for satirical critique which examines the detrimental impacts of technology or questions current levels of consumption. The other two broken guidelines relate to the application's donations to charities, with Apple's guidelines forbidding the collection of charitable donations through any means other than the Safari web browser or SMS, and forbidding apps which allow donations to charitable organizations to incur an economic cost. Phone Story does not allow users to make donations; however, Molleindustria pledged to donate all funds received from the one-dollar cost of the application (minus the App Store fee of 30 per cent) to charities who raise awareness of issues explored in the application, with the initial recipient being SACOM, an NGO whose campaigning focuses upon labour rights abuses within the microelectronics industry.

Apple's decision to ban Phone Story from the App Store created a story which was covered by mainstream print media (Dredge 2011), online technology centred publications such as *Wired* (Brown 2011) and *PcWorld* (Mack 2011) and numerous blogs, entailing that Apple's decision to censor the application resulted in the generation of a significant volume of attention for Phone Story and its themes surrounding the ecological costs of IT, alongside the authoritarian manner in which Apple polices content within its App Store. Apple's censorship ironically resulted in achieving Phone Story's aims, as the story regarding Apple's decision to exclude the App focused more attention and awareness towards these issues than had the game simply existed within the long tail distribution of the two million apps within Apple's store.

Phone Story, then, presents a case which exhibits how issues pertaining to content, software and hardware are not distinct, but form an entangled media ecosystem. This also demonstrates how engaging with the ethics and politics of architectures of software and hardware can build systemic and configurative awareness, locating user actions and agencies within the complex globalized flows of contemporary systems of production and consumption. Ecological costs and ethical issues surrounding software and hardware are often best illustrated by forms of mediated content, which raise awareness, garner attention and mobilize action via the creation of systemic awareness of these issues. However, while Phone Story provides a useful example which delineates scalar entanglement and configurative

awareness, creating a performative engagement whereby the power structures surrounding modes of production reveal themselves via the user's explorative and configurative engagement with content, its impacts largely end at raising awareness. Although $0.70 raised by each sale of the app is donated to SACOM, this revenue would be highly unlikely to meaningfully alter the exploitative systems of production the game depicts. The issue may then be that although users are enraged by their complicity with these systems through their smartphone ownership, there is no obvious outlet for practical political action designed to affect this situation.

We frequently become overloaded with affectively powerful images representing social and environmental crises from around the globe in our social media feeds, on the news and elsewhere. War, famine, natural disasters, drone strikes, climate change, exploitation, child soldiers and countless other crises seem to be all around us, and all too often we are left feeling powerless to impact any of these issues and can easily fall into apathy and defeatism. As per Dean's critique of communicative capitalism, which was discussed in Chapter 3, mediated systems need to go beyond just raising awareness, instead empowering users to take action.

Open Source Ecology

The Open Source Ecology (OSE) project is an example which attempts to translate awareness into action. Founded by Marcin Jakubowski, a physicist turned farmer, in 2003, OSE aims to create the Global Village Construction Set (GVCS): 'a modular, DIY, low-cost, high-performance platform that allows for the easy fabrication of the fifty different Industrial Machines that it takes to build a small, sustainable civilization with modern comforts' (OSE 2017). The GVCS is composed of OSH designs for machines varying from tractors and compressed earth brick presses to 3D printers, CNC-precision multimachines and automobiles. The machines are designed to be modular, cheap to construct, easy to maintain and repair, and built to last rather than designed to become rapidly obsolete, which as we saw in Chapter 5 are hallmarks of OSH.

By 2018, OSE had created functional prototypes of about one-third of the GVCS, including a tractor, hydraulic power unit, laser cutter, brick press and CNC torch table. The OSE team work and live at the Factor E Farm, located near Kansas City, United States, and are supported by a distributed network of volunteers, some of whom attend dedicated project visits, assisting with prototyping and manufacturing, infrastructure, and agricultural production (the farm is a working sustainable farm using the GVCS machines). The GVCS prototypes designed thus far demonstrate significant economic and ecological savings over commonly deployed industrial alternatives. Whereas a commercially available tractor and compressed earth brick press would

retail between US$40,000 and US$55,000 apiece, the OSE versions cost around US$4,000 apiece (OSE 2018). For each machine, OSE releases design rationale, 3D CAD files, 2D fabrication drawings, exploded part diagrams, circuit diagrams, control codes for automated devices, scaling calculations, the physics of why the device works, and cost and performance comparisons to contemporary industry standard machines, entailing that other engineers or interested amateurs can copy, share, alter and improve their designs. The documentation is all published online, allowing a distributed audience to access and interface with their work, and to become participants in the process of creating and refining the GVCS.

This further demonstrates how software and hardware form an entangled meshwork for OSH projects; without the connectivity afforded by the internet, this type of distributed peer-to-peer collaboration would be impossible, relegating the scope of the project from collaboratively designing the GVCS with a distributed community and sharing their work with a global audience, to a group of talented individuals working on a project by themselves or with a small-scale network of personally known collaborators, and whose results would only be accessible to this limited network. The fact that the design information, which is crucial to the dissemination of the project, exists as varying forms of content ranging from video documentation to 3D CAD files also demonstrates how sharing content over the networks of hardware and software which compose the internet is key to the viability of the project. Hardware, software and content do not exist separately to another, but function within a triadic relationship whereby without any one of these scales, the entire project would effectively fail to function.

Furthermore, the way in which the project has been funded again highlights entanglement between content, software and hardware. OSE is financially sustained through crowdfunding, both carried out through their own website and via a campaign on the crowdfunding website Kickstarter in 2011, which raised over US$63,000 from 1300 contributors. By using various forms of media content, housed on software platforms including their own website, the Kickstarter website and Vimeo, which are in turn predicated upon a vast and spatially distributed hardware infrastructure, OSE not only communicates the existence of its projects to a distributed audience, and builds a distributed community of like-minded people to work on the GVCS projects, but additionally raises the capital required for the project to sustain itself by leveraging these digital technologies and their affordances.

Where OSE goes somewhat further than Phone Story is in implementing an ecological praxis through producing systems whereby supporters can become involved in contributing towards a project, which if successful presents an eco-ethical alternative to contemporaneous forms of industrial production. In addition to contributing financially towards the project, supporter/participants can get involved through volunteering on dedicated

project visits at the farm; contributing technical expertise towards the prototyping and fabrication processes; assisting with project management; peer-reviewing designs; programming and coding elements of the scalable open-source product development platform; creating documentation for each of the designs and for the overall project (including tasks such as distributed off-site video editing); composing artwork animations and other design assets; and contributing to the OSE website's forums and wikis. This allows people with a diverse set of skills and experiences to become actively involved in the project, and, indeed, the potential success of OSE is dependent upon a network of individuals being able to competently accomplish these varied goals and outputs.

Rather than simply critiquing existing processes – encouraging people to feel guilty about behaviours and consumptive practices without a means of addressing them – OSE provides opportunities for individuals to create the world they would like to inhabit, with these opportunities encompassing the entangled scales of hardware, software and content. Consequently, the potential problematic associated with the awareness-raising strategy of Phone Story – that while people attain insight into the materialities of their technology, they feel powerless to intervene in ways which create positive change – is negated by means of encouraging interested parties to become participants in the process of building ethically orientated alternatives. Indeed, without the collaborative efforts of a distributed community in the design, prototyping, refinement, documentation, funding and publicity surrounding OSE and the GVCS, the project itself would present a near-insurmountable challenge for the core team. As a result, OSE exemplifies two thematics which have been central to this book: first, the way that the domains of hardware, software and content, which are often approached as separate and bounded wholes in fact compose entangled assemblages, and, second, projects which resonate with the ethics and politics that media ecology proposes require forms of praxis that not only encourage understanding and raise awareness of issues but additionally mobilize actions designed to enact positive changes across technocultural systems.

Critical instabilities and lines of flight

Understanding digital media as open, complex ecosystems has been pivotal to the methodology I have outlined. This is not merely the deployment of metaphors to draw analogies between ecological and technical systems, but an exploration of how media systems are nonlinear dynamic systems that are dependent upon external flows of human attention, (primarily electrical) energy, and matter in order to continue sustaining themselves. Without access to these flows, media ecologies would wither and die, just as ecosystems would perish if severed from the flows of solar energy, water and nutrients

required for their primary producers (plants) to photosynthesize. Detailed analysis of the assemblages and entanglements which compose media systems allows us to explore the conditions necessary for, or conducive to, emergence, and considering these conditions and their specificities allows us to better understand the dynamics of media systems and their capacities to enact changes across various ecological registers.

Entanglement and synthesis must not, however, be understood as meaning that anything goes. Indeed, one of the difficulties presented when working with themes of emergence and complexity are that these tropes are frequently applied without sufficient rigour or conceptual clarity, invoking a macro-reductionism via vague invocations that the interplay of determining forces at work cannot be fully understood within open dynamical systems. For media ecology, the concept of the assemblage, which rejects both macro- and micro-reductionisms is therefore useful in mapping of the entanglement of lines, forces, vectors and affects which constitute media systems.

Using the language and insights gleaned from complexity theory, media ecology is interested in exploring the topography of attractors and bifurcations which determine the trajectories of technocultural systems in non-teleological ways. This mapping of potentiality constitutes the understanding of probabilistic conditions of emergence, asking us to consider questions in terms of points of bifurcations and critical instabilities, moments of flux where there exist temporal openings for a line of flight to take a system into a new attractor state. This raises questions, both in terms of how to recognize such bifurcation points and in terms of what kinds of organizations and infrastructures are necessary to leverage them. A pertinent example here may again be the 2007/8 global financial crisis, where neoliberal models of capitalism were shaken by the thoroughgoing failure of global financial markets to self-organize, but a lack of credible alternative political and economic practices saw a retrenchment of neoliberal ideologies and continuing widespread successes for political parties who had wrongly placed their faith in the ability of financial markets to regulate themselves.[1] Rather than bemoaning this as a missed opportunity, we must ask why this moment of critical instability was followed by the rise of a politics of austerity and increasing economic inequality rather than a reversal of failed market-led policies? What structures were lacking to prevent the left from effectively forming lines of flight?

On the one hand, we may point to what theorists such as Jameson, Zizek and Mark Fisher (2009) have referred to as success of globalized capitalism

[1]While this is partially contested by the rise of supposedly anti-establishment right-wing populist nationalisms as witnessed by the success of the Brexit and Trump campaigns in 2016, we should remind ourselves that the political parties which headed these campaigns, the US Republican Party and the UK Conservative Party are the traditional bastions of neoliberalism.

in fostering a worldview that argues that there is no alternative to the status quo, that it has become easier to envisage the end of the world (or at least of human civilization and a large proportion of other presently existing life forms) than the end of capitalism. This rather monolithic approach to capitalism contrasts with what Gibson-Graham (2006) describe as a post-capitalist politics that contests the totalizing nature of the imagined global capitalist system, instead focusing upon how we inhabit a hybrid economy where alongside for-profit, private and market-based solutions there exist a wide gamut of alternative and non-market practices. This includes gifting, sharing, public (state or local government-based) ownership, co-operatives, familial networks, domestic (household) work and other practices, a list to which we may usefully add creative commons-licensed content, FOSS-licensed software and open-source hardware as modes of commons-based peer-to-peer production that are prominent within digital cultures. From this perspective, there exist a multiplicity of non-capitalist modes of ownership and organization which we encounter throughout everyday life. Thus, it is less a case of having to articulate a wholly new vision of a post-capitalist economy, so much as recognizing the latent potential within the diverse political and economic models active within contemporary hybrid economies.

The logic of the AND resonates with this articulation of non-teleological alternative political and economic models existing as latent capacities within current technocultural assemblages but which additionally expounds that such tendencies are frequently reterritorialized and reintegrated into dominant systems over time. As we have seen within the registers of content, software and hardware, it is wrong to assume some form of opposition to the market or neoliberalism is necessarily embedded within non-market systems. Examples such as corporate open-source software implementations, the entrepreneurial maker movement and the abilities of social media platforms and viral marketing companies to monetize user-generated content exemplify how within each practice there exists a multiplicity of pharmacological possibilities. Consequently, I have some concerns over following Gibson-Graham in labelling these practices as post-capitalist; while they undoubtedly could help bring forth a more ecologically, economically and socially just and equitable non-capitalist society, the ever-present potential for reterritorialization makes a departure from capitalism far from inevitable. In some cases, such as the corporate exploitation of free labour, they may simply usher in novel forms of exploitation and precarity.

Understanding media as material technocultural systems with varying geological, geographical and ecological histories re-connects 'cultural' ecology to 'natural' ecology, revealing that in fact they are one and the same material-discursive system, whose separation presents an epistemological error which gives rise to ill-founded notions of virtuality and immateriality. As Parikka (2015a: 34) explicates, contemporary media systems are

responsible for the global consumption of 'thirty-six percent of all tin, twenty-five percent of cobalt, fifteen percent of palladium, fifteen percent of silver, nine percent of gold, two percent of copper and one percent of aluminium'. We could add to that list numerous other materials whose primary contemporary usages are within the global microelectronics and optoelectronics industries such as tantalum, europium, erbium and neodymium. Consequently, any serious inquiry into the power relations associated with contemporary processes of mediation must go beyond the realm of symbolic representation and reception in order to engage with the materiality of technocultural infrastructures if they are to conduct a realistic appraisal of how digital media are entangled with the globalized flows of contemporary capitalism.

It is precisely this enormous mobilization of matter on a planetary scale which Parikka describes as revealing the alternative deep time of the media, one which departs from Siegfried Zielinski's work into cyclical patterns of invention and discovery, instead exploring the geology, geography and ecology of the nonhuman actants which form contemporary media assemblages. The process of literally unearthing vast volumes of materials which have accumulated in deposits strewn around the globe over hundreds of millions of years and deploying them to construct the material-discursive systems which underpin the contemporary attention economy should be contextually situated within the politics of speed of the Anthropocene: a new geological epoch in which technocultural activity is understood as a defining departure from the planetary conditions of the Holocene. Anthropogenic impacts can already be seen in atmospheric greenhouse gas concentrations, the deposition of radioactive nuclides from nuclear weapons, the production of hundreds of millions of tonnes on non-biodegradable technical materials and a species extinction rate which is 100 to1,000 times the background level, a rate of change only present during planetary mass-extinction events. While such mass-extinction events occur at infrequent intervals throughout the geological record, with five such extinction events occurring in the previous 540 million years, the fact that technocultural actions are now causing a sixth requires urgent political mobilization according to any notional form of ecological ethics and politics.

Ecological praxis

Feedback was one of the key concepts that arose from exploring cybernetics as one of the genealogical predecessors to ecology and complexity theory. With regard to contemporary digital media ecologies, questions surrounding feedback were particularly pertinent within the scale of content. Habermasian and Frankfurt-school critiques of mass media centred upon ways that media inhibited communication between participants, instead amplifying

the voices of powerful economic actors, entrenching the ideologies of the ruling class. The internet, however, has at face value dramatically altered this situation, allowing huge numbers of actors previously excluded from mediated discourse to engage in discussions, leading to claims surrounding the democratization of communication and the formation of a postmodern public sphere in which informed citizens would debate issues as equals within the global space afforded by digital information and communication technologies. This process correlates to a form of feedback, whereby citizens are able to interrupt and re-orientate discourse within mediated systems via participatory processes erstwhile absent from mediated communications.

As we saw in Chapter 3, while it is correct to emphasize that the internet has allowed vast numbers of people to engage in mediated discursive structures, it is erroneous to imply that the removal of barriers to access equates to creating equal participants within communicative systems. There exist various new forms of hierarchy within contemporaneous media systems, notably those surrounding attention, cultural capital and technicity, which have been accompanied by the introduction of practices such as astroturfing, trading up the chain and search engine optimization which currently ensure that privileged actors maintain a high degree of prominence in digital discourses. Indeed, as we have seen, network effects create power-law distributions in scale-free networks, systems in which hierarchy rather than equity is a powerful tendency which structures and reterritorializes digital spaces which cyber-utopians erroneously expected to form a rhizomatic realm of democratic debate and deliberation.

With regard to content, systemic feedback has dramatically increased, in both volume and depth, with co-creative media such as social media platforms affording online debate at increasing speeds, with thousands of responses emerging within hours of stories breaking. These changes have seen information move from being a scarce and valuable commodity to the circulatory system of communicative capitalism in which we are often warned of information overload. The same, however, cannot be said concerning relationships between feedback and the scales of hardware and software. Whereas technological infrastructures have been tremendously enlarged and complexified, affording information processing and algorithmic manipulation at greatly increased speeds, this has not been accompanied by a corresponding rise in systemic understandings of the material impacts of technology. Detrimental impacts throughout the life cycle of information-processing technologies are routinely externalized onto impoverished areas, nations and ecosystems, far removed from the affluent urban areas where the technologies are primarily utilized, entailing that these costs remain out of sight and out of mind for most consumers. Similarly, at the scale of software there is a marked lack of feedback with regard to what practices of algorithmic filtering, surveillance, data capture and protocological control are in place. Users are often unaware to whom they have given private data,

how that data is being used to generate profits, how the information they receive has been filtered by complex personalization algorithms or how these systems attempt to predict behaviours in order to be able to nudge them in particular directions.

Creating active and aware, media-literate citizens require such processes to be made visible, allowing users to better understand the impacts of the digital footprints they leave. This in turn raises questions pertaining to the formation of effective aesthetic and affective strategies for implicating users within media systems, in order to provide feedback upon mediated actions. As we have seen, many of the most promising pathways for addressing these problematics highlight what Stiegler describes as the pharmacological context of contemporary technics, whereby the digital devices which ostensibly create these negative ecological impacts simultaneously present the most promising pathways to remedying these same problems.

Digital literacy is not, however, enough to guarantee positive outcomes for societies and ecosystems. Numerous entities encountered across the book, from algorithmic trading companies to fossil-fuel lobbyists, from public relations firms to climate sceptics are among the most digitally literate actors. The issue is that they employ this literacy to benefit themselves to the detriment of social and ecological justice. Understanding media as open and dynamic ecosystems has become an increasingly popular approach as media moved from the seemingly closed and fixed objects of the broadcast era to open systems such as Facebook, Twitter and Instagram, which depend upon a constant stream of co-creative user activity. While applying understandings of dynamical systems to such media projects can prove useful in maximizing efficiency, increasing popularity and enhancing profitability, media ecology additionally requires the development of an ecological ethics and politics which emphasizes mobilizing actions designed to build equity, commons and mutualisms rather than competitive individualism and economic efficiency.

Normative ethics – whether deontological or consequentialist – refers to the value structures by which individuals and societies come to enact moral decisions, questions pertaining to rights and wrongs. Adopting a Deleuzo-Guattarian position departs from the universal notions of rights and wrongs present within deontological ethics, instead presenting ethics as a question relating to contextual continuums:

> Good has no more sense than Evil: in Nature there is neither Good nor Evil. … But because there is no Good or Evil, this does not mean all distinctions vanish. There is no Good or Evil in Nature, but there are good and bad things for each existing mode. … As Nietzsche put it, '*beyond good and evil* … at least this does not mean "beyond good and bad"'. … The distinction between good things and bad provides the basis for a real ethical difference, which we must substitute for a false moral opposition. (emphasis in original; Deleuze 1992a: 253/254)

This provides a perspective in which good and bad exist not as abstracted essences or moral values but as contingent truths dependent upon the particular forms and consistencies of the matter in hand. Consequently, ethics pertain to the ways that actions bring 'the relations constitutive of the agent into "composition" with the relations constitutive of another being' (Butler 2008: 141), with good acts being those which augment agential capabilities – such as symbiosis and mutualism – while bad acts reduce the capacities or relations of the agents.

Given the current forecasts for the Anthropocene, an ecological ethics emphasizes the urgent need for modifying current practices. As Cubitt (2005: 59) astutely observes, 'Techne is the only route through which we can now sense the world, most especially the part of the world's conversations which are not conducted in wavelengths we can hear, see or otherwise comprehend.' Without contemporary information-processing technologies, humans would not have sufficiently developed understandings of looming ecological crises to enact urgent calls to action. This is exemplified by the fact that when considering climatic trends, we are addressing global datasets with durations measured in decades and centuries – a temporal scale far slower and a spatial scale far larger than those readily perceptible to humans.

We can only understand climate change via technological mediations which allow us to see enduring trends within noisy, chaotic and complex global climatic systems. This technocultural assemblage includes satellites that measure tropospheric temperatures, thermal drills that can extract 3-kilometre-deep ice cores from polar regions and the storage facilities that preserves these geological artefacts, and the supercomputers that are used to simulate climatic futures. Ecological ethics, then, must not advocate abandoning mediation and technology as a means of retreating to a romanticized past but instead requires reorienting modes of production and consumption towards ecologically beneficial outcomes. Only through repurposing technics along ecological lines – creating commonwealth rather than commodities – are potential solutions to ecological crises likely to become visible; there exists no option to return to a pre-industrial state before technics supposedly altered the harmonious 'balance of nature', as is commonly suggested by conservationist and deep ecological discourses.

Applying such an ethics to contemporary media practices means considering the ways in which media systems at varying scales create novel connections and forms of commons and public good, and at the same time involve the usage of energy and materials which close off other avenues via their ecological costs. Ecological ethics is based on praxis rather than pure reason, encouraging experimentation and creative interventions designed to produce positive biopolitical impacts. It entails realizing that while there are detrimental consequences stemming from currently produced technologies, there are bifurcation points whereby the agential capacities of assemblages afford meaningful positive changes to be made to these systems by using the

offending technologies. This is not hypocrisy, but does require a praxis that abandons an idealistic purity.

At the level of content, this means exploring how information flows have created the commodified economy of attention, problematic discourses of Big Data and the context of communicative capitalism, while investigating how ideology, cognitive frames and cognitive dissonance act as brakes which prevent subjects from altering opinions and effecting change. At the level of software, this entails considering issues surrounding licensing, software development and the types of freedom maintained by the free software movement, alongside issues surrounding surveillance, user privacy and the contemporary movement towards the commodification of web protocols as evidenced within HTML5. Within the realm of hardware, this involves examining the flows of energy and matter which comprise and maintain the physical architecture of the network society, considering the material impacts that these flows have on ecological systems at every stage in the life cycle of microelectronics devices. Across all scales this additionally requires an examination of the multiple ways that powerful actors seek to utilize existing and novel hierarchies to perpetuate privileged positions and technocultural systems that are currently leading us towards social and ecological catastrophe.

Media ecology suggests that an experimental praxis with various commons-orientated projects across the scales of content, software and hardware is necessary if ecologically resilient and equitable alternatives are to supplant current practices of mediation. While openness is often proclaimed to be the defining characteristic of commons-based peer-to-peer systems, media ecology follows Bauwens in arguing that openness alone is not enough to guarantee ecologically beneficial outcomes. Alongside openness, projects require commitments to social solidarity and ecological resilience if they are to escape reterritorialization.

Rather than an abstract mode of thought, ecological ethics emphasizes embodied acts of engagement as a method of becoming-ethical. Praxis additionally forms a model which resists contemporary processes of proletarianization, which sees knowledge becomes embodied within technologies, constituting an industrialization of memory and the externalization of communal knowledge into corporate technics. Without some degree of knowledge and experience regarding the complex and distributed processes of mediation which are increasingly central to contemporary life, we have little agency to affect and alter these assemblages along eco-ethical lines. Ecological ethics contends that such knowledge is derived from material practices rather than abstract speculation; following Deleuze, we do not know what a digital assemblage can do, but through experimentation we can produce forms and practices that can help to realize change. 'Make a rhizome. But you don't know what you can make a rhizome with, you don't know which subterranean stem is effectively going to make

a rhizome, or enter a becoming, people your desert. So experiment' (Deleuze and Guattari 1982: 277). We cannot exhaustively know the capacities of systems in advance of this practical activity, so the process of activism, of creating projects, itself opens up points of critical instability and forms lines of flight that can lead to more equitable and resilient futures.

This does not, however, imply that such knowledge leads to mastery and control. Indeed, a basic comprehension of complex systems entails realizing that unilateral control is impossible. Unlike humanist accounts of agency which relegate technics and nature to the status of Cartesian automata, systems which are teleologically bound to particular pathways, media ecology contends that agency is a distributed property, existing throughout assemblages, rather than being an innate quality applying to one particular type of node. While forms of agency differ between varying types of actor, the diverse examples explored in this text have tried to elucidate numerous ways that nonhuman actants realize differential forms of agency.

Understanding the multiplicity of nonhuman agencies at play in technological systems – those associated with algorithms, codecs, file formats, operating systems, minerals, metals and energy supplies – has been posited as key to understanding ways that these ensembles, along with humans, work together to form media ecologies. Improving our understandings of the media systems we are entangled with entails comprehending various forms of nonhuman agency, how they manifest and what kinds of selection pressures they apply to the evolution of technical ensembles. Stiegler's account of the human as being fundamentally defined by its co-evolutionary relationships with technologies, which form an exteriorized mode of distributed and collective memory is useful here, insofar as it reminds us that 'we' do not exist outside of our technical support systems and suggests that the varying agencies which technologies mobilize produce divergent ethical and political imperatives. This goes beyond claims that 'technology is society made durable' (Latour 1990), which suggests that society precedes technology (which allows the former to endure), rather than there being a mutually constitutive co-evolution of technology and society.

The appraisal of the positive potentials of complexity theory and nonlinear dynamics to inform a media ecology where social and ecological justice are major components denotes a significant departure from Dean's (2013: 153) claim that

> invocations of complexity induce us, the people, to think that self-governance is impossible, too hard, over our heads. It's like an excuse for avoiding responsibility, an infantile fantasy that somehow we can escape politics. Global networks, neural networks, financial networks – if it's all just too complex for us to understand we are left off the hook for our abdication of political responsibility (no wonder the education system has been left to rot; no wonder higher education is a major front

> of political struggle – the more people believe the lie of 'too complex to understand', the more they concede). Unfortunately, academics contribute to the ideological effects of complexity. We emphasize that there is always more that needs to be known, that there are unknown unknowns and unintended consequences of whatever it is that we end up doing. Complexity's tagging of the multiplicity of interrelated and unpredictable effects presents us as so deeply enmeshed in our situations that we can't assess them; we can only react, and just in time, in a 24/7 ever faster market.

Contrary to Dean's claims, grasping complexity is precisely what allows for probabilistic claims to be made at scales that escape the chaotic unpredictability of short-term noise. I cannot claim to know precisely when high-frequency algorithmic trading will next assist in the formation of a flash crash, but the systemic instability that algorithmic trading introduces entails that they will continue producing such events. Similar arguments can be made for the difference between the unpredictability of the weather (short-term noise) and the probabilities of catastrophic climate change. The point is not that short-term noise makes long-term prediction impossible and should therefore lead to inaction, but that despite the inescapable uncertainties produced by short-term noise, complexity theory allows for precisely the kinds of longer-term predictions that are needed if we are look beyond the immediate horizon of 24/7 capitalism.

The focus on specificity, detail, nuance and complexity that has characterized the multi-scale assemblages of content, code and hardware that have been explored in Part 2 should not be read through Dean's aperture of being too complex to understand, but as resisting the proletarianization that externalizes and commodifies knowledge. My argument has been not that specificity mandates inaction but that to assess which kinds of actions are likely to be beneficial for particular circumstances, we require a nuanced grasp of both the problems at hand and the weapons that can address them. Emphasizing dynamism and complexity requires that solutions will always be contingent, partial and open to reterritorializations, but abandoning the reductive and utopian dream of the single glorious revolution that resolves all social and ecological strife everywhere, forevermore, does not mean abandoning a struggle for social and ecological justice through multiple molecular revolutions. At the same time, the chaos and uncertainty that are produced by noise within complex systems should also be read as a way of resisting the type of systemic stasis that accompanies the central claims of capitalist realism; that there is no alternative to the inhuman system of technocratic financial markets and venture capitalist funded tech start-ups that 'innovate' around exploitative models of digital labour. Rather than providing a justification for conservative inaction, uncertainty should be a

call to arms for experimentation and action, of finding lines of flight that forge more equitable and resilient technocultures.

A biopolitics for the Anthropocene

Delineating an ecological ethic, a value system which presents an alternative to economic determinism, cannot by itself mobilize action. For this to occur, what is required is the transition from ethics to politics, in this case from an ecological ethics to a biopolitics that approximates Hardt and Negri's definition of the term; as both the production of the conditions for life, affects and the interactions of bodies, alongside the manner by which biopolitical production produces new forms of subjectivity that resist strategies of control. The emphasis on a politics concerned with ecological relationships and affects generates relations between humans, technical and organic entities which gestures towards futures which are rooted in contemporaneous modes of biopolitical control but escape the shackles of capitalist realism. As Cubitt adeptly argues (2005: 137):

> Why do people give power to Exxon Mobil? We cannot blame Exxon for exercising what we seem to so freely donate. … The political issue is not how to get wealth and power from the rich and powerful as if they were objects they could own. Money and influence are systemic qualities – money is communication, power is communication, not things that can be owned. What generates wealth? The ecosystem and the work that ordinary people do on it. We have to learn to stop giving our money away to nodes of the network where it is amassed, where it stops circulating, stops communicating. It is not a question of taking money away from the wealthy: it is about stopping giving it to them day after day after day. Ditto power and ditto mediation.

The question for a post-capitalist ecopolitics of media, then, surrounds how to construct assemblages which re-route flows of communication, power and wealth away from commodities and towards resilient forms of commonwealth and public good that are designed with ecological and social justice in mind.

Many of the examples presented within this book outline groups and communities building open access, commonwealth-related systems based on peer-to-peer models of organization, forging models of production that offer avenues for recuperating aspects of the destructive, profit-orientated approaches endemic to neoliberal capitalism. Chapter 3 explored communities of scientists, computer modellers and other concerned citizens forging participatory and didactic structures to explore and explicate various

aspects of climate change, including crowdsourcing datasets pertaining to the global climate, affording others the ability to conduct their own analyses. Chapter 4 examined ways that the FOSS community have been creating and refining a software ecosystem predicated on providing open access, defending user freedoms and privacy. Chapter 5 investigated the nascent open source hardware movement, which potentially presents an alternative mode of production to economies of scale and industrial capitalism, predicated instead upon distributed peer-to-peer networks and commonwealth. These examples challenge market-based methods of production which draw clear distinctions between producers and consumers, instead resembling Stiegler's notions of associated milieus and an economy of contribution.

It would be wrong, however, to automatically assume that all commons-creating activities represent the biopolitical constitution of eco-ethical alternatives to neoliberalism. As the successful open source strategies of multinational corporations such as Google, IBM and Microsoft demonstrate, informational exceptionalism and digital commons can prove a useful revenue generating resource for market actors. Indeed, capitalism has always relied on expropriating commonwealth, both 'natural resources' such as land, metals and water alongside cultural commons such as language, ideas and knowledge in order to function. As ever, there remains the possibility that attempts to create autonomous peer-to-peer networks will be subject to reterritorializations which reabsorb such energies into the flows of global capitalism.

Of course, commons-based production is far from new, as Gibson-Graham and others have gone to great lengths to demonstrate, non-market production has always been a pivotal feature of so-called capitalist economies. However, the successes of Wikipedia, BitTorrent, Arduino and other commons-based peer-to-peer systems are worth foregrounding as cases that challenge the dogma of markets and competitive individualism, instead positing that forms of mutualism can produce economically efficient and ecologically resilient structures. Alongside discourses of the sharing economy, which herald venture capitalist backed multibillion-dollar corporate ventures such as Uber, Facebook, Kickstarter and Airbnb as the market entities which have best found ways of monetizing the productive power of distributed networks, there exist a range of commons-based organizations which are centrally concerned with social solidarity and ecological resilience, rather than exploiting precarious labour and monetizing user attention within the context of post-global financial crisis austerity politics. That said, commercial start-ups supported by millions of dollars of venture capital benefit from the fact that this financial investment is itself a significant driver of the informational traffic, which kickstarts trending activities and thus begins the consolidation process of network effects. Within current and future contestations between communal and corporate peer-to-peer systems what we see is a highly uneven field, where

corporate funding buys development time, features, and the publicity and exposure required to become the next big thing.

One critical area that shapes the nonlinear dynamics of this technocultural system comes in the form of governmental and intergovernmental regulation. As we have seen in cases such as the European Union's RoHS directive, legislation can be an effective way that democratically elected representatives can act collectively to curb some of the most socially and ecologically toxic and damaging practices which are produced by market-led drives towards increasing profits through the externalization of costs onto vulnerable humans and ecosystems. Equally, however, when we consider the current steps towards the commodification of web protocols though HTML5 and EME, we see how regulations and standards can be a way of supporting corporate enclosures. This denotes that the national and international legislation are key sites of contestation that mould the configuration of digital ecosystems. While the neoliberal mantra that markets and competition are the ideal model for driving efficiency have dominated policymaking for the past several decades, the resurgence of democratic socialist discourse as evidenced by the rise of the Jeremy Corbyn-led Labour Party in the United Kingdom, Podemos in Spain and Bernie Sanders in the United States suggests that the era of neoliberal hegemony may be drawing to a close. If so, this may afford a regulatory environment in which state support for cooperative, commons-based digital systems may flourish while the most antisocial and ecologically destructive elements of digital capitalism are curbed.

Such a call for national and international legislative activity to support a twenty-first-century digital commons is a clear departure from the anti-statist strategy of exodus that Hardt and Negri (2000) posit. However, examples such as RoHS and the Montreal Protocol (which enacted a global moratorium on CFCs, thereby halting and eventually reversing the destruction of Earth's ozone layer) demonstrate that global, regional and national legislative actions are needed alongside activist endeavours if we are to address the crises of the Anthropocene. There is a need not for top down or bottom up action, but for actions that take place across many scales, working from the middle outwards, top down and bottom up. Effective legislation requires pressure from activists, NGOs, academics and citizens accompanied by electoral success in removing neoliberal governments. Applying the logic of the AND to biopolitics entails adopting many tools and techniques to address ecological crises from many angles.

While the agencies of digital technoculture afford activists new tools and technologies to work with, and powerful tools at that, it must be remembered that they still inhabit political and technocultural fields marked by huge inequalities with regard to mobilizing resources. Crowdsourcing and distributed systems of peers have reduced these inequalities in some important ways, particularly in terms of barriers to access, and the ability

to form geographically dispersed networks, but in many other capacities, activist groups currently struggle to compete with multimillion-dollar marketing, lobbying, research and developmental budgets.

Although there currently exists a range of commons-based practices across software, content and hardware, they are frequently confined to the margins of mediated activity, largely being practised by particular hacker/geek/tech-activist networks that have problematic affinities with the white, male geek culture of Silicon Valley-styled capitalism. For positive action to match the terror-inducing scale of ecological crises forecast within the Anthropocene, these projects must grow from seeds into vibrant assemblages, moving from their current position at the margins of neoliberal consumer culture towards preferentially attached positions. Such a project involves the construction of a very different digital media ecology to the current model, one that values commons over commodities, equity over inequalities, collectives over a misplaced focus upon individuals and resilience over the toxic short-termism of digital colonialism and platform capitalism.

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