Darwin and Reductionisms:
Victorian, Neo-Darwinian and Postgenomic Biologies[1]

Angelique Richardson

> At the present time there is hardly any question in biology of more importance than this of the nature and causes of variability
>
> (Charles Darwin, 1880)[2]

In cultural studies biology tends to be viewed as deterministic, bearing little relation to environmental factors. In this article I argue that this was not necessarily so for the Victorians, but that reductive thought and practice which emphasised determinism developed in the second half of the nineteenth century in response to a number of social and scientific factors. Separating organism from environment, it focused on a biology divorced from social and historical context and was informed by rising concern over urban poverty, degeneration, and imperial rivalries and by a newly professionalised and institutionalised science. I argue that in rejecting biology as deterministic and emphasising fluidity, postgenomic biology recapitulates a Victorian insight.

Reductionism in science, much like reductionism outside science, simplifies. It can be ontological, epistemological, and methodological. In science it is often a powerful and necessary method which seeks to isolate and control phenomena in order to explain them.[3] But it can fall into ideology, especially in the context of human behaviour. Stumbling at complexity, it may seek to explain higher-level processes (e.g., adaptation, adultery or addiction) by lower-level processes (e.g. heredity, molecular biology, genes), or seek to bring essentialist concepts (e.g. biological sex) to indeterminate social processes (e.g. map reading).[4] Reductionism, as method or as ideology, and sometimes as both, seeks to explain the complex, the whole, or the interactive or dynamic according to the simple, the part, or the linear or unidirectional. Reductionism is usually deterministic, allowing little possibility for individual agency or choice. Where, exceptionally, determinism acknowledges complexity, or competing or converging causes, and does not seek to explain the higher by lower, complex by simple, it is not inherently reductive. In *The Disorder of Things* (1993) John Dupré observes the connections between reductionism, determinism and essentialism as the three pillars of conventional classification,

pointing out that contexts which affect perceptions of causal relations and essences are provided by the goals of an investigation.[5] Dupré argues that reductive explanation can account for how things of a certain kind do what they do, but does not usually help to explain or predict what a complex thing will do (106).

The debates surrounding biological reductionism are wide ranging and where they relate to questions of individual freedom, race or gender they have ethical implications. The historical roots of reductionism can be seen in late nineteenth-century nature/nurture debates and in interpretations of Darwin. Victorians such as Darwin, G. H. Lewes, George Eliot and Thomas Hardy appreciated the close relations between organism and environment and valued the complexities of the natural world. They share ground with postgenomic science which emphasises the dynamic relations between world and organism, questioning traditional boundaries, rejecting essentialism, and asking new questions about what constitutes an organism.[6] Neo-Darwinism was coined as a negative term by the zoologist George Romanes - a close follower of Darwin - in *Darwin and After Darwin*, which appeared in three volumes in the 1890s. He used it to signal the departure from Darwin's views of the German zoologist August Weismann. In the *Contemporary Review* he acknowledged necessary limits to Darwinian ideas: 'mechanical the Darwinian theory unquestionably is [...] and the reason why it is mechanical is because it seeks to explain biological phenomena by natural causes' and emphasised complexity: '[w]hen, for instance, we speak of "heredity" as a cause, what we mean is that in the complex and obscure physiology of generation there are a number of unknown causes at work'.[7] Through the twentieth century Neo-Darwinism invented its own story, extending a pervasively deterministic world deep into microbiology and most recently finding expression in literary studies as a gene-intensive, literary Darwinism. In *The Literary Animal* (2005) Joseph Carroll offers a reading of *Pride and Prejudice* centred on 'resources and reproduction', arguing that the ultimate regulative principle is 'inclusive fitness, the transmission of genes'.[8] Carroll argues that 'Darwinian criticism' can avoid 'the often false reductions in the postmodern conceptions of human nature' (103), but he does not address its own reductions. Literary Darwinism acknowledges some environmental influence but argues overall for deep unchanging biological imperatives, finding little scope for the cultural

specificity of roles, and claiming that literary theory fails to take account of elemental biological motives and governing principles.[9] It counters approaches over the last three decades that explore what Gillian Beer has called the 'two-way' traffic between science and literature.[10] In *Darwin's Plots* Beer argues that 'discourse can never be expunged from scientific *enquiry*',[11] but for the Neo-Darwinians discourse and representation are subordinated to genes, narratives are underpinned by reproductive drives. In his foreword to *The Literary Animal* the biologist E. O. Wilson refers to 'the dictates of our genes' (25) and argues that narrative is deterministic, a cultural expression of the genetic.

The mid Victorians were able to avoid opposition between environment and biology. Lewes remarked in 'Mr Darwin's Hypothesis' in 1868 that 'by "conditions" we are not to understand geographical or climatal influences simply, or even mainly; but the whole group of conditions, external and internal, physical, organic, and social, which determine the result.'[12] This sense of complexity is at odds with post-Weismann and early eugenist views as well as with more recent neo-Darwinian ideas. Awareness of complexity could, however, co-exist with reductive approaches that fitted the new institutionalised contexts; these approaches did not deny the impact of the environment but sought to exclude it in experimentation. The emphasis in postgenomic science on complexity and on a synthesis of nature and nurture is part of a wider resistance, perhaps, to anxieties that the human genome project would reduce life to a series of coding sequences, and to concerns over the potential of genetics for control.[13] These ideas are not in themselves new: microbial genetics developed as an area of experimental research in the 1940s and 1950s, and opened up new ways of thinking about biology. William Hayes, a leader in the field, discovered transferable genetic elements between bacteria. In his classic text book *The Genetics of Bacteria and their Viruses* (1964) he wrote 'what is inherited is not the character itself but the potentiality to express it, and [...] this potentiality may be profoundly affected by the environment to which the organism is exposed.'[14] The dynamic relations between organism and environment are now receiving new emphasis in postgenomic biology.

Neo-Darwinism reduces evolutionary development and culture to biological and deterministic principles, but somewhat paradoxically it is an idea that is now

more prevalent in literary studies. Molecular biology has become less reductionist with the new methodologies of systems biology.[15] And while evolutionary biology has moved beyond Darwin, the more complex aspects of Darwinian thought which emphasise interdependence are paralleled in postgenomic thinking.[16]

Recent historical and literary scholarship focuses on the openness and the progressive thought of the Victorian Darwin, but highlights too the diversity and contrariety of Darwinian ideas. David Amigoni, Gillian Beer, Janet Browne, Adrian Desmond, Thomas Dixon, George Levine and James Moore together give us a scientist who is scientific and sympathetic, who wonders at difference, and opposes slavery, who thinks, in Gillian Beer's phrase, in the third edition of *Darwin's Plots* (2009, 242), about 'the consciousness of others' across all forms of organic life. Darwin offers new ways of thinking about scale, about chance, about intimate interrelatedness. He provides models for observing the natural world, giving us narratives of growth and profusion, of thinking about *telos*, and progress.

But the Darwin celebrations of 2009 were, overall, less historically engaged. Steven Shapin observes that the events, focused on Darwin and his perceived present implications, marginalised the historical, taking Darwin out of his intellectual and social context and reinforcing myths.[17] Perhaps a focus - however non-reductive - on one scientist risks reductive effects, tending to reinforce single explanations and detracting from wider social and cultural influences. Of recent biographies, Janet Browne's *Charles Darwin: Voyaging* (1995) and *Charles Darwin: The Power of Place* (2002) go furthest in detailing the world in which Darwin was writing, providing a complex account of his life and work by focusing on friendship, family, and social networks as scientific arenas, and the Cambridge Darwin Correspondence Project offers invaluable insight into these networks.

I

Questions

The *Origin of Species* is expansive and unsettling. Birds sing in the bushes of an entangled bank, insects flit about, and worms crawl through the damp earth. 'It is interesting', Darwin writes, with both measure and wonder, that 'these elaborately

constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us'.[18] Darwin gives as these laws:

> Growth with Reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the external conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less-improved forms (489-90).

There is a stress on environment, on extrinsic causes. Inheritance is 'almost implied by reproduction', but nonetheless listed in its own right. The tentative distinction between the two reflects both an uncertainty but also an acknowledgement of its necessity. Inheritance was elusive. It didn't map entirely onto the process of reproduction.

Darwin's gaze was meticulous and scrutinising but for all its observation it was not without some of the biases of his contemporaries, accepting and working within conventional racial hierarchies. This drive to understand and explain everything might be seen as reductionist, at least methodologically, resonant at times with Casaubon's will to find the key to all mythologies in *Middlemarch*. But Darwin remained open and speculative, in contrast to the approach emerging in a developing, institutionalized, science. He introduced greater complexity into his work subsequent to the *Origin*, seeking explanations that did not depend on natural selection, and giving new attention to sexual selection which returns agency and choice to individuals acting in social groups. And the scrutinising gaze is tempered, countered, even, by a sense of wonder and eccentric curiosity which tends to disallow ideology. Earthworms at Down House were whistled at, the children played them music and Darwin shouted at them, to see if they could hear. Darwin records in his last publication: 'They were indifferent to shouts, if care was taken that the breath did not strike them. When placed on a table close to the keys of a piano, which was played as loudly as possible, they remained perfectly quiet.'[19] Darwin's fascination with the world, with environment - with, in one instance, the 'experience of the plants in pots'[20] - continued. In *The Formation of Vegetable Mould* (1881) he remarked, 'It may be doubted whether there are many other animals which have

played so important a part in the history of the world, as have these lowly organised creatures'.[21] The idea surprises, and recognises extensive relations between organism and environment.

Darwin asks questions, contemplates with interest, aware that the world will not yield itself fully for analysis. As complex life forms come into the world, he remarks, 'this planet has gone cycling on according to the fixed law of gravity' (*Origin*, 490); here, gravity is contrasted with the multitude of variables which lead to biological development. The world Darwin gives us is characterised by chance complexity.

II

Responses

Darwin's work was taken in various and contradictory directions by his readers. Sir John Herschel, mathematician, astronomer, chemist and philosopher, referred to natural selection as the 'law of higgledy-piggledy'[22] and the Cambridge Professor of Geology Adam Sedgwick famously wrote to him: 'There is a moral or metaphysical part of nature as well as a physical [...] You have ignored this link; &, if I do not mistake your meaning, you have done your best in one or two pregnant cases to break it.'[23]

However, the Reverend and writer Charles Kingsley wrote to Darwin in the same month:

> I have gradually learnt to see that it is just as noble a conception of Deity, to believe that he created primal forms capable of self development into all forms needful pro tempore & pro loco, as to believe that He required a fresh act of inter-vention to supply the lacunas w^{h}. he himself had made. I question whether the former be not the loftier thought.[24]

Reading the *Origin,* George Eliot wrote to Barbara Bodichon: 'to me the Development Theory and all other explanations of processes by which things came to be, produce a feeble impression compared with the mystery that lies under the processes',[25] and G. H. Lewes remarked two decades later:

> Sentiment is shocked at the attempt to explain Nature on mechanical principles only, and is sustained by Common Sense, which sees other

> facts besides facts of motion, and sees that Nature is not mechanical only. [...] When the moral impulse to cherish the weak and sickly is condemned because Nature (which is *not* moral) cherishes the strong and pitilessly destroys the weak, Common Sense protests, and the protest helps to intensify the popular distrust of Science.[26]

But, as Lewes noted, mechanistic thinking was neither exclusive to nor uniform in science: 'the wiser heads among men of science are equally alive to the mistakes of such applications' (413). In *The Descent of Man*, Darwin suggested it was both possible and desirable to improve the health of the nation through controlled breeding: 'excepting in the case of man himself, hardly any one is so ignorant as to allow his worst animals to breed', but he immediately countered this: 'Nor could we check our sympathy, if so urged by hard reason, without deterioration in the noblest part of our nature'. Sympathy, human nobility, stood in the way of reductionism.[27]

The social implications of Darwin tended in various directions, pointing further to competing aspects in his work but also suggesting ways in which interpretation of his ideas, ranging from the ennobling to the mechanistic, can be contingent on beliefs and social and political values. His cousin Francis Galton developed the idea of eugenics for 'improving stock' in humans, arguing this was 'practical Darwinism', while for the exiled Russian biologist Peter Kropotkin Darwin's ideas led to mutual aid; co-operation throughout the plant and animal world. [28] Kropotkin's *Mutual Aid: A Factor of Evolution*, which collected his essays from the 1890s in the *Nineteenth Century*, appeared in 1902. In the early twentieth century hereditarians divided into biometricians and Mendelians. The Cambridge biologist William Bateson rapidly became the leading British Mendelian, coining the term 'genetics' which, he said in 1906, 'would sufficiently indicate that our labours are devoted to the elucidation of the phenomena of heredity and variation [...] after more or less undirected wanderings, we have thus a definite aim in view.[29] As historians and sociologists have noted, Bateson dismissed aspects of Darwinism, referring to 'the utilitarian view of the building up of Species' in his *Materials for the Study of Variation* (1894), which rejected the role of natural selection in producing variation.[30] He also opposed Weismann's theory. While the

biometricians, headed by Karl Pearson and W. F. R. Weldon, acknowledged that every individual is different and environment has to be taken into account, they dealt with the complexity thus identified by inventing the techniques of what became mathematical statistics. These, they claimed, would allow reliable predictions of the characteristics of populations of individuals and hence expert control of society and its members. Challenging reductionist statistical theories, Bateson deployed Mendelism to oppose this sort of scientism.[31] He disliked the narrowly middle-class values of the eugenics movement, and feared that its success might lead to the further success of utilitarian rationalisation and modernisation.[32]

III
Uncertainties

In 1880 Darwin wrote a preface to a collection of essays on descent by the German zoologist August Weismann, flagging up uncertainty around questions of inheritance and environment:

> Several distinguished naturalists maintain with much confidence that organic beings tend to vary and to rise in the scale, independently of the conditions to which they and their progenitors have been exposed; whilst others maintain that all variation is due to such exposure, though the manner in which the environment acts is as yet quite unknown. At the present time there is hardly any question in biology of more importance than this of the nature and causes of variability. (vi)

While Weismann's ideas lent themselves to a shift towards hard-line hereditarian thought, Weismann himself was aware that organisms were extremely complex and that their environment profoundly affected them and their capacity to survive. His thinking in relation to inheritance was structured by a reductive approach at a time when science was rapidly professionalising and specialising and thought was increasingly linked to occupational roles, situations and practices. Frank Turner notes that in the later nineteenth century the professionalising efforts of the young guard of scientists who championed the empirical method - relying on observation and experiment - and claimed it as 'the exclusive foundation for legitimate science' was led 'to undermine the intellectual legitimacy of alternative modes of scientific

thought and practice'. [33] It was in part under these new conditions that emphasis was refocused on the organism itself; specialisation would be likely to lead to partial sightedness. Sometimes, this was a partial sightedness that was fully aware of the wider picture, but questions were closed down by a newly professionalised context. The developing laboratory and new technologies of observation and experiment limited the questions and connections that can be investigated with precision.[34]

Awareness of complexity could co-exist with narrowed and reductionist thinking in the more limited purview of a new, strongly bounded professional context. Weismann wrote of heredity: 'The great complexity of the subject has alone rendered it hitherto insuperable' noting that 'we certainly have not reached the limits of attainable knowledge', and it was complexity that Darwin chose to focus on in his preface to Weismann's essays.[35] In his later essay 'Remarks on Certain Problems of the Day', Weismann pointed out that his thoughts on heredity were not final but were to serve 'as a starting-point for further thought' (II, 82). He drew an analogy between the question of heredity and 'certain anatomical and physiological problems, e.g., the structure and function of the human brain. Its structure - with so many millions of nerve-fibres and nerve-cells - is of such extraordinary complexity that we might well despair of ever completely understanding it' and argued that as knowledge here might be advanced by investigating the nervous systems in lower forms: 'we should not abandon the hope of arriving at a satisfactory knowledge of the processes of heredity, if we consider the simplest processes of the lower animals as well as the more complex processes met with in the higher forms' (71-2). This assumption that the simple might provide unproblematic insight into the complex tends to reductionist thinking.

Darwin, working independently at Down House, was able to stay with questions, remarking in the *Origin*: 'The laws governing inheritance are quite unknown; no one can say why the same peculiarity in different individuals of the same species, and in individuals of different species, is sometimes inherited and sometimes not' (13). Professions of uncertainty would similarly abound in *The Effects of Cross- and Self-Fertilisation in the Vegetable Kingdom* (1876), Darwin's meticulous write-up of eleven years of detailed research through experimentation. The cause of variation is both vital and elusive. The *Origin*, G. H. Lewes remarked,

was 'the product of an immense series of tentative gropings [...] the product of long-continued though baffled research'.[36] Laws of heredity perplex George Eliot's Mr Tulliver in *The Mill on the Floss*: 'a pleasant sort o' soft woman may go on breeding you stupid lads and 'cute wenches, till it's as if the world was turned topsy-turvy. It's an uncommon puzzlin' thing'.[37] The suggestion that somehow heredity ought to be more straightforward seems here suspect, almost nonsensical.

IV
Organism and Environment

Darwin's science had greater affinity with the Victorian novelist, both in terms of method and ethos, than with a late nineteenth-century German laboratory researcher such as Weismann. In 1853, in his exposition of Comte, who he held to be 'the greatest thinker of modern times', Lewes wrote

> if Bichat had only steadily considered the indispensable *co-operation* of the medium (or surrounding circumstances in which an organization is placed) *with* the organization itself [...] he would have seen that so far from organic bodies being independent of external circumstances they became more and more dependent on them as their organization becomes higher.[38]

He defined medium as 'the whole of the surrounding circumstances necessary to the existence of the organism'. Eliot, turning over questions of inheritance and environment, shared this sense of the integral relationship between organism and environment. In 'The Natural History of German Life', her review of the first two parts of W. H. Riehl's *Naturgeschichte des Volkes* in the *Westminster Review*, she emphasises the reciprocal relations between character and environment and their centrality to development:

> The external conditions which society has inherited from the past are but the manifestation of inherited internal conditions in the human beings who compose it; the internal conditions and the external are related to each other as the organism and its medium, and development can take place only by the gradual consentaneous development of both.[39]

The emphasis on agreement, on mutual consent between organism and environment, as though both are entities with choice and agency, is striking. The model is one of dynamic interaction: the biological and the historical inscribe each

other. This, Eliot argued, was '*incarnate history*' (127, emphasis in original). Here was a manifesto against reductionism, for the historian, the scientist, and, implicitly, the novelist. Eliot emphasised that any study of 'the natural history of our social classes, especially of the small shopkeepers, artisans, and peasantry' would have to take into account their entire environment, including their relations with each other. In referring not simply to history but to natural history, she brings the present, in the form of interdependent living systems, to the past. Natural history was concerned with the whole organism, and its relation to its environment, as biology was not necessarily. Eliot describes a complex welter of relations and influences that resonates with Darwin: 'local conditions, their maxims and habits, the points of view from which they regard their religious teachers [...] the interaction of the various classes on each other, and what are the tendencies in their position towards disintegration or towards development' (112). Disintegration and development are at once biological and social terms. Eliot advances a form of development that is both natural and historical.

The questions Lewes and Eliot were turning over in the 1850s find expression in Eliot's fiction. *Middlemarch*, a sustained study of organisms in their social medium, presents us with a twenty-seven-year-old Lydgate who is determined to provide the next sequence to Bichat's work in pursuing a knowledge of living structure. Lewes saw Bichat as too exclusively focused on the organism, and Lydgate determines to go more deeply into the structure of tissue, wrongly thinking that he can shut out environment at will, doing 'good small work for Middlemarch, and great work for the world'; he is bounded by a desire to 'contribute towards enlarging the scientific, rational basis of his profession' but his science cannot proceed independently of his social environment.[40]

Cusped between his nature and his environment, Lydgate's career at this point is a 'fine subject for a betting' (140). The moment encapsulates a process central to novel writing. Possibility is unfixed, free will, tendency and circumstance are in precarious balance. Lydgate has reached a starting point 'with all the possible thwartings and furtherings of circumstance, all the niceties of inward balance, by which a man swims and makes his point or else is carried headlong' (140). In the prelude Eliot suggests an analogy between human history and science through the

terms ‘mixture’ and ‘experiment’, referring to ‘the history of man, and how the mysterious mixture behaves under the varying experiments of Time’ (3). Character is a ‘mysterious mixture’, fluid, unpredictable, but on the other hand Lydgate is marked, mottled by ‘spots of commonness’ somewhere between nature and nurture (141). He walks, Eliot tells us, ‘by hereditary habit’ (327). The phrase is significant, undercutting the sense of a determining heredity. Eliot had referred in the *Mill on the Floss* to ‘hereditary custom’ (272). Habits are not hereditary in the sense of being inevitable, but are somehow learned: they are ultimately chosen rather than given and may be thrown off.[41] For Eliot, character can be delible. Character, she emphasises in *Middlemarch*, is not fixed. ‘“My dear Mrs. Casaubon” said Mr. Farebrother, smiling gently at her ardour, “character is not cut in marble—it is not something solid and unalterable. It is something living and changing”’ (692). Eliot was familiar with Bain’s associationist ideas, in which repeated activities left pathways through the mind so that character was to an extent formed physiologically, but her fiction advances a more fluid conception of character, in dynamic relation to its social medium, with habit as educable, at least as much as hereditary.[42]

The capacity to transform habit was under scrutiny at this time. In the same year as the *Origin*, Samuel Smiles’ *Self-Help* (which had originated as a series of lectures to the Leeds Mutual Improvement Society in 1845) appeared. In one of these lectures Smiles had declared: ‘it is alleged that education would give [the working classes] aspirations to rise above their present position, and might endanger institutions now established among us, and held to be “glorious”. Welcome to all such aspirations!’[43] The work emphasised the capacity for autonomy and self-development, going against fixed hereditarian ideas of social hierarchy: ‘it may be observed how greatly the character may be strengthened and supported by the cultivation of good habits’.[44] In *Self-Help* Smiles quoted Joseph Butler: ‘“As habits belonging to the body,” he says, “are produced by external acts, so habits of the mind are produced by the execution of inward practical purposes.”’[45]

These were questions with which John Stuart Mill was engaged. In his *Autobiography* (1873) he wrote:

> In particular, I have long felt that the prevailing tendency to regard all the marked distinctions of human character as innate, and in the main indelible, and to ignore the irresistible proofs that by far the greater part of those differences, whether between individuals, races, or sexes, are such as not only might but naturally would be produced by differences in circumstances, is one of the chief hindrances to the rational treatment of great social questions and one of the greatest stumbling blocks to human improvement.[46]

It was, he thought, a tendency 'so agreeable to human indolence, as well as to conservative interests generally', that it would need to be attacked 'at the very root' (184).

V

Relations between the sciences

Eliot saw social science as comprising elements which corresponded to the 'grand and simple generalizations' of 'mathematics and physics' but noted that it had other departments which, embracing 'the conditions of social life in all their complexity [...] may be called its Biology carrying us on to innumerable special phenomena which outlie the sphere of science, and belong to Natural History' ('Natural History', 130). Figured in this way, resisting reductive specialisations, biology allowed for observation and particularity, and a means for seeing the whole organism in its habitat. For Eliot, biology, with its affinity to natural history, is more than a science, and must be if it is to account for life:

> And just as the most thorough acquaintance with physics, or chemistry, or general physiology will not enable you at once to establish the balance of life in your private vivarium, [...] so the most complete equipment of theory will not enable a statesman or a political and social reformer to adjust his measures wisely, in the absence of a special acquaintance with the section of society for which he legislates [...]. In other words, a wise social policy must be based not simply on abstract social science, but on the Natural History of social bodies. (130-1)

Here, Eliot suggests that no single science can apprehend society, each may offer some light, but it is natural history that is the most illuminating. She draws on Comte, but also diverges from him. Comte did not see the phenomena of biology as outlying the boundaries of science, arguing instead that they obeyed a law

of higher complexity.[47] Eliot resists Comte's hierarchy of the sciences which viewed social science as the most complex, following on from astronomy, physics, chemistry, and biology, instead taking social science outside science, and turns to natural history to open up a space for biology and social science that allows for indeterminacy.

Lewes is illuminating here. He wrote in his exposition of Comte that 'all phenomena of life [are] more complex than chemical or physical phenomenon, and hence less easily reduced to simple laws' (*Comte's Philosophy of the Sciences*, 164). He went on to quote Comte: 'if anyone will turn to the section on Organic Chemistry, and consider the arguments which force a repudiation of the encroachment of Chemistry into the proper domain of Biology, he will see how irresistibly they apply to this encroachment of Biology into Psychology' (211); each science was limited. In *Popular Science Monthly* he observed that each science 'is restricted to its own class of facts, none can legislate for others'.[48] Eliot was concerned to distinguish between the sciences, pointing also to their limitations: 'Biology embraces phenomena which are not explicable by Chemistry; and no biological generalization will enable us to predict the infinite specialities produced by the complexity of vital conditions' (130). The argument foreshadows Karl Popper's statement, as part of a wider critique of reductionism in his Medawar Lecture, 'A New Interpretation of Darwinism' (1986), that biochemistry is not reducible to chemistry.[49] The neurobiologist Steven Rose, in his challenge to reductionism, *Lifelines: Biology, Freedom, Determinism*, notes: 'whatever the case may be for the properties of physical and chemical systems, the nature of evolutionary and developmental processes in biology means that there is no such necessary primacy [of lower orders]' (93); 'every level of organization of the universe has its own meanings, which disappear at lower levels' (296). That which may appear intrinsic can usually be seen to have at least some extrinsic aspect. Rose argues that the new genetics has fuelled the reductionist argument of neurogenetic determinism which argues for a directly causal relationship between gene and behaviour - what has come to be seen as the 'genes for' idea[50] - and emphasises that 'living systems are by definition open ones'; 'a living organism cannot exist independently from its environment, with its constant interchange of energy and

information, threats and promises' (95).

The close-knittedness of organism and environment, of insides and outsides, is integral to the Victorian realist novel. Characters move in a bulky social milieu of events, gossip, stories, and other people, very few of which are immediately predictable. Only the author knows what is going to happen, and he or she can equally decide in favour of something else happening. If character were fixed and determined by biology most novels would be very short, indeed there would likely be no need for such environmental stimuli as novels. And characters that are impervious to circumstance, to others, to the world around them, do not make for page turners. Even Emile Zola's characters, seemingly in thrall to heredity, find themselves in relentless environments. Fiction at a formal level tends to present a challenge to the idea of character as biologically produced and determined, elaborately detailing conditions necessary to existence. As he prepared his novels for the Macmillan 1912 Wessex Edition, Hardy gave them a retrospective classification, designating the first and pre-eminent group, the 'novels of character and environment'. The earliest of the nine works grouped in this category was *Under the Greenwood Tree* (1872); it would be another three years before Darwin first used the term. He wrote in the second edition of *The Variation of Animals and Plants under Domestication* (1875) '[I]f it profited a plant to inhabit a humid instead of an arid station, a fitting change in its constitution might possibly result from the direct action of the environment.'[51] In the first edition he had referred to a plant having to be 'modified so as to become fitted to inhabit' an altered station; this was now reformulated, with the environment gaining a more active role.[52] Herbert Spencer popularised the term, referring in his *Principles of Psychology* (1855) to 'the division of the environment into two halves, soil and air'.[53] The idea of environment entered biological discourse, having the precise meaning of influences which could act on and determine the development of an organism or character, and offered resistance to reductionist hereditarian explanations. All Hardy's novels explore to varying degrees the individual unfolding in, chafing against, thriving or wilting in their environment. Jude the Obscure is eventually overwhelmed by his, but Donald Farfrae effects changes in his, and thrives. *The Woodlanders*, rustling with trees, explores implicit and explicit analogies between humans and other life forms. Grace

Melbury, uprooted from her environment, loses something of herself. Hardy's novels of character and environment share the purview of all novels which explore the relation between character and world. In this way, the novelist and the Darwinian biologist share a common interest in external influences, including social relations, on the development of life.

VI

Eclipse of the Environment

So how did we get from an enworlded sense of development to reductive neo-Darwinism - or what Steven Rose refers to as Ultra-Darwinism - the idea of the organism isolated from environment? Even the British zoologist Ray Lankester, in the profoundly deterministic *Degeneration: A Chapter in Darwinism* (1880), related his pessimistic model of development to environment: 'Degeneration may be defined as a gradual change of the structure in which the organism becomes adapted to less varied and less complex conditions of life [...] Any new set of conditions occurring to an animal which render its food and safety very easily attained, seem to lead as a rule to Degeneration'.[54] But in the 1880s, rising concern over urban poverty, degeneration, and imperial rivalries, drove changing perceptions of human nature. Heredity came to be seen as playing a more decisive part as increasingly troubling social questions were displaced onto the biological. A concomitant focus on the organism, divorced from environmental concerns, was privileged in a new professional context. Weismann dismissed the effects of Lamarckian use or disuse and the inheritance of any acquired characteristics, delivering a dramatic challenge to environmental influence. Lewes had remarked of Lamarck:

> naturalists before his time had been wont to consider the Organism apart from the Medium in which it existed; he clearly saw that vital phenomena depended on the relation of the two; but in his hypothesis he sacrificed the one factor somewhat to the other; he paid too little regard to the Organism and its laws of development.[55]

Darwin increasingly made use of Lamarck's idea of acquired characteristics in successive issues of the *Origin*. Weismann's work veered in the other direction, providing a resolute argument in favour of nature over nurture, and suggesting a decisive break with past conceptions:

> the substance of the germ-cells [...] transfers its hereditary tendencies from generation to generation, at first unchanged, and always uninfluenced in any corresponding manner, by that which happens during the life of the individual which bears it [...] if these ideas [...] be correct, all our ideas upon the transformation of species require thorough modification, for the whole principle of evolution by means of exercise (use and disuse), as proposed by Lamarck, and accepted in some cases by Darwin, entirely collapses.[56]

Germ-plasm – which bore the factors determining the transmission of characters – was apparently isolated from the body of the organism that carried it, and was transmitted unchanged from generation to generation. The matter which controlled heredity simply passed through the organism, without contributions from the somatic cells, and apparently impervious to environmental influence. Weismann declared, 'it is impossible to imagine any way in which the transmission of changes, produced by the direct action of external forces upon the somatic cells, can be brought about' (80). Organism and environment were cut off from each other. 'The germ-plasm is the essential part of the germ-cell, and determines the nature of the individual that arises from it' reported Grant Allen in the *Academy*.[57] The role of culture in this narrative of evolutionary development was redundant.

Conditions for the reception of Weismann's ideas were as favourable as they were for their production. Even Hardy records 'dipping into' them in 1890.[58] There were other perspectives. Alfred Wallace, for example, developed the idea of cultural evolution and saw human progress as largely independent of natural selection, but this proved less popular.[59] The degrading effects of slum life and factory work, and the conditions of the poor, were receiving sensational coverage in such articles as 'How the Poor Live' by George Sims, which became a regular feature of *The Pictorial World,* and these fuelled fears of degeneration. The journalist and eugenist Arnold White, who published his first explorations of the poor in *The Problems of a Great City* (1886), wrote in *Empire and Efficiency* (1901) of 'street-bred brains' and 'country-born labourers in the prime of life' becoming 'white-faced workmen living in courts and alleys'. He warned that 'the Empire will not be maintained by a nation of out-patients' and that 'the marriage of destitute and sickly minors is a fruitful recruiting-ground for the unfit.'[60] 'London. Four Million forlorn hopes!' wrote Hardy in his diary in 1889.[61] In a chapter called 'Pathological', in *The Nether World*,

George Gissing remarks of Clara Hewett:

> you must try to understand this girl of the people, with her unfortunate endowment of brains and defect of tenderness [...] like a creature that is beset by unrelenting forces, she summoned and surveyed all the craft faculties lurking in the dark places of her nature.[62]

Like the characters that inhabit it, this urban world is diseased, as the chapter title suggests; it is biologically determined and seems incapable of improvement.[63] The depiction of the poor in these biologistic terms continued. In Jack London's more sympathetic *People of the Abyss* (1903), a term Wells employed in his *Anticipations of the Reactions of Mechanical and Scientific Progress Upon Human Life and Thought*, the poor are: 'a new species, a breed of city savages.'[64] The brutalising effects of poverty in cities were made unavoidably obvious. Hereditarian thought, which refused environmental influence, held that environment itself could be explained by biology.

Weismann shows awareness of the effects of environment, but these are downplayed in his laboratory experiments.

> abundant nourishment can make the body large and strong, but can never make a giant out of the germ-cell destined to become a dwarf. Unhealthy sedentary habits or insufficient nourishment makes the factory-hand pale and stunted; life on board ship with plenty of exercise and sea air, gives the sailor bodily strength and a tanned skin; but when once the resemblance to father or mother, or to both, is established in the germ-cell it can never be effaced, let the habit of life be what it will (*Essays upon Heredity*, 102).

There was resistance both within and outside the scientific community. In *The Biological Problem of Today: Preformation or Epigenesis?* (1896) the zoologist Oscar Hertwig referred to Weismann's doctrine of determinants as 'a closed system, finding within itself a formal explanation of all development'.[65] It was, he argued 'an abandonment of explanation rather than an explanation; for it explains by sign and tokens that elude verification and experiment, and that cannot encounter concrete investigation' (140). Hertwig defined epigenesis as the doctrine that the formation of a new individual was not simply the outgrowing of particles in the egg-cell, but the result of 'moulding external forces' (143). In his introduction to Hertwig's study the zoologist Peter Chalmers Mitchell wrote, 'we are only at the beginning of inquiry into the problems of heredity' (xiv).

Weismann's hard-line hereditarian approach would continue into the twentieth century, finding expression, for example, in *The Bell Curve* (1994), the work of the psychologist Richard J. Hernstein and the political scientist Charles Murray. Franz Boas, the Columbia anthropologist, mounted a sustained attack on eugenics and argued that IQ tests were affected by education and social and cultural environment, and in *The Mismeasure of Man* (1981) Stephen Jay Gould disputed E.O. Wilson's claims that certain traits were universal in humans.[66] Further resistance to hereditarianism from within the scientific community came from Barbara McClintock, the 1983 Nobel Laureate,[67] and the geneticist Richard Lewontin, who opposes genetic determinism and its expression in sociobiology and evolutionary psychology.[68]

VII

Interdependencies

In 1910 Hardy, who referred to himself as one of the earlier acclaimers of the *Origin*, observed:

> Few people seem to perceive fully as yet that the most far-reaching consequence of the establishment of the common origin of all species, is ethical; that it logically involved a readjustment of altruistic morals by enlarging as a *necessity of rightness* the application of what has been called "The Golden Rule" beyond the area of mere mankind to that of the whole animal kingdom. Possibly Darwin himself did not wholly perceive it, though he alluded to it.[69]

New research in biology emphasises intersubjectivity, not just between humans but between species. The biologists Frans de Waal, Marc Bekoff and Jessica Pierce demonstrate that nature can be a source of value, a network of empathy, trust, and reciprocity.[70] Postgenomic thinking shares ground with the dynamic Darwinian model of interaction, arguing that organisms have a constructive role in relation to their environment. Postgenomic biologists working on genes and environment in relation to race, and who are involved in the politics of health equality, include Esteban González Burchard, a medical doctor specialising in genetic epidemiology, and Rick Kittles, who researches issues surrounding race, genetic ancestry and health disparities.[71] Postgenomic science evidences a world that is probabilistic

rather than deterministic and emphasises the centrality of social relations to evolutionary development. John Dupré and Barry Barnes write that 'it could still be that our inclination to identify the essence of ourselves with what is written in our genomes would greatly diminish if we chose to reflect more deeply on our social life' and 'the interaction with others in which it consists'.[72]

Popper argued for 'active Darwinism', which saw the living organism as helping to determine its own fate by modifying its environment to meet its needs, and Lewontin writes against one of the central concepts of neo-Darwinism, the idea that an organism does not influence but merely fits its environment.[73] This is one of the most fertile questions in evolutionary biology.[74] Recent research reinforces the idea that gene expression is influenced by early environment.[75] For twenty-first-century postgenomic biologists, life is no longer understood in terms of fixed taxonomies or essences, but as a dynamic world of various microbial combinations. The dynamic world of postgenomic biology, resonant with the interconnected world of the mid-Victorians, rejects the traditional dichotomy between nature and nurture, and recognises the centrality of cooperation to life forms (seen in its most extreme form in mutualistic symbiosis). Using the term 'the politics of life' to contrast the present with Foucault's politics of health in the eighteenth century, the sociologist Nikolas Rose argues that contemporary biopolitics is not defined by health and illness, or by parameters of sexuality and procreation. He writes 'it is a space of problems concerning the optimization of life itself' and sees ways out from a causal relationship between geneticization and determinism, making the point that 'to place something on the side of nature is no longer to place it on the side of the unalterable'.[76] Once individuals who are genetically at risk are identified there can be interventions to reduce that risk (249); and interventions such as gene therapy can be life giving. The realisation we are all biological creatures should not, he argues, be a cause for critique but for optimism (254). Rose offers a challenge to the polarised positions of social constructionism and biological determinism. As he points out, there has been a seismic shift from the position of second-wave feminism, whereby the body was a natural object which needed to be rescued from medical experts, to a situation where bodies have become central to our expectations, hopes and identities; it is, he argues, a time of an emergent form of

life. We are entering a complex, confusing time, and to view as negative all development in genetics is analogous to opposing medical research, and misses some of the possibilities of humanity.

The historian of health sciences Dorothy Porter has recently brought the new conceptions of environment and organism to bear on the question of race, problematising claims that developments in genomic science will lead to new forms of social hierarchy and discrimination determined by genetic heritage.[77] Charting ways in which the genome revolution in microbiology has led to new macro-studies of population genetics and the role of ancestry in understanding human disease, she observes the ease with which scientific investigations of race are seen as racialist science and as reinforcing of cultural racism[78] and cautions against ill-defined uses of the term 'personalized medicine', which carries the sense of 'designer' health and other apparent expressions of the excesses of capitalist individualism; Porter shows that recent developments in molecular biology are unlocking variable genomic risk to diseases and revealing the likely effectiveness of pharmaceutical therapeutic interventions.

The latest scientific thinking about race has more to do with history than biology. Porter points out that ancestry population geneticists are not biological essentialists and compares them to historians of sociological activities such as migration and mating, and draws on González Burchard on the importance of appreciating different layers of complexity, from environmental, historical and demographic factors to genetic ancestry.[79] This understanding of the centrality of the environment returns us to the Victorians who understood the dynamic relations between history, environment, and biology. Eliot emphasised that it was environment, the various circumstances that grow from the physical geography and 'land culture' of the German peasantry, which gave rise to their 'numerous specific differences in manner and character' ('Natural History', 126). These differences acknowledged and expressed the interrelations between the environmental and the biological. There is some correlation here with eighteenth-century conceptions of race, such as Buffon's view that race was temporal; it 'persists as long as the milieu remains and disappears when the milieu is changed'[80] but Buffon's work is characterised by a sense of racial hierarchy,[81] while Eliot and her Victorian

contemporaries resisted deterministic thought.

Opposed to racial feeling, Hardy urged in 1917 in a letter to the Secretary of the Royal Society of Literature that 'the sentiment of *Foreignness* [...] attach only to other planets and their inhabitants, if any'.[82] In his poem 'The Pity of It', published the same year, he reads race historically, finding kinship between the English and Germans through common language. An environmental perspective must open up race to social as well as biological influences. Darwin himself observed in the *Descent* that races 'graduate into each other'; 'it is hardly possible to discover clear distinctive character between them' (I, 226).

Nature in Hardy makes mistakes, unexpectedly and entertainingly. There is little deterministic about it, and those who are its familiar inhabitants take note of these quirks:

> To people at home there these changeful tricks had their interests; the strange mistakes that some of the more sanguine trees had made in budding before their month, to be incontinently glued up by frozen thawings now; the similar sanguine errors of impulsive birds in framing nests that were now swamped by snow-water, and other such incidents, prevented any sense of wearisomeness in the minds of the natives.[83]

But to the stranger the accidental and impetuous are invisible. The novel brings home the reciprocal relations between the natives and their complex, fallible, habitat. The unpredictable precludes the reductive and thwarts the deterministic.

'Proud Songsters', in Hardy's last published volume of poetry,[84] brings us back to the unexplained birds of the *Origin of Species*.

> The thrushes sing as the sun is going,
> And the finches whistle in ones and pairs,
> And as it gets dark loud nightingales
> In bushes
> Pipe, as they can when April wears,
> As if all Time were theirs.
>
> These are brand new birds of twelvemonths' growing,
> Which a year ago, or less than twain,
> No finches were, nor nightingales,
> Nor thrushes,
> But only particles of grain,
> And earth, and air, and rain.

Science, philosophy and poetry combine. Reflection follows observation. The 'only'

of the penultimate line is belied by the iterative, and elemental, clauses of the last. Biology is more than chemistry, and the proud songsters are expressly, and inexpressibly, more than the sum of their parts. The transcendental counters the reductive; Victorian wonder resists Neo-Darwinian closure.

---

[1] I would like to thank Barry Barnes, Carolyn Burdett, John Dupré, Regenia Gagnier, Phillip Mallett, Dorothy Porter and Paul White for their valuable comments in the writing of this article, and the Arts and Humanities Research Council for supporting the research. I am also grateful to the Wellcome Trust, Exeter Centre for Medical History, the ESRC Centre for Genomics in Society, and Exeter Interdisciplinary Institute for supporting the Darwin, Medicine and the Humanities Symposium (Exeter, 2009) which informed this research.

[2] Charles Darwin, preface to August Weismann, *Studies in the theory of descent*, 2 vols (London: Low, Marston, Searle, & Rivington, 1880), p. vi. Translation of *Studien zur Descendenz-Theorie*. 2 vols (Leipzig: Engelmann, 1875-6).

[3] On reductionism as methodology see Steven Rose, *Lifelines: Biology: Freedom, Determinism* (London: Penguin, 1997); republished as *Lifelines: Life Beyond the Gene*, (Oxford: Oxford University Press, 2003), chapter 2.

[4] On this slippage see S. Rose, *Lifelines*, esp. chapter 4. On reductionism in classical genetics and molecular biology, see Sahotra Sarkar, *Genetics and Reductionism* (Cambridge, Cambridge University Press, 1998). Sarkar demonstrates that practically all complex human behavioural traits cannot be explained simply by genes.

[5] John Dupré, *The Disorder of Things: Metaphysical Foundations of the Disunity of Science* (Cambridge, MA: Harvard University Press, 1993), p. 6.

[6] See *Nature After the Genome*, ed. by Sarah Parry and John Dupré (Oxford: Wiley Blackwell, 2010), and Dupré, 'Postgenomic Darwinism', in *Darwin*, ed. by W. Brown and A. Fabian (Cambridge: Cambridge University Press, 2010), pp. 150-171.

[7] George Romanes, 'Recent Critics of Darwinism', *Contemporary Review*, 53 (1888), 836–54 (p. 852).

[8] Joseph Carroll, 'Human Nature and Literary Meaning: A Theoretical Model illustrated with a Critique of *Pride and Prejudice*', in *The Literary Animal: Evolution and the Nature of Narrative*, ed. by Jonathan Gottschall and David Sloan Wilson (Evanston: Northwestern University Press, 2005), pp. 76-106 (p. 84).

[9] On literary Darwinism see David Amigoni, 'A Consilient Canon? Bridges to and from Evolutionary Literary Analysis', *English Studies in Canada* 32: 2-3 (2006), 173-85 and Gowan Dawson, 'Literature and Science under the Microscope', *Journal of Victorian Culture* 11.2 (2006), 301–15.

[10] Gillian Beer, *Darwin's Plots. Evolutionary Narrative in Darwin, George Eliot and Nineteenth-Century Fiction*, 3rd edn (Cambridge: Cambridge University Press, 2009), p. 5.

[11] Beer, *Darwin's Plots.* p. 46, emphasis in original.

[12] 'Mr Darwin's Hypothesis', Part I, *Fortnightly Review*, 9 (1868), 353-373, in *Versatile Victorian, Selected Critical Writings of George Henry Lewes*, ed. by Rosemary Ashton (London: Bristol Classical Press, 1992), pp. 299-316 (pp. 310-11).

[13] On new configurations of nature and nurture see for example Massimo Pigliucci, *Phenotypic Plasticity: Beyond Nature and Nurture* (Baltimore: Johns Hopkins University Press, 2001), and *Reconciling Nature and Nurture in the Study of Behavior and Cognition Research,* special issue, ed. by K. Stotz and C. Allen, *Philosophical Psychology*, 21:2 (2008).

[14] William Hayes, *The Genetics of Bacteria and their Viruses: Studies in Basic Genetics and Molecular Biology,* 2nd edn (Oxford: Blackwell, 1969), p. 5, emphasis in original.

[15] See Dorothy Porter, 'Darwin in the Clinic', Wellcome-Trust Darwin, Medicine and the Humanities Symposium, University of Exeter, 2009, forthcoming in 'Essentialism in Science and Culture', *Critical Quarterly* special issue (2011) 54.3, ed. by A. Richardson; M.D. Mesarovic, S.N. Sreenath and J.D. Keene 'Search for Organising Principles: Understanding in Systems Biology', *IEE Systems Biology* 1 (2004), pp. 19-21.

[16] On the development of biology beyond Darwin's ideas see Dupré, 'Postgenomic Darwinism'. Darwin's tree of life itself is arguably a reductionist model of life; Dupré discusses its obsolescence here.

[17] Shapin, 'The Darwin Show', *London Review of Books* (7 January 2010), 3-9.

[18] Charles Darwin, *Origin of Species* (London: Murray, 1859), p. 489.

[19] Charles Darwin, *The Formation of Vegetable Mould, Through the Action of Worms, with Observations on their Habits* (London: Murray. 1881), p. 26.

[20] Charles Darwin, *The Effects of Cross and Self Fertilisation in the Vegetable Kingdom* (London: Murray, 1876), p. 18.

[21] Darwin, *Formation of Vegetable Mould*, p. 313.

[22] See Darwin to Charles Lyell (10 December 1859), Darwin Correspondence Project, http://www.darwinproject.ac.uk/entry-2575 (accessed 17 July 2010).

[23] Adam Sedgwick to C.R. Darwin (24 Nov 1859), Darwin Correspondence Project, http://www.darwinproject.ac.uk/entry-2548 (accessed 17 July 2010).

[24] Charles Kingsley to Darwin (18 Nov 1859), Darwin Correspondence Project, http://www.darwinproject.ac.uk/entry-2534 (accessed 17 July 2010).

[25] Gordon S. Haight, *The George Eliot Letters* (Oxford and New Haven: Oxford University Press and Yale University Press: 1954- 78) 9 vols, III, p. 227, emphasis in original.

[26] G.H. Lewes, 'On the Dread and Dislike of Science', *Popular Science Monthly* 13 (1878), 410-420 (p. 413).

[27] Darwin, *The Descent of Man, and Selection in Relation to Sex* (London: John Murray, 1871), 2 vols, I, pp. 168-9. On Darwin's physiological approach to feeling in *The Expression of the Emotions in Man and Animals*, and the reductive implications of this, see Paul White 'Darwin Wept: Science

and the Sentimental Subject' (*Journal of Victorian Culture*, forthcoming).

[28] Karl Pearson, *The Life, Letters, and Labours of Francis Galton*, 4 vols (Cambridge: Cambridge University Press, 1914–30), II, p. 86.

[29] William Bateson, 'The Progress of Genetic Research', in *Report of the Third International Conference 1906 on Genetics*, ed. by W. Wilks (London, Royal Horticultural Society, 1907), p. 91.

[30] Bateson, *Materials for the Study of Variation*, *Treated With Especial Regard to Discontinuity in the Origin of Species* (London: Macmillan, 1894), p. 11, cited in Donald MacKenzie, *Statistics in Britain 1865–1930: The Social Construction of Scientific Knowledge* (Edinburgh: Edinburgh University Press, 1981), p. 145.

[31] For Bateson's debate with the biometricians, see Barry Barnes and Donald Mackenzie, 'Scientific Judgement: the Biometry–Mendelism Controversy', in *Natural Order: Historical Studies of Scientific Culture*, ed. by Barry Barnes and Donald Mackenzie (1979), pp. 191–210. See also Robert Olby, 'The Dimensions of Scientific Controversy: The Biometric–Mendelian Debate', *British Journal for the History of Science*, 22 (1989), 299–320.

[32] MacKenzie, *Statistics in Britain 1865–1930*, p. 147.

[33] Frank Turner, *Contesting Cultural Authority: Essays in Victorian Intellectual Life* (Cambridge: Cambridge University Press, 1993), p. 182.

[34] See M. Norton-Wise, *The Values of Precision* (Princeton: Princeton University Press, 1997); Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton: Princeton University Press, 1996); Lorraine Daston and Peter Galison, *Objectivity* (Cambridge, MA: Zone, 2007). See also Soraya de Chadarevian, 'Laboratory Science versus Country-House Experiments. The Controversy between Julius Sachs and Charles Darwin', *British Journal for the History of Science* 29 (1996), 17-41.

[35] *Essays upon Heredity and Kindred Biological Problems*, ed. by E.B. Poulton, S. Schönland and A.E. Shipley, 2 vols (Oxford, 1889-1892) I, p. 71.

[36] Lewes, 'Mr Darwin's Hypothesis', p. 299.

[37] George Eliot, *The Mill on the Floss*, ed. by Gordon S. Haight (Oxford: Oxford University Press, 2008), p. 20.

[38] G.H. Lewes, *Comte's Philosophy of the Sciences: Being an Exposition of the Principles of the Cours de Philosophie Positive of Auguste Comte* (London: Bell, 1887), p. 1; p.167, emphasis in original.

[39] George Eliot, 'The Natural History of German Life', *Westminster Review* (1856), 51-79, reprinted in *Selected Essays, Poems and Other Writings*, ed. by A.S. Byatt and Nicholas Warren (London: Penguin, 1990), pp. 107-139 (p. 127).

[40] George Eliot, *Middlemarch*, ed. by David Carroll (Oxford: Oxford University Press, 2008), p. 139; p. 138.

[41] See Paul White, 'Acquired Character: The Hereditary Material of the Self-Made Man' in *Heredity Produced: At the Crossroads of Biology, Politics, and Culture, 1500-1870*, ed. by Staffan Müller-

Wille and Hans-Jörg Rheinberger (Cambridge, MA: MIT Press, 2007), pp. 375-397.

[42] Alexander Bain, *The Senses and the Intellect* (London: Parker, 1855) and *Emotions and the Will* (London: Parker, 1859).

[43] Smiles, 'The Education of the Working Classes', address to the Leeds Mutual Improvement Society, 1845, quoted in Alexander Tyrrell, 'Class Consciousness in Early Victorian Britain: Samuel Smiles, Leeds Politics, and the Self-Help Creed', *The Journal of British Studies,* 9 (1970), 102-125 (p. 116).

[44] Smiles, *Self-Help; with Illustrations of Character, Conduct, and Perseverance,* ed. by Peter Sinnema (1866; Oxford: Oxford University Press, 2008), p. 319.

[45] *Analogy of Religion, Natural and Revealed* (London: Knapton, 1736), in Samuel Smiles, *Self-Help,* p. 319.

[46] J.S. Mill, *Autobiography of John Stuart Mill* (New York: Columbia University Press, 1960), p. 184.

[47] See Sally Shuttleworth, *George Eliot and Nineteenth-Century Science: The Make-Believe of a Beginning* (Cambridge: Cambridge University Press, 1984), p. 26.

[48] 'On the Dread and Dislike of Science', *Popular Science Monthly* 13, 410-420 (p. 413).

[49] Cited in S. Rose, *Lifelines: Biology: Freedom, Determinism*, p. 73.

[50] See John Dupré 'Are there "Genes for" traits?', *BioNews* 548 (8 March 2010), http://www.bionews.org.uk/page_54781.asp (accessed 17 July 2010).

[51] Darwin, *The Variation of Animals and Plants under Domestication* 2 vols (London: Murray, 1875), II, p. 281.

[52] *The Variation,* 2 vols (London: Murray, 1868) , II, p. 290.

[53] Spencer, *Principles of Psychology* (London: Longman, Brown, Green and Longmans, 1855), p. 391. See Trevor Pearce, 'From "Circumstances" to "Environment" – Herbert Spencer and the Origins of the Idea of Organism-Environment Interaction', *Studies in History and Philosophy of Biological and Biomedical Sciences*, 41 (2010). Pearce notes that the term was coined in 1827 by Thomas Carlyle who translated the German *Umgebung*, usually translated as 'surroundings', as 'an environment of circumstances' in 'Goethe's Helena', *Foreign Review* I.2 (1828), 429-68.

[54] John Lankester, *Degeneration: A Chapter in Darwinism* (London: Macmillan, 1880), pp. 32-3.

[55] 'Mr Darwin's Hypothesis', p. 301.

[56] Weismann, Preface, 'On Heredity', p. 69.

[57] 'Essays upon Heredity' (review of Weismann's *Essay*s), *Academy*, 37 (1890), 83-4 (p. 84).

[58] *The Life and Work of Thomas Hardy* 2 vols, ed. by Michael Millgate (London: Macmillan, 1984), I, p. 240.

[59] Alfred Wallace, *Darwinism: An Exposition of the Theory of Natural Selection, with Some of its Applications* (London: Macmillan, 1889).

[60] Arnold White, *Efficiency and Empire* (Brighton: Harvester, 1973), pp. 95, 97, 96, 111, 100.

[61] Hardy, *The Life and Work,* I, p. 227 (5 April 1889).

[62] George Gissing, *The Nether World*, ed. by Stephen Gill (Oxford: Oxford University Press, 1999), p. 79.

[63] See Phillip Mallett, 'The Novel amid the New Sciences', in *The Cambridge History of the English Novel*, ed. by Robert Caserio and Clement Hawes (Cambridge: Cambridge University Press, forthcoming, 2011).

[64] H. G. Wells, *Anticipations of the Reactions of Mechanical and Scientific Progress Upon Human Life and Thought* (New York: Dover, 1999), p. 107.

[65] *The Biological Problem of Today: Preformation or Epigenesis? The basis of a Theory of Organic Development* (London: Heinemann, 1896), p. 140.

[66] See Daniel Kevles, *In the Name of Eugenics*: *Genetics and the Uses of Human Heredity* (Cambridge, MA: Harvard University Press, 1995), p. 284 for discussion of Wilson.

[67] On environmental factors in genomics see Barbara McClintock, 'The Significance of Responses of the Genome to Challenge' *Science* 226 (1984), 792-801.

[68] See Lewontin, *Education and Class: The Irrelevance of IQ Genetic Studies* (Oxford: Oxford University Press, 1987); Richard Lewontin and Richard Levins, *Biology Under the Influence: Dialectical Essays on Ecology, Agriculture, and Health* (New York: Monthly Review Press, 2007).

[69] Hardy, *Life and Work*, II p. 377, emphasis in original. For Hardy on the *Origin* see Hardy, *Life and Work*, I p. 158. In the 'Write a Letter to Darwin' project at Exeter (2009), in collaboration with the Cambridge Darwin Correspondence Project, school children responded on a number of subjects including the interdependencies of the natural world and contemporary environmental issues.

[70] See Marc Bekoff, 'The Emotional and Moral Lives of Animals', in *Darwin and the Emotions: Mind, Medicine and the Arts*, ed. by A. Richardson (California: University of California Press, forthcoming 2012); Marc Bekoff and Jessica Pierce, *Wild Justice: The Moral Lives of Animals* (Chicago: University of Chicago, 2009); Frans de Waal, *Primates and Philosophers: How Morality Evolved* (Princeton: Princeton University Press, 2006).

[71] Burchard is at the University of California San Francisco and Rick Kittles is at the University of Chicago; I am grateful to Dorothy Porter for drawing their work to my attention.

[72] Barnes and Dupré, *Genomes and What to Make of Them* (Chicago: University of Chicago Press, 2008), p. 252.

[73] Popper, First Medawar Lecture, Royal Society (1986), cited in Rose, p. 75.

[74] See Richard C. Lewontin, 'Organism & Environment', in *Learning, Development, and Culture: Essays in Evolutionary Epistemology*, ed by H. Plotkin (New York: Wiley, 1982), pp. 151-170; Lewontin, 'Gene, Organism and Environment', in *Evolution: From Molecules to Men*, ed. by D.S. Bendall (Cambridge: Cambridge University, 1983), pp. 273-285; Lewontin 'Gene, Organism and Environment: A New Introduction', in *Cycles of Contingency: Developmental Systems and Evolution*, ed. by S. Oyama, P. E. Griffiths and R. D. Gray (Cambridge, MA: MIT Press, 2001), pp. 55-58. In 'The Developmental Systems Perspective: Organism environment systems as units of development and evolution', in *Phenotypic Integration: Studying the Ecology and Evolution of*

Complex Phenotypes, ed. by Massimo Pigliucci and Katherine Preston (Oxford: Oxford University Press, 2004), Paul E. Griffiths and Russell D. Gray contrast a static model of environment and organism proposed by neo-Darwinism with the more reciprocal relations Lewontin and Odling-Smee posit. In 'Niche-constructing phenotypes' in *The Role of Behavior in Evolution*, ed. by H. C. Plotkin (Cambridge, MA: MIT Press, 1988), pp. 73-132, F. J. Odling-Smee argues that the organism-environment relation is an open system. In 'The Coevolution of Organism and Environment', in *Concepts and Methods in Evolutionary Biology*, ed. by R. Brandon (Cambridge: Cambridge University Press, 1996), pp. 161-178, Richard Brandon and Janis Antonovics argue for three senses of environment - the 'external environment' which all organisms in a certain space and time share, the 'ecological environment' which consists of environmental parameters which influence the reproductive output of members of the group, and the 'selective environment', which contains adaptive evolutionary pressures and differentially affects variant forms of an evolving lineage.

[75] See for example D.C. Dolinoy and R.L. Jirtle, 'Environmental Epigenomics in Human Health and Disease', *Environmental and Molecular Mutagenesis*, 49 (2008), 4-8.

[76] Nikolas Rose, *The Politics of Life Itself: Biomedicine, Power, and Subjectivity in the Twenty-First Century* (Princeton: Princeton University Press, 2006), pp. 82, 249.

[77] Porter, 'Darwin in the Clinic', 2011.

[78] See Brian Beaton, 'Racial Science Now: Histories of Race and Science in the Age of Personalized Medicine', *The Public Historian* 29 (2007), 157-162, cited in Porter, 2011.

[79] Burchard, Science Café Interview 2007, cited in Porter, 2011.

[80] George Louis Leclerc Buffon, *Natural History, General and Particular*, 3rd edn trans. by William Smellie (London, 1791), VIII, pp. 34-35. See Nicholas Hudson, 'From "Nation" to "Race": The Origin of Racial Classification in Eighteenth-Century Thought', *Eighteenth-Century Studies* 29.3 (1996), 247-264. A more biologistic account of race would develop through Johann Friedrich Blumenbach's craniology.

[81] On Eliot and race see Brenda McKay, *George Eliot and Victorian Attitudes to Racial Diversity, Colonialism, Darwinism, Class, Gender, and Jewish Culture and Prophecy* (Lampeter: Edwin Mellen Press, 2003).

[82] Hardy, *The Life and Works,* II, p. 405, emphasis in original.

[83] *The Woodlanders*, ed. by Patricia Ingham (London: Penguin, 2003), p. 126.

[84] *Winter Words in Various Moods and Metres* (London: Macmillan, 1928).