SQUARING THE CURVE:

THE ANATOMO-POLITICS OF AGEING, LIFE AND DEATH

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Abstract

In this paper we observe that, while critical studies of biomedical interventions on the ageing body have focussed on associated social and cultural reconfigurations of ageing and death, the epistemic practices of bio-gerontology have rarely been examined. Extending these rarer studies, we argue that changes in the scientific articulation of ageing processes and death over a longer historical period than has been considered hitherto offer important insights into the ontology of the emergent politics of 'life itself'.

Keywords: Ageing; death; anatomo-politics; 'life itself'.

Introduction

Drawing on the work of Michel Foucault, but also significantly departing from Foucault's own understanding of bio-political governmentality, Paul Rabinow (1996), Nikolas Rose (2001) and others suggest very persuasively that we are currently witnessing an epochal transformation in the organisation of embodied life. We should now speak of the advent of a politics of 'life itself' insofar as the individual of the nineteenth century bio-political imaginary, a human body whose biological constitution was irremediably fixed at birth, is giving way to an understanding of the human body as an assembly of bio-molecular components that can be freely recombined so as to maximise the resultant unit's cultural, social and political productivity. What is unclear, however, is what might be happening to death.

If Rabinow and Rose can be said to articulate and detail Gilles Deleuze's claim that the emerging governmental order is one in which the modern calculus of finitude gives way to unlimited recombination of a finite number of components, it is also important to note that death, the seemingly inescapable moment in which all vital activities cease, underpins the modern concern about finitude (Deleuze, 1988: 126-9). It then seems crucially important to ask what the notion of unlimited recombination entails in regard to this critical moment. Stephen Katz and Barbara Marshall (2003) have discussed at length how, within so-called 'advanced societies', the process of ageing, which in many ways has been symbolically construed as prefiguring death, is today being reconfigured so as to undermine the classical, cultural partitioning of the life cycle into birth, sex and death. This reconfiguration sets the stage for what the publicly acclaimed, leading bio-gerontologist Thomas Kirkwood (2001) calls the coming 'end of age'. Furthermore, others point to a new social configuration whereby the avoidance of ageing and the pursuit of immortality are becoming normatively binding (Powell & Biggs, 2004; Vincent, 2006; Mykytyn, 2006a; 2006b). These socio-cultural shifts are clearly related to both the increasing organisation of health care around the mode of consumption and a re-orientation of biomedical research and practice towards the bio-molecular characterisation pathological processes associated with ageing, aiming to offer thereby new, preventative modes of intervention in these processes (see Petersen, 1997). On the other hand, none of these accounts attends to the reconfiguration of death as a specifically biological phenomenon. Providing a detailed account of what Foucault would call the anatomo-political reconfiguration of death sustaining the prospective 'end of age', an account comparable to that which Foucault advanced in *The Birth of the Clinic* (1964), would seem crucially important, however. As Rabinow (1999) himself has noted, the new medical technologies which are often associated with the emerging politics of 'life itself' raise weighty ontological questions, but, in turning to a very modern definition of 'nominalism' to lay such questions to rest (see Dupré, 1993), the new bio-political

order is reduced to no more than an ideological construct imposed upon a historically unchanging material substratum (see Canguilhem, 1977; Bachelard, 1984). This conceptual difficulty cannot be any more evident than in those cases where the analysis of the new medical technologies touches on death, supposedly the one phenomenon which is refractory to all negotiation and which, ever since Martin Heidegger, is to be understood as the very bedrock of human consciousness (see Lock, 2002: 200-7). Melinda Cooper has begun, however, to outline the contours of a new understanding of life and death by focussing on recent developments within the much heralded field of stem-cell technology, developments which seem to offer the prospect of endlessly regenerating the otherwise inevitably declining capacities of the human body, and she is doing so with an eye to the ontological foundations of the emerging bio-political order (see Cooper, 2002; 2006). This said, Cooper also seems to have been swept up by the promissory economy of 'regenerative medicine', so that it seems worth examining instead the ways in which leading figures in the field of bio-gerontology, including the abovementioned Kirkwood, have repeatedly mounted concerted efforts to call into question the much bandied notion that the dramatic extension of human life-span, if not the achievement of human immortality, is today within reach of the biomedical sciences (see Vincent, 2003; also Moreira & Palladino, 2005). While one might ask quite legitimately whether these objections are no more than a wholly predictable, conservative response to the prospect of losing the very field of problematisation that defines the discipline of bio-gerontology, understood here as the epistemic field simultaneously engaged in the bio-molecular and bio-demographic characterisation of pathological processes associated with ageing, one could also situate these objections within a longer history of scientific reflections on death, exploring some crucially important tensions between the practices of evolutionary explanation and techno-scientific intervention. In this paper we offer therefore a close reading of those theories of ageing and death which are associated primarily with Kirkwood, Leonard Hayflick and Alex Comfort.

We focus on Kirkwood, Hayflick and Comfort not simply because their ideas, as well as related analytical practices and professional affiliations, fully capture the range of the more sceptical perspectives on the plasticity of ageing and death which are currently pursued within the field of bio-gerontology, and which are the main focus of socio-cultural studies of the contemporary reconfiguration of old age. Neither do we focus on these three figures simply because Comfort can be viewed as the founder of bio-gerontology as a novel, distinct and coherent field of intellectual inquiry, Hayflick as he who developed the material and institutional wherewithal for the expansion of the enterprise, and Kirkwood as he who has reframed the evolutionary considerations first articulated by Comfort to rebuild the expansive intellectual, material and institutional network encompassed by contemporary bio-gerontology. To us, Kirkwood, Comfort and Hayflick are instead

especially important figures because they offer very different readings of one and the same historical text, namely August Weismann's speculative reflections on the biological evolution of ageing and death, which were first articulated in *The Duration of Life* (1881) and *Life and Death* (1883). We approach these readings not as post-hoc reconstructions to legitimate otherwise autonomous scientific developments, but as central to the transformation of bio-gerontology and its emergence in the public sphere during the last quarter of the 20th century. Scientists' stories, as one of us has put it, '[are] not only a topic in the practical accomplishment of the history and social studies of science, technology and medicine, but also in the accomplishment of facts, artifacts, representations, bodies and so on' (Moreira, 2000: 425). This leads us to our second concern. As Foucault noted in *Birth of the Clinic*, Xavier Bichat's *Physiological Researches on Life and Death* (1800) radically transformed contemporary understanding of biological life, by positing firstly that 'life is the sum of all activities that resist death' (Bichat, 1994: 57), and by then materially mobilising death to reveal the physiological details of these activities. Death, in Foucault's words, became 'the great analyst that shows the connexions by unfolding them, and bursts open the wonders of genesis in the rigour of decomposition' (Foucault, 1994a: 145). Strikingly, however, while this understanding entailed the presence of biological death wherever there is biological life, regardless of scale, death itself remained outside the domain of biological inquiry, at least until the publication of Weismann's reflections on ageing and death. In these reflections, Weismann advanced the radical notion that the first organisms in evolutionary history were immortal and that death was an incidental product of the division of labour under natural selection. Death, in other words, ceased to be anything like Bichat's external, but none the less primary and defining, feature of biological process. Drawing on Deleuze's observation that, within Bichat's modern formulation of the relationship between life and death, the advent of death was to be understood as comparable to the 'violent death' which the sovereign power visits on the transgressing political subject (Deleuze, 1988: 130; see also Bichat, 1994: 200-9), it is then possible to argue even more incisively that there is no such thing as 'natural death' (see also Alter & Carmichael, 1997). From this perspective, all that exists is continuous and endless transformation. There only is 'life itself'. Furthermore, Weismann's iconoclastic, evolutionary account of the origins of death was critically important to the emergence of the modern theory of heredity, which is predicated on the division of the organism into an immortal germinal line and a mortal somatic line (see Churchill, 1987; Griesemer & Wimsatt, 1989). In other words, not only is Weismann the more productive point of historical reference for any inquiry into the ontology of the politics of 'life itself', but he could also be said to effectively delineate the 'conditions of possibility' for the emergence of contemporary bio-gerontology as the epistemic field simultaneously engaged in the bio-molecular and bio-demographic characterisation of pathological processes associated with ageing (Foucault, 1994b: xxii; cf. Hirshbein, 2001).

The exact interpretation of Weismann's argument, however, divides Comfort, Hayflick and Kirkwood in ways that are crucially important to understanding the fuller complexity of the re-alignment of the anatomo-political and bio-political ordering of ageing and death in the age of 'molecular biology' (Deleuze, 1988: 131).

In sum, while most socio-cultural analysis of ageing and death tend to frame bio-gerontology as a contested field of knowledge, structured by negotiations of professional and scientific boundaries, in this paper we explore intellectual formations, material infrastructures and institutional context simultaneously, to advance the notion that the field of bio-gerontology is better understood as a complex space, in which the interactions between policy considerations, inter-professional relations, and competing epistemic frameworks and experimental practices form partially connected assemblages (see Law & Mol, 2002). We suggest that this complexity is particularly evident in the periodic re-reading and re-working of Weismann's argument. From this more complex, historical perspective, scientific objections to contemporary promises of effective immortality become centrally important to the construction of the 'end of age', a construction in which, we also argue, death is radically displaced, but never wholly disappears from the epistemic practices of bio-gerontology. This perhaps calls for further reflection on the meaning one might attach to Deleuze's notion of 'unlimited finity' and its connotation of an epochal, onto-historical transformation (Deleuze, 1988: 131).

Why do ageing and death matter?

Before examining the re-reading and re-working of August Weismann's argument about the nature of death, it is useful to understand the broadest context in which such re-reading and re-working has unfolded.

As Michel Foucault famously argued in *The History of Sexuality* (1976), the distinctive feature of modern governmental forms is their investment in maximising the productive powers of the embodied, human subject (see also Foucault, 2004a: 239-264). Historically, this investment was enabled by two different forms of organising and structuring the modes of being in relation to others, the anatomo-political and bio-political articulations of power. The first of these terms designated the articulation of political power and the material constitution of the human body as it was disclosed by modern disciplinary discourses such as those of anatomy and physiology. The second term designated instead the articulation of political power and the reproductive potential of the human species, which was operated by the administrative institutions of the state. While very different in their mode of institutional organisation, the relationship between the two forms of power over embodied life was a co-constitutive one, best exemplified by the discourse of 'sexuality':

> Sexuality, being an eminently corporeal mode of behaviour, is a matter for individualizing disciplinary controls that take the form of permanent surveillance … But because it also has procreative effects, sexuality is also inscribed, takes effect, in broad biological processes that concern not the bodies of individuals but the element, the multiple unity of the population. Sexuality exists at the point where the body and population meet. And so it is a matter for discipline, but also a matter for regularization (Foucault, 2004a: 251-2).

It should not be surprising that the modern bio-medical disciplines took shape at the point of intersection of the anatomo-political and bio-political forms. Importantly, while the precise role of these bio-medical disciplines has proved to be a matter of intense, but perhaps misguided, debate (see Colgrove, 2002), there is little disagreement that, wherever modern governmental forms held sway, these disciplines, when taken together, did aid the elimination of infectious diseases such as tuberculosis as major causes of mortality, and then contributed to delaying the impact of chronic diseases such as cancer. The net effect of this particular, historical regime was that human longevity has increased extraordinarily during the past century and a half. Although the statistics of this demographic change have created much confusion, such as the common, but arguably mistaken, assumption that human life span has also increased (see Fries, 2005), the problems presented by an ever larger fraction of the population reaching old age have resulted in the massive expansion of geriatric medicine and the medicalisation of ageing generally (Estes & Binney, 1989; Katz, 1996; see also Armstrong, 1983: 85-92). Concomitantly, questions posed by ageing and death as strictly biological phenomena have been relegated to the margins of orthodox bio-medical discourse, to the domain of quacks and their promises of eternal youth (see, for example, Hirshbein, 2000; Sengoopta, 2003). Moreover, while Philippe Ariès (1987), and Zygmunt Bauman after him (1992), were perhaps mistaken when they argued that these same modern bio-medical disciplines and associated governmental forms have contributed to the disappearance of death from daily life, there are good grounds for believing that these disciplines and forms have contributed greatly to the ontological evacuation of death. In other words, there are good grounds for believing that death has not so much disappeared from modern daily life, as it has become instead dying, an undoubtedly productive performance around a simultaneously emptied centre, devoid of any intrinsic meaning (Palladino, 2004; cf. Seale, 1998). At the same time, however, these socio-cultural changes have come at a great cost, scarcely compensated by a burgeoning death industry. While the expense of defeating infectious diseases and postponing the effects of chronic diseases was defrayed by one insurance scheme or another, this has become increasingly difficult to sustain as the relationship between the number of socially functional individuals, usually defined as those gainfully employed and paying into the insurance funds, and the number of biologically functional individuals have so diverged that the insurance funds characteristic of the modern governmental form are said to be increasingly unsustainable and requiring new answers (see Foucault, 2004b; also Dillon & Lobo-Guerrero, in review). While this has resulted in massive investments in

reshaping the organisation of old age, so as to synchronise the social and biological functionality of the individual (see Katz & Marshall, 2003; 2004), such possibilities would seem to be limited by the plasticity of ageing and death as biological phenomena. Perhaps unsurprisingly, whether the age-specific mortality curve (see Figure 1) can be effectively squared at the individual, physiological level, so that the pathological burdens of old age are not just statistically compressed into a few months of 'catastrophic illness' just before death, but become the normal experience and common understanding of embodied life and its progress from birth to death, is a question that has greatly exercised the bio-medical disciplines since the 1970s (see Fries, 2005).

Insert figure 1 here

The accompanying discussions of mortality and immortality have attracted much public attention, especially as bio-medical scientists such as Aubrey de Grey (2005a) have claimed that these same bio-medical disciplines should re-orient their research toward the achievement of human immortality, because, thanks to developments emerging from the bio-molecular sciences, it is now within their grasp (see also Breithaupt & Hadley, 2005; Bourg, 2000). As noted earlier, such claims are not unprecedented, and have once again resulted in concerted, disciplinary efforts to pit the truth of the matter against the unreasonable hopes invested in so-called 'anti-ageing medicine'. These efforts have frequently occasioned animated debates which have sometimes spilled into the media, for example, when Thomas Kirkwood (2005) reviewed very unfavourably the promises of anti-ageing medicine, and the editors of *Nature*, where Kirkwood's review had first appeared, refused to grant De Grey any opportunity to respond (De Grey, 2005b; Morelle, 2006; see also Warner et al., 2005; Olshansky, Hayflick & Carnes, 2000).

This said, analysing the work of bio-gerontology itself, rather than its conflict with anti-ageing medicine, is perhaps a more productive approach to understanding the complex relationship between death and the emerging politics of 'life itself'.

Can organisms live forever?

In 1982, Thomas Kirkwood and Thomas Cremer sought to situate the former author's relatively novel, evolutionary theory of ageing and death, the theory of 'disposable soma' (Kirkwood, 1977), within a long tradition of evolutionary considerations about the two phenomena, a historiographical construct in which August Weismann became a founding and prophetic, but forgotten, figure (Kirkwood & Cremer, 1982). The

striking feature of this account is that Weismann has been mobilised, both before and after Kirkwood and Cremer's intervention, to articulate quite different theories of ageing and death to that which Kirkwood has promoted very successfully since 1977 (see Kirkwood, 1999), culminating in 2001, with in his invitation to deliver the prestigious BBC Reith Lectures (Kirkwood, 2001).

Kirkwood and Cremer continue their historical reconstruction of bio-gerontology by noting that Leonard Hayflick's work on the life cycle of the cell 'opened fresh speculation into the possibility that ageing might be due to intrinsic limitations in the life of somatic cells' (Kirkwood & Cremer, 1982: 108; see also Cooper, 2006: 1-2). In 1961, while still working in the field of experimental oncology, Hayflick called into question the prevailing notion that somatic cell lines, those lines of cells which are found in multicellular organisms and do not divide or differentiate to produce a new line, were immortal when cultivated *in vitro* (Hayflick & Moorhead, 1961). While many doubts had previously been expressed about this notion that somatic cell lines were potentially immortal (see Witkowski, 1979; Landecker, 2003), its credibility was consolidated by the embedding of the assumption within the repertoire of material practices underpinning the expansive domain of research into the causes of cancer (see Patterson, 1987). In the process of examining the differences between cancerous and non-cancerous cell lines, however, Hayflick concluded that the lifespan of non-cancerous cells lines was in fact finite, and that an internal mechanism limited the number of replications the cell lines could undergo, a limit which Hayflick and Paul Moorehead named the 'Phase III Phenomenon', but now goes by the name of 'Hayflick limit' (see Shay & Wright, 2000). On the one hand, while many contemporary researchers remained unpersuaded by both Hayflick's claim and by his controversial suggestion that the contrary, prevailing view was in fact an artefact of material practices within experimental oncology, the notion that somatic cells were potentially immortal meant that ageing and death were determined either at higher levels of biological organisation than the cell or by factors wholly external to the organism. From this perspective, the process of ageing and the advent of death were a matter of interest to clinical, geriatric medicine alone. On the other hand, Hayflick's claim that ageing and death were determined at the cellular level became increasingly attractive to bio-medical researchers as research into possible treatments for cancer was perceived as having reached an impasse, so much so that its central experimental practices were coming under close, critical scrutiny (see Löwy & Gaudillière, 1998: 231-2), and the field of bio-gerontology, thanks to growing concerns about the bio-political implications of an ageing population, was simultaneously acquiring its own, distinctive institutional basis (see Katz, 1996). Importantly, Hayflick was no passive bystander, but was instead centrally involved in mediating these growing concerns about the bio-political implications of an ageing population into institutional structures which might support research

into the cellular and sub-cellular bases of ageing and death. His efforts were so successful that, in 1974, he was offered the opportunity to become the first director of the National Institutes of Health National Institute of Aging (NIA), which had just been established by legislative act of the United States Congress (Rattan, 2001).[1] By 1975, moreover, not only had Hayflick's formerly heterodox claim been rearticulated into the notion that the mechanism controlling cellular ageing and longevity was located in the cellular nucleus, which implied some form of genetic control (Wright & Hayflick, 1975), but it also helped to consolidate a new approach to investigating the causes of cancer, focussing on the capacity of viruses to somehow re-programme the genomic control of cellular functions so as to bring about the limitless reproduction of somatic lines. While these developments firmly positioned the emerging field of 'bio-gerontology' within the expanding genomic sciences, the notion that ageing and death were genetically determined also threatened to undermine the autonomy of bio-gerontology, so that it was equally important to maintain an exclusive and distinctive link to the simultaneously expanding field of clinical, geriatric medicine and its investment in the physiological complexity and distinctiveness of the diseases of old age (Katz, 1996; Holstein, 2000; see also Keating & Cambrosio, 2003: 49-82).

Considerations about the relationship between bio-gerontology and the genomic sciences, a relationship which arguably was inaugurated by Hayflick's experimental studies of the cell's life cycle, became particularly important in the wake of ever-increasing public concern about the prospect of old age and its accompanying frailties, especially as some of the new specialists in bio-gerontology began to draw on the promises of the genomic sciences to argue that ageing was so genetically 'programmed' as to hold out the further promise of being able to engineer the end of ageing (see Milburn, 2002). Thus, if much of this promise seems a matter of blurring the boundaries between science and fiction, the mechanism underlying the 'Hayflick limit' has been traced much more prosaically to the shortening of telomeres during the process of genomic replication, so that it is now possible to extend the life of a somatic cell lines by modifying the telomeres and so 'immortalise' the lines. This, in turn, has generated great interest in the therapeutic potential of telomerase to halt the process of ageing, currently sustained and explored by companies such as the appositely named Geron Corporation (see Magalhães & Toussaint, 2004; also Hall, 2003). Consequently, as Hayflick extended his understanding of cellular ageing and death to address and capture the growing public concern about the prospect of ageing, but with an eye to maintaining the links between bio-gerontology and clinical, geriatric medicine, he repeatedly stressed that questions of ageing and longevity were not to be confused (see Hayflick, 1995; see also Rattan, 2000). Admittedly, Hayflick himself had contributed to such confusion, so

that, in 1997, in a technical review of research on cellular mortality and immortality, he insisted in noting that, in his original investigations of cellular immortality:

> Our suggestion that the Phase III Phenomenon was aging at the cell level was made because it was relatively simple to eliminate other explanations for our observations but we were unable to eliminate the possibility that the phenomenon was, indeed, aging at the cellular level. Our failure to eliminate aging as the cause of the event was not based on our inability to design the right experiment but because there were no accepted criteria for identifying biological aging – a problem that to this day remains substantially unresolved (Hayflick, 1997: 1183; emphases added).

Of key importance is that the principal intellectual resource for maintaining this epistemic and political boundary between the genetic determination of life span and the physiological process of ageing has been the recourse to evolutionary theory. In 1989, for example, Hayflick argued that,

> Evidence that longevity is determined by genetic events is overwhelming but evidence that age changes are the result of gene expression is not. … [N]atural selection could not have favoured the development of a genetically programmed aging process. In the 2 or 3 million years of human existence, too few old humans existed to have provided a selective advantage favouring the development of a genetic program that would determine age changes. The selective advantage of maintaining physiological vigour for as long as possible in order to insure maximum reproductive success may be the essential indirect determinant of longevity (Hayflick, 1989: 355; emphases added).

The reference point for Hayflick's evolutionary considerations and the problems they posed for any notion of a genetically programmed ageing process was none other than Kirkwood and Cremer's historical review. Further, in the later, revisionist account of his pioneering research on the life cycle of the somatic cell, Hayflick again drew on Kirkwood and Cremer's historical review, this time to tie his work to Weismann's statement that 'death takes place because a worn-out tissue cannot forever renew itself, and because a capacity for increase by means of cell division is not everlasting but finite' (Hayflick, 1997: 1180). Had Hayflick read Weismann's text itself, he might have latched onto the following, even more germane historical antecedent:

> It is, in my opinion, an advance if we may assume that the length of life is dependent upon the number of generations of somatic cells which can succeed one another in the course of a single life; and furthermore, that this number, as well as the duration of each single cell-generation, is predestined by the germ itself (Weismann, 1883: 147; emphasis added).

More importantly, however, the history of Hayflick's evolutionary considerations could also be said to have started much earlier than it transpired in 1989.

Why must organisms age and die?

The notion that the extension of longevity need not entail any change of life-span is not nearly as arresting and provocative as the notion that ageing is not in fact a universal feature of biological life, the extreme case being the Pacific salmon, *Oncorhynchus* spp., which does not age, but dies immediately after completing its task of reproduction. Ageing, it would seem, is peculiar to those species that can survive long after reproduction, thanks, for example, to the social mores that call on younger humans to help and protect the elderly, so much so that ageing, like cancer, might be said to be a 'disease of civilisation' (see Porter, 1993). These ideas were critically important to the emergence of evolutionary explanations of ageing and death. As early as 1973, Leonard Hayflick was drawing on such explanations to consolidate his argument that longevity was genetically determined and was doing so by drawing tacitly on Alex Comfort's very successful and influential *The Biology of Senescence* (see Hayflick, 1973). In fact, if Hayflick can be viewed as he who developed the material and institutional wherewithal for the constitution of bio-gerontology as a major, autonomous field of biomedical research, Comfort's *The Biology of Senescence*, first published in 1956 and then twice re-published, in 1964 and 1979, provided the intellectual foundations for the redefinition of clinical, geriatric medicine as resting on an understanding of ageing and death as fundamentally biological problems (see Medvedev, 2000).

Strikingly, the very passage from August Weismann which Hayflick cited in 1997, is the very same passage which, according to Thomas Kirkwood and Thomas Cremer, had created much confusion among earlier readers of Weismann's work on the evolution of ageing and death, particularly Comfort (see Kirkwood & Cremer, 1982: 113). Comfort opens *The Biology of Senescence* with the following words:

> Man throughout history, and every individual since childhood, has been aware that he himself, and those animals which he has kept in domestication, will undergo an adverse change with the passage of time. Their fertility, strength and activity decreases, and their liability to die from causes which, earlier in life, they could have resisted, increases.
>
> This process of change is senescence, and senescence enters human experience through the fact that man exhibits it himself. This close involvement with human fears and aspirations may account for the very extensive metaphysical literature of ageing. It certainly accounts for the profound concern with which humanity has tended to regard the subject. To a great extent human history and psychology must always have been determined and moulded by the awareness that the life-span of any individual is determinate, and that the expectation of life tends to decrease with increasing age … Every child since the emergence of language has probably asked 'Why did that man die?' and has been told 'He died because he was old'.
>
> Interesting psychological and historical speculation could be made on the part which this awareness has played in human affairs. From the biologist's standpoint, its main importance has been the bias which it has injected into the study of senescence. The child who asks the question and receives the answer, is familiar with 'old' clothes and 'old toys'. He has always known that he, his pets, his cattle and his neighbours will become increasingly prone to breakdown and

> ultimate death the older they get. He has observed from the nursery that inanimate and mechanical systems also deteriorate with the passage of time. He appears at a later age to derive some degree of comfort from the contemplation of the supposed generality, universality and fundamental inherence of ageing – or alternatively from drawing a contrast between Divine or cosmic permanence and his own transience. However inspiring this type of thinking may be – and it features largely in the past artistic and philosophical productions of all cultures – its influence and its incorporation as second nature into the thought of biologists throughout history has seriously handicapped the attempt to understand what exactly takes place in senescence, which organism exhibit it, and how far it is really analogous to the process of mechanical wear. One result of the involvement of senescence with philosophy and the 'things that matter' has been the prevalence of attempts to demonstrate general theories of senile change, including all metazoan and even inanimate objects, and having an edifying and a metaphysical cast. Prominent with among these have been the attempts to equate ageing with development, with the 'price' of multicellular existence, with hypothetical mechano-chemical changes in colloid systems, with the exhaustion induced by reproductive processes, and with various concepts tending to the philosophical contemplation of decline and death (Comfort, 1956: 1-2).

The prime target of this rhetorical onslaught was Weismann, as proponent of a theory of ageing which 'though untenable', none the less enjoyed 'considerable surviving influence' (Comfort, 1956: 9).

Comfort's principal objection was to Weismann's statement that 'death takes place because a worn-out tissue cannot forever renew itself … Worn-out individuals are not only valueless to the species, but they are even harmful, for they take the place of those which are sound' (as quoted in Comfort, 1956: 9). The fuller statement of Weismann's proposition is:

> Worn-out individuals are not only valueless to the species, but they are even harmful, for they take the place of those which are sound. Hence by the operation of natural selection, the life of our hypothetically immortal individual would be shortened by the amount which was useless to the species. It would be reduced to a length which would afford the most favourable conditions for the existence of as large a number as possible of vigorous individuals, at the same time.
>
> If by these considerations death is shown to be a beneficial occurrence, it by no means follows that it might be solely accounted for on grounds of utility. Death might also depend on causes which lie in the nature of life itself. The floating of ice upon water seems to us to be a useful arrangement, although the fact that it does float depends upon its molecular structure and not upon the fact that its doing so is of any advantage to us. In the like manner the necessity of death has been hitherto explained as due to causes which are inherent in organic nature, and not to the fact that it may be advantageous.
>
> I do not however believe in the validity of this explanation; I consider that death is not a primary necessity, but that it has been secondarily acquired as an adaptation. I believe that life is endowed with a fixed duration, not because it is contrary to nature to be unlimited, but because the unlimited existence of individuals would be a luxury without corresponding advantage. The above-mentioned hypothesis upon the origin and necessity of death leads me to believe that the organism did not finally cease to renew the worn-out cell material because the nature of the cells did not permit them to multiply indefinitely, but because the power of multiplying indefinitely was lost when it ceased to be of use (Weismann, 1881: 24-5).

Comfort's specific criticism of this explanation of ageing and death was that it 'both assumes what it sets out to explain, that the survival value of an individual decreases with increasing age, and denies its own premise, by suggesting that worn-out individuals threaten the existence of the young' (Comfort, 1956: 9). In other

words, according to Comfort, Weismann did not explain why, but instead simply assumed that increasing age led to impaired biological function, and then argued, not wholly coherently, that this debilitating process none the less was of some benefit to the species. Comfort advanced instead the notion that 'senescence is to be regarded not as the positively beneficial character which Weismann believed it to be, but as a potentiality lying outside the part of the life cycle which is relevant to evolution' (Comfort, 1956: 39). More specifically, drawing on J.B.S. Haldane and Peter Medawar's bio-mathematical considerations on the genetics of populations and evolutionary process, he argued that natural selection operated most forcefully on those phases of the life cycle which were related to reproduction, so that the phenotypic expression of any deleterious mutations in these phases would be targeted more strongly than their expression in post-reproductive phases. This, according to Comfort, led to an accumulation of deleterious genes whose expression occurred in the later phases of the life cycle, eventually resulting in the genetic determination of the post-reproductive, gradual weakening of the organism commonly known as 'ageing'. In other words, the emergence of ageing and death was not the fruit of any selective advantage to the species, but a secondary and accidental consequence of the selective forces shaping earlier phases of the individual organism's life cycle, up to the termination of reproduction. Given such an intimate link between sex and death, which Comfort may have started to consider much earlier that the publication of *The Biology of Senescence* might suggest (see Comfort, 1950), it perhaps is no surprise that that Comfort is today more famous as the author of *The Joy of Sex* (1972) (see also Katz & Marshall, 2003; 2004).

The problem that Comfort's evolutionary account posed for Hayflick, however, was that the so-called 'age specific diseases' were to be understood as genetically determined diseases that expressed themselves in older populations, that is to say, in those populations which, thanks to social mechanisms, were able to survive beyond the completion of their reproductive functions. Ageing, from this evolutionary perspective, was a fundamental problem for geneticists and social policy analysts alone. Moreover, this understanding of ageing and death as fundamentally plastic has proved enormously captivating, especially as geneticists were increasingly able to demonstrate experimentally the plasticity of life span by repeatedly selecting sub-populations of fruit-flies such as *Drosophila melanogaster* and worms such as *Caenorhabditis elegans* which reproduced later than the norm for the population under examination (Meek, 2001; see also Haraway, 1997). Figures such as Hayflick then had to redouble their insistence that questions of life span were of little relevance to understanding the far more complex and clinically pressing questions of ageing, and it is no surprise therefore that Hayflick has latched on to more recent findings that those strains of *C. elegans* bred for longer life span are evolutionarily less fit than the normal strains (Hayflick, 2005). Extending the

organism's life span beyond the limits fixed by natural selection comes at the cost of increased illness, which is the problem that motivated the expansion of bio-gerontology in the very first place, so that the proper task of bio-gerontology is to understand the complex cellular and sub-cellular processes resulting in the decay of the organism's 'vigour'. In sum, Hayflick's thesis is that the central, organising question for bio-gerontology should be 'why are old cells more vulnerable to pathology and disease than young ones?' (Hayflick, 1998: 639; emphasis added). This construction of bio-gerontology and its task is important to understanding Hayflick's eventual shift from Comfort's to Kirkwood's evolutionary explanation of ageing and death.

Why do organisms live as long as they do?

While drawing on the evolutionary approach to understanding the phenomena of ageing and death which Alex Comfort popularised with the publication of *The Biology of Senescence*, Thomas Kirkwood's disposition toward August Weismann is far more positive that Comfort's. This is not simply because Kirkwood, as he himself suggests, attends to Weismann's *Life and Death*, rather *The Duration of Life*, the former of which offers an evolutionary explanation that avoids the group-selectionism implied by the statement that 'worn-out individuals are not only valueless to the species, but they are even harmful, for they take the place of those which are sound'. Rather, it is because, in this essay, Weismann articulates more clearly a pivotal distinction between 'germ' and 'soma', a distinction which, despite much conceptual confusion, has proved fundamentally important to the emergence of the genetic theory of heredity and its ambitions to account for all biological phenomena, from the genetic to the populational and evolutionary levels (see Churchill, 1987; Griesemer & Wimsatt, 1989).

According to Kirkwood's reading of Weismann, if there is continuity of life despite the ubiquity of death, it is because all organisms are potentially immortal, but the division of labour under natural selection has resulted in some organisms evolving two fundamentally different types of cells, somatic and germinal, to better insure the continuity of life against external, accidental causes of mortality, that is, against what Gilles Deleuze would eventually label as 'violent death'. It is this more general understanding that, Kirkwood claims, underpins Weismann's following statement:

> Probably at first the somatic cells were not more numerous than the reproductive cells, and while this was the case the phenomenon of death was inconspicuous, for that which dies was very small. But as the somatic cells relatively increased, the body became of more importance as compared with the reproductive cells, until death seems to affect the whole individual, as in the higher animals, from which our ideas upon the subject are derived. In reality, however, only one part succumbs to natural death, but it is a part which in size far surpasses that which remains and is immortal, the reproductive cells (Weismann, 1883: 145).

This distinction between the immortality of the germinal line and the mortality of the somatic line, rearticulated in terms of genes and organisms, is critically important to Kirkwood's alternative evolutionary explanation of ageing and death. Beginning in 1977, and drawing on optimality theories of evolutionary fitness, greatly popularised by Richard Dawkins' *The Selfish Gene* (1975), Kirkwood argued that the organism is the product of a process of balancing energetic investments in the somatic body, to enhance the chances of successful reproduction, and the cost of these investments to the continuity of the genetic line, which is equally exposed to entropic dissipation (see Kirkwood, 1977; Kirkwood & Halliday, 1979; see also Dawkins, 1975: 42-5). That Kirkwood's first two expositions of this idea have now been cited in over a thousand scientific papers, attests to its momentous importance. On this alternative evolutionary understanding of death and ageing, Comfort's notion that natural selection delayed the expression of deleterious genes is compatible, but it also is an unnecessary hypothesis which detracts attention from the genetic mechanisms that neutralise the phenotypic effects of any deleterious mutations. In other words, not only is the organism to be understood as constantly confronting the problems posed by entropic dissipation, specifically by genetic mutation, from its very birth, but the theory of 'disposable soma' also redirects the attention of evolutionary perspectives on the processes of ageing and death toward 'the evolved capacity of somatic cells to carry out effective maintenance and repair' as the key to understanding 'the time taken for damage to accumulate to levels where it interferes with the organism's viability, and hence … longevity' (Kirkwood & Austad, 2000: 235).

Importantly, from this alternative evolutionary perspective, which combines bio-demographic and molecular perspectives, the notion that ageing and death are genetically programmed is untenable, and the notion that there are any such things as genetically determined 'age-specific' diseases, though still plausible, is less than useful to bio-gerontology. The controversial nature of these implications is evident in the arguments around the question 'is there a program for aging?', which the editor of *Aging Cell*, Simon Melov, staged with the aid of one of Kirkwood's most important collaborators, the behavioural ecologist turned experimental gerontologist Steven Austad (Melov, 2004; see also Kirkwood & Austad, 2000). Furthermore, Hayflick's distinction between questions of longevity and ageing also collapses insofar as the two become intimately related, secondary effects of any damage to the genetically determined mechanisms which preserve the viability of the organism until successful reproduction and transmission of the genetic line. On the other hand, bearing in mind that Hayflick's prescriptive question for bio-gerontology is 'why are old cells more vulnerable to pathology and disease than young ones?', this alternative, evolutionary perspective entails a

partly shared redefinition of bio-gerontology as engaged in the identification of both those genomic mechanisms which ensure the preservation of reproductive functionality and the causes of their decay, whose complex and manifold, long-term, secondary consequences are expressed as the symptoms of old age and are a matter of concern to clinical, geriatric medicine. This approach might then entail, for example, attempting to trace the bio-molecular and bio-demographic pathways of aging individuals who might be 'at risk' of developing diseases such as Alzheimer's Disease backward, to the earliest possible manifestations of forgetfulness, to the earliest possible manifestations of Mild Cognitive Impairment (see Moreira, 2007). The aim here is to develop multiple interventions, both biomedical and behavioural, which might prevent clinical progression from Mild Cognitive Impairment to Alzheimer's Disease. This said, insofar as the differences between Alzheimer's Disease and non-age specific dysfunctional states are blurred in the process, Kirkwood also insists on jettisoning all qualitative contrasts between 'young' and 'old' as biologically meaningless and distracting. What is important is instead to better understand and intervene in the chain of external events which shorten or lengthen the 'time taken for damage to accumulate to levels where it interferes with the organism's viability, and hence … longevity' (see also Holstein, 2000; Ballenger, 2006).

In other words, following Kirkwood's alternative evolutionary explanation of ageing and death, the business of biomedicine is to enhance the ability of the individual to imitate the immortal germinal line. Though immortality itself is irretrievably denied by the evolutionary history of the human species, this redefinition of the business of bio-gerontology will at least result in squaring the mortality curve, that is, it will at least result in the fuller synchronisation of mortality and bio-social functionality. Such anatomo-political restitution of bio-social functionality, which is consonant with contemporary anti-ageist social policies, might even have evolutionary consequences, if it were to enhance the successful transmission of the genetic line. As Kirkwood and Daryl Shanley have put it, with respect to the evolution of menopause:

> Menopause enhances fitness by producing post-reproductive grandmothers who can assist their adult offspring by sharing in the burden of provisioning and protecting their grandchildren (Shanley & Kirkwood, 2001: 282).

Collapsing the boundaries between nature and culture, Kirkwood's argument is that the selfish logic of the gene does not necessarily disown obligation and responsibility to the elderly, but could in fact greatly enhance such sense of obligation and responsibility, if only humans were to fully come to terms with their constitution as disposable vehicles for the reproduction of the genetic line, if not life more generally. Arguably, this is no more than the biological translation of the Durkheimian arguments about immortality, which Zygmunt Bauman (1992) has advanced at the more orthodox, symbolic level (see also Rabinow, 1996).

Stabilisation?

As James Griesemer (2005; see also Griesemer & Wimsatt, 1989) has argued, with regard to Richard Dawkins' notion of the 'selfish gene', the appropriations of the categorical distinction between mortal, somatic lines and immortal, germinal line, which August Weismann articulated at the end of the nineteenth century, are conceptually problematic, insofar as they have involved an increasingly radical abstraction from the specific material entities and physiological processes to which the distinction originally referred. Not only is it then increasingly unclear how the distinction is supposed to relate to the different material contexts in which it is deployed, but it is also unclear how it is to be tested empirically. Perhaps unsurprisingly, the same applies to Thomas Kirkwood's intimately related theory of 'disposable soma', which seems difficult experimentally to tease apart from alternative evolutionary perspectives on ageing and death, and is not obviously supported by human demographic data (see Bourg, 2001; see also Promislow & Pletcher, 2002). The crucial historical question then is what stabilises the theory of 'disposable soma', despite these conceptual and empirical problems. Drawing on Michel Callon (1986) and Bruno Latour (1987), we suggest that the stabilisation of Kirkwood's understanding of ageing and death rests on a reconfiguration of the assemblage of interested actors.

The roots of the great success enjoyed by Kirkwood's theory among bio-gerontologists are to be found primarily in the way in which it directs attention away from death itself, toward the mechanisms involved in maintaining the viability of the organism in the light of its inherent fragility. This reorientation is partly operated by downplaying the importance of Alex Comfort's contributions to evolutionary explanations ageing and death, which limit the possibilities of intervention (see Holliday, 2000a; 2000b). This enables a fuller alignment of evolutionary perspectives with the field of bio-gerontology opened up by Leonard Hayflick's experimental demonstration that somatic cell lines are far from immortal. At the same time, however, this perspective also moves bio-gerontology away from Hayflick's thesis that the central question should be 'why are old cells more vulnerable to pathology and disease than young ones?', a thesis that still assigns a fundamental, biological meaning to chronological terms such as 'old' and 'young'. The aim of bio-gerontology becomes instead to understand the differences between the repair mechanisms of germinal and somatic lines. There can be little doubt that investigation of these mechanisms greatly expands the potential market for those pharmaceutical companies that have invested in the development of treatments for the ailments of old age, such as the Geron Corporation with respect to Alzheimer's Disease, because the threshold of treatment moves ever backward to encompass a greater fraction of the population. This said, Kirkwood

distinctive approach to the reconstruction of Alzheimer's Disease as an early onset 'degenerative' disease, which integrates research into the molecular bases of disease and bio-demographic considerations, is a reminder that the field of bio-gerontology is today developing within a more general reorientation of health policy toward the promotion of individual choices to avoid careless behaviours toward oneself and others (see Conrad, 1992; Petersen, 1997). In Kirkwood's case, it means both avoiding behaviours that undermine the continued viability of the molecular repair mechanisms, and engaging in those activities that apparently enhance the responsiveness of these repair mechanisms. In this, bio-gerontology seems partially disconnected to the technology-based interventions that appear to characterise contemporary bio-medicine (see Clarke et al., 2003) As Kirkwood puts it, in the last lines of *Time of Our Lives*:

> Freedom makes us individually responsible for our choices and our actions. Is this why we so readily drug ourselves into inactivity with low-demand time-fillers when we could do so much? Let us be truly alive, so that when old age finally robs us of our vitality, we may feel that the time of our lives was well spent (Kirkwood, 1999: 242; see also Katz & Marshall, 2004).

This call-to-arms to maximise the returns of human capital has resonated so loudly that, in 2004, Kirkwood became the scientific adviser to the House of Lords inquiry into the *Scientific Aspects of Ageing*, which was 'especially interested in the biological processes of ageing, and in promising areas of research which might benefit older people and delay the onset of long-term illnesses and disabilities' (House of Lords, 2005; emphasis added).

In sum, Kirkwood has striven firstly to distance bio-gerontology from geriatric medicine, insofar as the latter might be understood as a field of clinical specialisation concerned with the diseases of a nosologically distinct population, the elderly. As these diseases are re-articulated as unfolding temporally onto antecedent risk factors and bio-molecular pathways, they become part of that wider set of 'degenerative diseases' which characterise advanced societies, that is, those societies where the anatomo-political and bio-political governmental forms converge most forcefully. Within this configuration of bio-gerontology, all of these diseases might be said to entail 'ageing', but in so expanding its domain of application the term 'ageing' loses its identity as a process of its own kind. Secondly, bio-gerontology can then speak to all clinical practitioners involved in managing these degenerative diseases, from the primary care practitioners controlling their middle-aged patients' hypertension to the specialised clinician assessing the earliest symptoms of Alzheimer's Disease. From this perspective, bio-gerontology also offers opportunities of development to a great variety of actors in the market for health care, not only those interested in developing drugs to modulate and possibly prevent the mechanism that lead to degenerative disease, but also to those providing

the wherewithal and support to secure 'healthy lifestyles' . Thirdly, bio-gerontology stabilises a central expectation of health providers, private and public, namely reducing the prevalence of degenerative diseases and thus reducing the aggregate cost of provision: from their perspective, it would be better if we all died of a sudden, massive heat-attack or some such 'catastrophic illness', rather than developing long-term, debilitating and ultimately fatal conditions such as Alzheimer's Disease. Fourthly and finally, and perhaps most importantly, bio-gerontology re-articulates what has been called the 'problem of aging' in contemporary, advanced societies by reinforcing the increasing re-orientation of health policy towards prevention and health surveillance. In so doing, diseases of the elderly come to represent failures of these preventive and surveillance systems, and thus the unwelcome remains of a previous epoch where death, as terminus of a biologically unavoidable process of decay, dominated the epistemological and political landscape of medicine.

Importantly, if this is the more credible horizon of bio-gerontology, mediating the interaction between the therapeutic culture of modern, clinical medicine and the emerging discourse of personal responsibility for bodily dysfunction, ageing, the gradual process of declining biological function, will eventually be no longer. This is crucial to better understand the implications of Gilles Deleuze's claim that the emerging governmental order is one in which the modern calculus of finitude gives way to the unlimited recombination of a finite number of components. After Martin Heidegger (1962: 297-311), the notion of human finitude, to which Michel Foucault and others attached great importance (see Palladino, in press), could only be constructed around the phenomenological experience of ageing and decline. If, however, this experience of ageing and decline were to disappear and be replaced by the sudden death conjured by the perfectly squared mortality curve, so would the notion of finitude, for which death has long been the symbolic figure. In other words, despite Kirkwood's objections to the claims articulated by the like of Aubrey de Grey that the genomic sciences will soon deliver something approaching human immortality, Kirkwood's more conservative programme for the future development of bio-gerontology very powerfully helps to constitute a wholly new understanding of human embodiment. If the effective contamination of youth by old age, which bio-gerontology effects by pushing the physiological precursors of ageing and death ever backward in time, might seem to reaffirm and materially bolster the old adage that 'as soon as man is born, he begins to die', by proposing the biological needlessness of ageing, bio-gerontology also begins to lend material foundations to the growing perception among successive cohorts that death is a preventable and unnecessary event. From this perspective, the arguments around 'anti-ageing' medicine are perhaps best described as the equally proverbial 'storm in a tea-cup'.

Conclusion

Paul Rabinow, Nikolas Rose and others have argued that we are currently witnessing a truly epochal transformation of governmental mechanisms, which Rose himself has characterised as the advent of a politics structured around 'life itself'. Since the argument is indebted ultimately to Gilles Deleuze's observation that, in the age of 'molecular biology', the governing truth no longer is the finitude of human life, but the endless possibilities of bio-molecular recombination, we have then sought to ask how the phenomenon of death might figure within the emerging governmental order.

While aware of, and in fact indebted to, an extensive literature on the contemporary social and cultural reconfiguration of ageing and death, we have sought to answer our question about the fate of death by attending to the complex relations within the epistemic practices of bio-gerontology, the scientific field which seeks to characterise the bio-molecular and bio-demographic mechanisms involved in the process of ageing and its consummation in death. We have also sought to consider death as a specifically biological phenomenon because it is only at this level that we can properly examine the extent to which the contemporary transformation of governmental mechanisms might be understood as marking a properly onto-historical rupture. It is from this perspective that we have explored the interactions of intellectual formations, material infrastructures and institutional contexts that have shaped the emergence of bio-gerontology and its programme to deliver what the leading bio-gerontologist Thomas Kirkwood calls the 'end of age'. We have argued that, although figures such as Kirkwood have challenged the scientific merits of ever-more frequent public statements that immortality is today within reach of the bio-medical sciences, these very critiques are critically important to the elimination of death: although immortality itself might be foreclosed by the evolutionary history of the human species, the prospective elimination of chronic, degenerative diseases and the resultant squaring of the mortality curve powerfully, if not definitively, exorcises the spectral presence of death from the contemporary discourse of public health.

This said, we also wish to suggest rather more tentatively that this reconfiguration of death should be interpreted as exactly that, as a re-configuration of the same. In other words, death and the epistemic values attached to it have in fact neither disappeared nor been evacuated, but have instead moved further into the role of epistemic material within the practices of laboratory science that both support bio-gerontology and the experimental programmes of the bio-medical disciplines concerned with degenerative diseases. In this process, death is not the primary object of experimentation, as was the case with the practices that fascinated Michel Foucault, but it becomes part of an interpretative strategy to make sense of experimental outcomes.

If, as Kirkwood and others suggest, death is mainly the work of accident and the violence of our life-styles, the death of cells in the laboratory is interpreted as evidence of unsound handling or managing of life within experimental systems, that is to say, it is interpreted as experimental error. This understanding reaffirms Georges Canguilhem's perceptive suggestion that the genomic sciences introduce a new understanding of disease and death, namely that they are the consequence of 'error', the computational error of a life system (Canguilhem, 1991: 275-287). On the other hand, as Canguilhem would have also commented critically, death still figures as a possible outcome of bio-medical research, as a possible outcome of a particular experimental procedure or therapeutic intervention, and, moreover, it is the comparison between life and death which constitutes the epistemic value of the experiment or the intervention in question. This understanding of bio-gerontology and its epistemic practices, we suggest finally, might be quite important to our more general understanding of the politics of 'life itself'.

Paraphrasing Michel Foucault, we might say that the centrality of death to the modern governmental formation derived from the triangulation of ontology, epistemology and existential meaning (see also Ariès, 1987). From this perspective, bio-gerontology's articulation of death might be said to have destabilised this triangular relationship by undermining the radical epistemic obscurity that troubled Xavier Bichat, but such destabilisation has not resulted in any concomitant ontological and existential shift. After all, death or the productive process of dying continues to be a significant component of social life in contemporary societies, and the ontology of death remains at odds with the epistemic path blazed by bio-gerontology. In other words, Deleuze's formative suggestion that the contemporary development of the bio-medical sciences heralds a properly onto-historical shift must remain a matter of further debate, because, despite all the epistemic, techno-scientific reconfigurations which we have only begun to trace in this paper, contemporary culture and society would not seem to have moved any great distance from Bichat's famous dictum that 'life is the sum of all activities that resist death'.

Notes

[1] Significantly, the offer was withdrawn in the wake of the court litigation between Hayflick and the National Institutes of Health over the ownership of the WI-38 somatic cell line, long before the question of legal ownership over living materials was settled by the United States Supreme Court (see Jaffe, 1990; Rattan, 2000). From this perspective, Hayflick might also be said to have contributed very importantly to the contemporary reorganisation of the political economy of the biomedical sciences.

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Figure 1

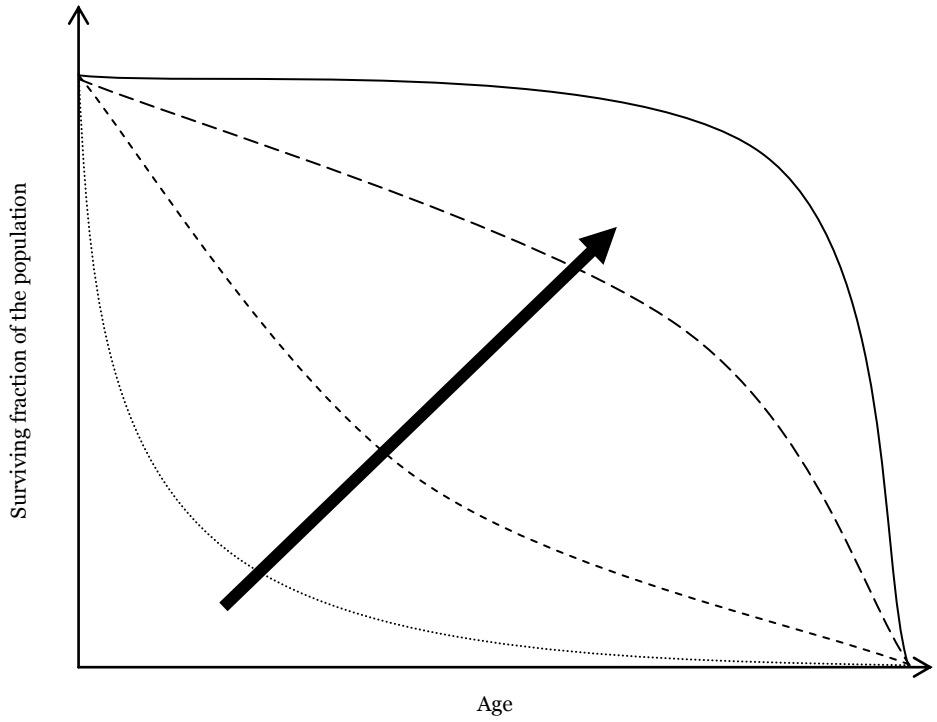

Figure 1: Squaring the mortality curve