Anticipatory Measure: Alex Comfort, experimental gerontology and the measurement of senescence

Ageing is routinely measured by counting the number of years lived since the birth of an individual, as this both facilitates a wide range of classificatory practices and decision making procedures inherent to modern bureaucracies (Kohli, 1986; Treas, 2009), and is a good predictor of age-specific mortality at an aggregate level (e.g. Kirkwood, 2015). Since at least the 1930s, however, the validity, precision and sensitivity of chronological age as a measure has been criticised across the biological and behavioural sciences focused on ageing (Moreira, 2017: 71-95). In the biological and biomedical sciences, the search for an alternative, more accurate, individualised index of ageing, while drawing on earlier work seeking to mobilise concepts and techniques used in child development research in the 1920s and 30s into the ageing domain (Moreira and Palladino, 2011), has been led by isolated researchers since the late 40s (e.g. Benjamin, 1947), acquiring a more collective dimension from the late 1980s, with the National Institute of Aging Biomarkers of Aging Funding Initiative (Baker and Sprott, 1988). In this process, establishing a measure of individualised 'biological age' has become a central concern for biologists of ageing and epidemiologists in the past three decades, supported by a variety of research programmes and consortia, hinged on the possibility of technologically manipulating the rate of ageing to delay the onset the age-associated diseases (e.g. Lopez Otin et al, 2013; Burkle et al, 2015; Lara et al, 2015; Horvart and Raj, 2018; Niedernhofer and Robbins, 2018; Partridge, Deelen and Slagboom, 2018)

However, despite continued and on-going work to establish and implement a biomarker of ageing, there are currently no validated measures of biological ageing in use. What might explain this inability to put an alternative measure of ageing into operation? Researchers in the biology and epidemiology of ageing have attempted to explain this failure in two ways. On the one hand, they argued that fundamental methodological problems hindered research on biological age. Key in this was the suggestion that the variation on the rate of ageing across organ systems and within the life course of individuals undermine the ability to devise a single metric of biological ageing for specific organisms (Costa and McRae, 1980; Ludwig and Smoke, 1980; McClearn, 1989). On the other hand, they proposed that biological age measurement, if implemented, would disrupt established ways of researching age-related physiological or pathological processes, and of linking these to technological innovation, policy and practice in health care, which relies substantively on chronological age (Costa and McCrae, 1980: 45). In other words, biological age would unsettle the infrastructural, institutional economic and political arrangements that historians have variously labelled techno-medicine (Pickstone, 2000) or biomedicine (Keating and Cambrosio, 2003).

In this article, I argue that measures of biological ageing have not come into use for *both* methodological, scientific reasons *and* institutional, political reasons. To do this, I explore the work of Alex Comfort between the early 1950s and the late 1970s. Comfort (1920-2000), nowadays mostly known for being the author of *Joy of Sex*, was arguably the foremost gerontologist of the second half of the 20th century, writing the standard textbook, of the time, for biology of ageing (Comfort, 1956/1964), founding and editing the journal *Experimental Gerontology* (1964-), popularizing the scientific study of ageing and publicly advocating for the rights of older people (e.g. Comfort, 1976).

As referred above, while it is possible to identify earlier attempts to develop a measure of biological age, ageing researchers usually agree that Alex Comfort's work in this area at the turn of the 1970s (Comfort, 1969; Comfort, 1972) established the scientific justification and methodological foundations for the current approach to this problem (Kirkwood, 1998; Jackson, Weale and Weale, R. A., 2003; Levine, 2012; Lara et al, 2015).

This is a somewhat surprising role to attribute to a researcher who had, in the previous two decades, been consistently arguing for an evolutionary understanding of ageing as "a weakening of the directive force of [genetic/developmental] programmes" (Comfort, 1956: 190). In this earlier, framework, the only meaningful measure of ageing was seen to be an estimate of senescence – the "increased liability to die with advancing chronological age" – "determined statistically upon a population" in the form of age-specific mortality rates (Comfort, 1956: 17-18). Understanding Comfort's shift in approach to the measurement of senescence, from an early emphasis on the effects of the 'force of mortality' on populations, to the development of instruments to gauge individuals' somatic 'vulnerability', requires, I suggest, not only paying close attention to the trajectory of Comfort's experimental programme but also to how Comfort himself articulated, over three decades, this work with a vision of a new experimental gerontology, which he saw as key in bringing to bear a new approach to the management of health and disease, and a correlated transformed biosocial order.

Drawing on published and archival sources[1], the paper describes how this dynamic between research and 'vision' unfolds in the evolution of Comfort's work on ageing. The paper first describes the establishment of Comfort's laboratory at University College London between 1952 and 1963, and its role in evidencing the usefulness of the 'modern evolutionary synthesis' for the study of ageing. In the second section, the focus is on how the position of the laboratory was destabilised by experimental difficulties, institutional instabilities, and a progressive shift in Comfort's position on gerontology's capacity to modify human life span. In this period, between 1964 and 1968, Comfort outlined the contours of a gerontological utopia, drawing closely on Julian Huxley's technocratic imaginary (Smocovitis, 2009; Esposito, 2011; Renwick, 2016). In the third section, the paper describes how Comfort's development of a new form of age measurement was prompted by threats to the existence of his laboratory, stemming from institutional scepticism about gerontology's capacity to transform human life-span. In this context, Comfort's metric of the rate of ageing should be seen as an attempt to embed experimental gerontology in a new institutional arrangement of researching and managing health and illness. In the last section of the paper, I describe how, following the closure of Comfort's lab in 1973, and his move to the US, his attention progressively shifted towards detailing the human and social implications of the new gerontology, and attempting and failing to embed its technological expectations in central policies and programmes of the US federal government.

While the paper suggests that Comfort's proposal for the measurement of ageing is a historically contingent, locally induced attempt to reposition biological research on ageing in a specific policy landscape and institutional network, I propose that the failure to do so is indicative of wider challenges in developing and implementing biological ageing metrics. In the conclusion, I discuss

[1] The principal archival sources are the Alex Comfort Papers and the Medical Research Council Archive, both in the National Archives. References will be coded as ACP: [box number]: [document title and date] and MRC: [document title and date]

how the configuration of conditions that stymied Comfort's scientific and political work is key to understand the marginal position biology of ageing has occupied until recently.

Evidencing the evolutionary theory of ageing (1951-63)

As recounted by Park (2016: 192-93), in 1951, Alex Comfort persuaded Peter Medawar to support his application to the Nuffield Foundation to research ageing. Medawar, having moved from Birmingham to UCL's Department of Zoology, viewed ageing a key domain to make the 'modern evolutionary synthesis' – the combination of Mendelian genetics with Darwinian evolutionary theory (e.g. Huxley, 1942; also Smocovitis, 1992) - relevant to contemporaneous social and economic problems (Medawar, 1952). Comfort, a qualified physician, then a Lecturer in Physiology at the London Hospital Medical School, was also mildly popular novelist and an established political activist and theorist, but had no formal postgraduate training in evolutionary biology. However, his proficiency in physiological and biochemical experimental techniques combined with a keen interest in the relationship between growth, development and ageing, on which Medawar has focused a significant proportion of his work (Park, 2016), counted in his favour.

The Nuffield Fellowship grant enabled Comfort to establish his own laboratory and commence the reviewing work that would lead to *The Biology of Senescence* (Comfort, 1956). Experimentally, his first project addressed the genetics of growth and senescence. A few years earlier, Albert I. Lansing, working with rotifers as experimental animals, had proposed that development and longevity of offspring was affected by parental age (Lansing, 1948). This meant that the relationship between the cessation of growth and the launch of senescent processes, originally posited by Charles Sedgwick Minot, was a transmissible factor embedded in the germinal line. Working with *Drosophila Subobscura*, Comfort (1953) questioned the universality of this claim. In parallel, Comfort's lab hosted John Maynard-Smith[2] work with *Drosophila* on heterosis and hybridity, which suggested that the development and life-span of outbred organisms was less susceptible to environmental conditions than that of inbred ones (Smith and Smith, 1954). Both of these were in close alignment with J. B. S. Haldane's[3] (1932) view on the genetic basis of Darwinian fitness, but pointed to a deeper problematic about the biological nature of senescence.

If there was no genetic factor for longevity or the onset of senescence, how could ageing be explained biologically? This had been Medawar's focus on his inaugural lecture at UCL in 1951, *An Unsolved Problem in Biology* (Medawar, 1952). Drawing on the work of R. A. Fisher (1930), his theory was that, in an optimal population, the reproductive value of organisms was inversely correlated with the probability of death (Medawar, 1946: 37-39). If, as Fisher (1930:29) suggested, natural selection processes acted primarily on traits expressed in reproductive age, "the incidence of natural death had been to a large extent moulded by the effects of differential survival". This meant that in natural populations, where accidental death is widespread, "failure to become senescent early, or at all, has little value from the point of view of survival" (Comfort, 1954: 309). This proposition amounted to a rejection of Weismann's hypothesis about the evolution of senescence as an adaptive response to Malthusian pressures (Medawar, 1946; also Moreira and Palladino, 2008).

[2] John Maynard-Smith conducted post-graduate research under JBS Haldane's supervision, working on Drosophila Subobscura at Helen Spurway's laboratory, before integrating Comfort's lab in 1952.

[3] John Burdon Sanderson Haldane was Professor of Genetics from 1933 and Professor of Biometry from 1937 at UCL, a post he held for the next twenty years.

From the perspective of the modern evolutionary synthesis, the weakening of the forces of natural selection explained the onset of senescence. This had two possible, if not incompatible, implications. One, originally articulated by Haldane (1941) and the main focus on Medawar's 1951 inaugural lecture, was that the weakening of natural selection had enabled the manifestation of deleterious genes which had been pushed to regions of the lifespan only experienced by domesticated animals and 'civilised man'. Famously, Medawar used the example of Huntingtons' to propose the 'theorem' that,

> *if hereditary factors achieve their overt expression at some intermediate age of life; if the age of overt expression is variable; and if these variations are themselves inheritable; then natural selection will so act as to enforce the postponement of the age of the expression of those factors that are unfavourable, and, correspondingly, to expedite the effects of those that are favourable —a recession and a precession, respectively, of the variable age-effects of genes.(Medawar, 1952: 67)*

In conditions where a significant proportion of individuals within populations were able to experience post-reproductive life, the consequence of this theorem was that that section of the lifespan "becomes, as it were, a dustbin for the effects of deleterious genes."(Medawar, 1952: 68). The 'dustbin' theory of ageing relied, however, on the hypothesis that the force of genetic determination of the organism was continuous across the lifespan.

Another possibility was that because natural selection had acted most forcibly on organisms in shaping their development and traits within reproductive age, post reproductive age was characterised by genetic scatter and stochastic effects. Such an hypothesis derived from the combination of Medawar's own work on the 'orderliness' of growth and form (e.g. Medawar, 1941; also Park, 2010) and the Fisherian inverse relationship between the reproductive value of organisms and the probability of death. The programmed order of growth and development contrasted thus with the disorderliness of post-reproductive age. Comfort labelled this phenomenon 'morphogenetic senescence':

> *At the point where a system of differential growth ceases to be regulated by forces which arose from natural selection, it would cease to be under effective directional morphogenetic control, and would resemble an automatic control device which has run out of 'programme'. In any such systems the equilibrium must be increasingly unstable (Comfort, 1956: 41)*

Comfort was convinced that while the genetic 'dustbin' theory was more applicable to organisms with longer lifespans, as populations would be more age differentiated, the morphogenetic theory was capable of unifying the diversity of effects - genetically determined or not- observed in post reproductive age. This he linked to the central biological concept of homeostasis, but conceptualised it by drawing on what he defined as a 'cybernetic' process, arguing that "senescence can be regarded as a continuously self-aggravating dis-equilibrium (a positive feedback process)" (Comfort, 1956: 175). Comfort's familiarity with cybernetic thinking was provided by Haldane, on whom he frequently relied for knowledge of the biological literature and more widely (ACP: 23: Scientific notes). Haldane had known Nobert Wiener, one the founders of cybernetics, since the 1930s, and, under his influence, had, just before Comfort took his fellowship at UCL, prepared a – ultimately never published - manuscript on the application of cybernetics to biology, taking genes to be information programmes –signals – controlling the behaviour of components of the system and their

response to each other (Kay, 1997: 43-44; also Galison, 1995, Rheinberger, 1995). Comfort's suggested that increasing noise to signal ratio in the system with ageing produced not only incremental, quantitative changes but also qualitative shifts in the nature of "biological cybernetic mechanisms" (Comfort, 1956: 176). These changes underpinned the increased somatic vulnerability that defined senescence, i.e. the "increased liability to die with advancing chronological age" because of the decreased ability to maintain equilibrium in changing circumstances.

This meant that while it made sense to standardise the physiological measures of growth and development (Medawar, 1941; also Moreira and Palladino, 2011), it was difficult, if not impossible to do the same for the measurement of senescence, given that it was inherently disorderly. This position set Comfort apart from the gerontological establishment of the time. Indeed, it had been one of the aims of gerontological research since its foundation in the 1930s that it should be possible to develop a measure of 'physiological time' or physiological ageing that indexed organisms' specific rate of biological ageing (Moreira, 2017: 71-95). Nowhere is this disagreement more evident than in this exchange between Comfort and some of the most well-known gerontologists of the time in the First CIBA Colloquium on Ageing in London in July 1954:

> *Shock: Does a definition of ageing have to be limited to decreasing functions? […]*
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> *Cowdry: [I]t can be increasing.*
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> *Krohn: Well, that is the meaning of ageing, isn't it? You use the word "ageing" to mean any change as the organism gets older. You have to use perhaps "senescing" for deteriorative changes.*
>
> *Cowdry: I have a definition. Ageing is change with time in the life cycle.*
>
> *Lansing: Would you care to qualify that and make it change with time in the adult organism?*
>
> *Cowdry: No. […]*
>
> *Comfort: In Prof. Medawar's temporary absence I would like to put in a plea for his definition of senescence, as the increase in liability to die with advancing age. It may be proper to distinguish ageing from senescence, but in that case I think we can scrap ageing altogether and call it development, because gerontology is an entity which only comes into existence to describe a process human beings don't like, a deteriorative process, and I take it that it is senescence with which we are concerned here. Earlier in the meeting Dr. Lansing made a declaration of faith on the subject of the overall unity of the senescent process. He said that we ought to look for underlying processes which explain all senescence[…] But if we do accept […] the idea of senescence simply as the increasing liability to die with increasing age, then the most striking thing in comparative studies is its diversity. […] don't want to speak out of turn, but I'm somewhat sceptical of this underlying unity of any ageing process; I think we should be empirical about it, and treat senescence simply as a name for that whole group of causes which make animals have a determinate life-span instead of an indeterminate one. (Wolstenholme and Cameron, 1955: 242)*

The disagreement was stark, as was the differential in status between Comfort and his interlocutors implied by the former's not 'wanting to speak of out of turn'. On the one side, Nathan Shock – then Director of the Section on Gerontology, Baltimore City Hospitals -, Vincent Cowdry – considered one of the founders of the field -, and Lansing – of the 'Lansing effect' (above) - seeking to agree on a

definition of ageing that differentiated it from development in the organism, and whether it should include physiologically deteriorative processes only. Comfort undermined the basis of their discussion by expressing scepticism about the 'overall unity of the senescent process', which their discussion presupposed. Comfort's argument, explicitly representing the British evolutionary synthesis approach, was that while it was possible to observe and measure 'an increased liability to die with advancing age' across many domesticated species, the physiological causes of this increase were too heterogeneous across and within populations to attempt developing a standard measurement, it being "*rare that we can determine the vulnerability of an individual*" (Comfort, 1956: 17; my emphasis)

This unsettled the foundation of the discipline of gerontology - as Shock, Cowdry and Lansing were articulating it -, as there would be no stable empirical referent (physiological ageing), gerontology instead coming only 'into existence to describe a process human beings don't like'. The redefinition of ageing proposed by Comfort implied not only a fundamental reorientation of the field, and but also a problematisation of the relationship between gerontology and geriatrics and medicine in general. Instead of seeking to define and measure 'normal ageing' to differentiate from 'pathological ageing', as had been proposed by Shock (Moreira and Palladino, 2011; Bookstein and Achenbaum, 1993), gerontologists should focus on the diversity of effects stemming from the weakening of natural selection. This implied another relationship with medicine. Comfort, trained as a physician, thought that it was necessary for gerontology to get to grips with the diversity of ageing before it could envisage how it could impact on human lifespan or health (Comfort, 1956: 189-200). From 1953-54 onwards, Comfort translated this research strategy into two different projects.

The first entailed testing whether senescence could be observed in domesticated vertebrate species of different sizes, growth patterns, life spans, etc. Drawing on Haldane's (1953) adaptation of actuarial methods to reconstruct survivorship curves in wild species, Comfort identified settings where record keeping of the births and deaths of individual animals would be good enough to enable the production of life tables: zoos, cattle, dog and thoroughbred racehorse breeders. However, he soon found out that those records mostly documented only "small batches of lives [where] the losses to the record, by sale, deliberate killing, or disappearance amount to half the initial population or more" (Comfort, 1958: 267; also Comfort, 1957). It was not only that archival research skills were unfamiliar to Comfort, but also that he had to rely on breeders informal knowledge of particular animals to piece together a cohort that would be statistically acceptable (ACP: 24: Scientific notes). One exception to this was *The General Stud Book of Racehorses*, which included not only information on progeny but also other details such as colour that enabled the testing of particular hypotheses of specific hazards. By 1958, Comfort had been able to assemble particulars of 5000 life stories of racehorses but was struggling with how to compute the amount of data he had collected, considering the use of IBM punch cards to calculate differences across sub-populations (ACP: 24: Scientific notes).

The second research project was equally challenging, but for different reasons. Guided by the 'morphogenetic hypothesis' (above), Comfort decided to abandon the fruit-fly as experimental model and to focus on the guppy (*Lebistes*). There were three reasons for this choice. Fish populations were reported to not experience increased mortality with age, representing thus an extreme case where growth was indeterminate. An explanation for this phenomenon had been proposed by George Parker Bidder's (1932) hypothesis that ageing had been the evolutionary price

paid by species that ventured into a land environment. Bidder had further suggested that for land living vertebrates, growth and aging were mutually antagonistic states, so that fish that grow throughout life would not exhibit aging, and hence, were potentially immortal. This was Comfort's second reason to select the guppy as experimental model because, like in his 'testing' of the Lansing effect, it enabled him to challenge an accepted evolutionary hypothesis about the origins of ageing.

The third reason was that the guppy was by the beginning of the 1950s, a standard animal model in experimental biology, having been the animal where Y-linked inheritance was first demonstrated (Schmidt, 1920). Again, Haldane's familiarity with this work appears to have been crucial. More important however was Comfort's link to Helen Spurway[4], Haldane's wife and collaborator, who was then a lecturer at the Biometry Department at UCL. Spurway, a meticulous experimenter and observer, had by 1953 amassed a stock of knowledge on the various conditions in which guppies might be kept (Comfort, 1956: 75). Drawing on Spurway's knowledge, Comfort was able to adapt Clive M. McKay's procedures for restricted food diet – originally developed for mice (Park, 2016: 129-169) - to the guppy, combining those with other conditions known to affect growth such as temperature or living space (Comfort, 1958). This he hoped to configure as a test of whether his interpretation of McCay's work as showing that caloric restriction "simply slow[s] down the perforated tape you're feeding to the calculating machine, senescence […] taking place when the tape is exhausted" would bear out (Comfort in Wolstenholme and Cameron, 1955: 30)

Experiments with guppies, however, had never focused on longevity or senescence, which implied recording growth variables and mortality over a long period of time. Although a short lived species by fish standards, guppies were known to live up to 1000 days. By 1956 Comfort became increasingly aware that 1000 days did not represent maximum life span. This considerably extended the amount of work Comfort had planned to dedicate to these experiments, compounded by his aims to combine measurements of growth and senescence with the work of dissecting animals, and preparing and analysing pathological slides of key tissues. Guppies' unexpected longevity meant that Comfort had to focus solely on recoding and measurement of growth and ageing. Almost nine years after Comfort first started working with guppies, he eventually published a series of papers demonstrating that aging in guppies occurs in the presence of the ability to grow (Comfort, 1960; Comfort, 1961a, Comfort, 1961 b). For Comfort, this overlap added strength to the 'morphogenetic hypothesis' and its cybernetic interpretation, demonstrating that ageing was not a measurable ordered series of physiological changes that followed development but simply a "programme [operating] with a steadily increasing noise" (Comfort, 1958: 278)

Envisioning experimental gerontology (1963-1968)

From 1962 to 1963, again linking to Medawar's position with key funders, Comfort's lab support was transferred to the Medical Research Council for an initial period of two years, extended in 1965 for another 5 years. The awarding of the grant was been predicated on the strength of Comfort's work on life tables and *Lebistes*, but also Maynard-Smith's research on, for example, the trade-off between fitness, longevity and fecundity (Smith, 1959). Although it was not possible to find the original grant proposal, from the archives it is possible to gather that the proposal was hinged on the aim to make gerontological research relevant to clinical medicine. The plan was to focus on "the

[4] Helen Spurway obtained a PhD in Genetics under Haldane's supervision, and was responsible for the UCL laboratory working on Drosophila Subobscura. She shifted to Lesbistes around the turn of the 1950s.

ageing processes present in fixed post-mitotic cells" (MRC: RGBA MRC Report 1969: 1)[5] but ended up including a variety of projects.

One entailed extending Maynard-Smith's research into age-related changes in the genome and protein synthesis in Drosophila, investigating the role of the amino-acid leucine in cell metabolism. Comfort, with the help of a graduate student, intended to shift to a simpler experimental model – the nematode – to investigate loss of regenerative capacity associated with senescence. A third major project – led by Irene Gore[6] - envisaged making use of a rat colony associated with the lab to research the biochemistry and physiology of muscle frailty, a well-known ageing phenotype which represented the clearest bridge to clinical practice. However, the network that had supported Comfort's lab success and productivity in the years before was showing increasing signs of strain.

Already in 1957, Haldane and Spurway had left UCL, Comfort losing both a key institutional and political ally in Haldane and a guide and mentor in animal experimentation in Spurway. Medawar, on which Comfort had relied to translate the significance of his work to funders and policy makers, left to head the National Institute of Medical Research in 1962, just before the MRC funded lab began operations. Just one year after into the MRC grant, Maynard-Smith left UCL to take up the position of Dean at the University of Sussex, which he had helped create. These appear to have hindered Comfort's ability and/or willingness to lead the lab, which manifested in a series of experimental difficulties in the years to come. Maynard Smith's main collaborator, Jean Trent, in his absence, experienced problems in calibrating methods of protein synthesis analysis and in maintaining batches of fruit flies alive in experimental conditions (MRC: RGBA MRC Report 1969: 6). Comfort's own study of nematode longevity was abandoned. Gore's work "ran into a lot of technical trouble" (MRC: RGBA MRC Report 1969: 8), requiring expertise in biochemistry techniques which she did not possess.

Indeed, between 1964 and 1969, Comfort did not publish one single scientific paper based on new experimental work and data. Instead, his attention appeared to have been focused on what he later described as "missionary and apostolic activities", "meddling with the research of other workers" (MRC: RGBA MRC Report 1969: 2). One of such activities was his editorial work in *Experimental Gerontology*. This involved a significant amount of networking and of seeking submissions from researchers who otherwise would not have thought of their work as relevant to gerontology. Comfort soon realised that to do this it was necessary to develop a vision of the aims of experimental gerontology so as to recruit and enrol researchers and policy makers. The unfolding of this positon would take a few years to develop, and was accompanied by a transformation of the character and extension of his research network

Already in 1956, in the first edition of *Biology of Senescence,* Comfort had aligned experimental gerontology as an "applied science of ageing" with what Esposito (2011) has labelled the technocratic utopianism of J.S. Huxley (1942). Arguing that "senescence has no function", Comfort suggested that the evolutionary "process of cephalization" would enable the development of a collective, scientific programme of experimentation to understand the basis on which extended

[5] Mitosis is the process of cell division whereby one divides to produces two 'daughter cells'. Mitosis is linked to growth and to cellular repair.

[6] Irene Gore, BSc and MSc in Biochemistry (Sidney), obtained a PhD (Mill Hill, London) on the biochemistry of cholesterol before integrating the UCL Research group on the Biology of Ageing in 1963.

longevity could be achieved (Comfort, 1956: 191).Then, he envisaged three possibilities: genetic interventions; developmental re-programming; and "piecemeal adjustments of homeostatic mechanisms" (Comfort, 1956: 194). However, he considered the first beyond human reach, the third limited in effect, leaving only the second as a viable research programme, even if at the time there was no "direct evidence that it applies to the later stages of life cycle" (Comfort, 1956: 196).

In the second edition of *Biology of Senescence*, Comfort (1964) maintained his vision of the three pronged programme for a gerontological utopia, but claimed that not enough was known about the genetics of development to "merit discussion", and expressed disappointment that most of the energy was focused on 'piecemeal adjustments' to human ageing processes "as opposed to fundamental research into its biology" (Comfort, 1964: 276). Insisting on the priority of focusing on the mechanisms of development and how it could be 'slowed down', Comfort tempered his own optimism with the argument that "the fundamental change which leads to eventual senescence [may have] already taken place at puberty" (Comfort, 1964: 277). This was an objection that emerged directly from an evolutionary framing of ageing, powerfully encapsulated by Bernard Strehler in his *Time, Cells and Aging*:

> *The evolutionary dereliction is probably so manifold and so deeply ingrained in the physiology and biochemistry of existing forms, including man, that the abolition of the process is a practical impossibility' (Strehler, 1962: 368)*

Strehler had been recruited in 1957 by Shock to the Gerontology Branch to reinforce their work on experimental biology of ageing, working on the role of radiation and temperature in the ageing process (e.g. Strehler, 1959). These were interpreted to be model conditions to test the 'adaptability reserve' of cells and tissues, an "organism consist[ing] of a number of subsystems, each of which has a certain maximum ability to re-store initial conditions after a challenge (Strehler and Mildvan, 1960: 133). Strehler's view was that such conditions had only limited effect on the deployment of genetic programmes resulting from natural selection. Although sharing a similar cybernetic view of ageing as Comfort, Strehler was sceptical about the malleability of 'genetic programming', and the capacity of environmental factors in accelerating or decelerating the onset of senescence. What was left, for the foreseeable future, were the 'piecemeal adjustments' to homeostatic processes.

Comfort viewed this position as limiting the scope and ambition of experimental gerontology, and the promises it embodied for social change. To challenges this position, Comfort drew again on the technocratic utopianism of Huxley, one where the application of knowledge was directed by an expert-led understanding of the direction and meaning of evolution, a process culminating in the development of modern science, and particular biology. Speaking to the technological forecaster Robert Prehoda in 1966 (see also Prehoda, 1968), Comfort suggested that,

> *[t]he rate of scientific progress in life extension might conceivably become so rapid that provided one was young enough for treatment, one might hope for a series of life extension bonuses. This has already happened in other fields of medicine such as chemotherapy. […] We ought to try and devise critical experiments and if we destroy more hypotheses that we demonstrate, gerontology can well stand such treatment in contrast to the speculation which has gone before [ACP: 6: Comfort in Prehoda, R (1967) Controlling the ageing process: 3; also Comfort, 1964: 282)*

For Comfort, scientific progress in medicine provided evidence of the potential of an experimental gerontology. Guided by strong methodological procedures, of hypothesis building and experimental design, gerontology would align itself with the direction other branches of biological knowledge had taken in modern times. As the extract makes clear, Comfort took as the model for this approach the field of 'experimental medicine', implicitly referring to the renewed optimism and investment in the therapeutic potential of chemotherapy following its relative success in leukaemia at the turn of the decade. Although he admitted that "the accessible points in the mammalian cycle where we might without injury modify it ha[d] not yet been located" (Comfort, 1966: 252), a concerted, collective programme of investigation would be able to ascertain whether it was possible to slow down ageing. Believing that "science is nearly omnipotent if properly applied", Comfort was however "quite prepared[…] to find out ageing cannot be slowed this century", viewing this cautious optimism as key to his work influencing the UK and US governments to support ageing research (ACF:51: Comfort to Prehoda, 10 October 1966).

In the next two years, however, Comfort increasingly distanced himself from likening research in experimental gerontology to that of 'experimental medicine', drawing important differences between the two fields. Whereas in 1966, cancer research provided the exemplar for how institutional design of research programmes impacted on technological outcomes, by 1968 Comfort had become vocal about the limited bearing of finding a "cure for cancer" on life expectancy, suggesting to the Director of the Fund for Research on Ageing that their focus should be on prolongation of "adult vigour" rather than on "anti-disease" programmes (ACP: 51: Bray to Comfort, 10 August 1968). This shift in Comfort's thinking was most likely encouraged by the 'proselytising work' he conducted in a tour of North American universities in 1968, funded by the Glenn Foundation, which had been initiated just three years before by the Wall Street banker Paul F. Glenn to support research to prolong longevity (ACP: 5: Newspaper clippings). The tour culminated in a lecture he delivered at the University of Saskatchewan.

The lecture, assertively entitled *Conquest of Ageing*, emplaced the search for longevity within a narrative of scientific progress where the fantasies and "preoccupation of lunatics" with immortality has been replaced by an "operational attack […] mounted all over the world by perfectly serious and respectable scientists backed, if there are such things, by perfectly respectable and serious governments" (Comfort, 1968: 7). Further, he distinguished between the effects produced on survivorship curves by medicine, and its focus on disease, on the one hand, and those resulting from a focus on 'vigour' that characterised experimental gerontology:

> *[T]he whole tendency of medicine, of public health – whether social or political – and of all the social progress which has been made in most countries [is] to produce a squarer and squarer curve.*
>
> *The assignment of the particular project I am engaged in is an entirely different one. It is to move the whole [curve] to the right by an unspecified amount. In order to do this it would be necessary for us to tamper with the clock mechanisms which determine the generalised loss of vigour in human ageing.(Comfort,1968:12-17)*

For Comfort, experimental gerontology was a logical progression from medicine and public health: it was the application of science not only to "make life more tolerable" at older ages but to "ensure we got more miles per dollar" (Comfort, 1968: 17). This represented a qualitative shift in the efficiency

of the application of science to human life, working to "increase the useful contribution each one of us can make to society" (Comfort, 1968: 26), by prolonging working lives. The gerontological utopia, like Huxley's, was a project of increased biological and economic efficiency: higher returns on life expectancy and health from investment in research, and more gain in terms of productivity from spending in education, child health services, etc. In this regard, Comfort vision was aligned with an emerging consensus amongst demographers of ageing that the most effective solution to the 'ageing society' would be, as the French demographer Jean Daric had it put two decades before , to make "a better use of our own human capital" (Daric, 1946: 73: my translation). But while most gerontologists had focused on doing so by understanding institutional barriers to employment of older workers, or by devising new arrangements between worker and machines to suit declining functionality with age (Moreira, 2017: 119-142), Comfort proposed that experimental gerontology should aim to change the 'clock mechanisms' that underpinned the structuring of the 'ageing society'. He was proposing a new biosocial order, that would be brought to bear "not only […] from gerontology, but also from the generality of biological advance" (Comfort, 1968: 25).

To be exact, by 1968, Comfort had still not developed this promissory vision in full, arguing that " in ten years' time we should be in a much stronger position to see our way ahead" (Comfort, 1968: 26). There were uncertainties about the applicability of caloric restriction experiments, conducted on experimental animals, to humans, about the meaning of radiation experiments to the understanding of ageing, about whether mutations associated with ageing were mostly located in proliferating or post-mitotic cells, and about the mechanisms of cell repair. These were issues that needed "to be settled amongst scientists" (Comfort, 1968: 24), before the full implications of experimental gerontology for society could be outlined. The key challenge that scientists faced in reaching this settlement was that there was no agreed measurement of ageing rate that would enable reliable testing of hypotheses, 'adult vigour' being a vague concept by Comfort's own admission (Comfort, 1964: 279), and single measures of physiological age relying on what Comfort saw as flawed, crude versions of the mechanism of development and ageing (see above). What was needed was a new 'test of senescence' that linked actuarial senescence to increased somatic vulnerability of individual organisms.

Anticipatory measure (1969-1973)

Shortly after returning from North America, Comfort received a request from the MRC to produce and circulate "a report describing the work of [his lab's] work since it was set up in 1965, together with a list of publications by the members of the group during that period" (MRC: Jones to Comfort, 9 August 1968). Although this was standard procedure within the MRC, it presented specific challenges to Comfort because, as we saw above, all the projects in the Research Group on the Biology of Ageing had run into some kind of trouble. In the report, Comfort contextualised the position of the laboratory as "the only department-like body in Britain devoted wholly to biological (non-clinical) gerontology" which, due to space limitations, could not expand its experimental activity (MRC: RGBA MRC 1969 Report: 1-2). His argument was that the original proposal to focus the laboratory on ageing in post-mitotic fixed cells would involve working on "several organisms, and depend on life time experiments on a range of critically kept populations in stable and highly repeatable culture" (Idem: 2), which was not possible with the resources provided by the MRC grant and UCL.

Instead, he suggested, the key activity of the group – no longer defining it as a laboratory – had been to collect and organise data gathered by other scientists and enrol their work in the project of experimental gerontology. In this, Comfort attempted to reframe the basis of the evaluation conducted by the MRC Biological research Board, from an assessment of the experimental activities of the group to an appraisal of his work leading what he viewed as "a centre for theoretical gerontology, complete with missionary apparatus", that would support "synoptic research planning" in ageing as well as training "what Lenin described in another context as 'cadres'" (MRC: RGBA MRC 1969 Report: 4-5). This strategy was only partially successful.

P.L. Krohn (Birmingham U.) – a former collaborator of Medawar, noted endocrinologist and armament-induced injury researcher - , in his referee assessment stated that "it does not appear that the work which is reported is outstandingly creative or substantial" (MRC: Krohn to Neale, 2 February 1969). Noting that Comfort's vision of a 'centre for theoretical gerontology' "seems to be the right way to make use of his undoubted talents" (Idem), he did not understand how or why the logistical reasons given by Comfort might have hindered work on post-mitotic fixed cells. The other referee letter was perhaps more damaging. Signed by Medawar himself, the letter was brief, declaring that,

> *I don't think anyone in the Biology Board will need to be told that the experimental work described in the report doesn't amount to very much. The most interesting part of it, Ms Trent's, was started under the guidance of Professor Maynard Smith, and there strikes me as nothing distinctive about the rest of it.*
>
> *Comfort's lengthy philosophic preamble combines a general case for the Group's apostolic mission with a number of special reasons why he seems unable to fulfil it – but the fact remains that Comfort is a most unusual and gifted person who does indirectly promote medically significant research, so I am and always have been in favour of him being supported as a man. What is quite clear is that he has neither the drive nor the organisational ability to run a Research Group in the conventional sense of this term (MRC: Medawar to Neale, 29 January 1969)*

The Board agreed with both Krohn's and Medawar's assessment, and decided,

> *to recommend to the Council that in view of its valuable function as centre for the coordination and dissemination of information, the Research Group in the Biology of Ageing should be commended to University College, London who has agreed to assume financial responsibility for it from 1 August 1970 (MRC: Biological Research Board Minutes, 18 February 1969: 2).*

This meant that "in considering the group as a whole, the college should consider directing effort away from laboratory research and that future staff appointments might more usefully be made in the statistical or secretarial categories" (MRC: Gray to Annan, 26 March 1969). Trent's work was to be transferred to another, more genetics-focused unit within the Zoology Department, and Gore's contract was to be terminated. Comfort was to focus on the 'apostolic mission' of experimental gerontology.

In these recommendations, both referees and the Board had ignored the experimental plans the Comfort had outlined in the 1969 Report. This included a long term experiment using the mouse colony to test the effects of exercise, obesity, anabolic steroids and anti-oxidants in the diet on life-

span and ageing; the creation of an extended experimental collaboration on the anti-oxidant ethoxyquin on various experimental models (MRC: RGBA MRC 1969 Report: 13); and a continuation of the work on fish by focusing on 'annual species'. From this, it is possible to gather that Comfort, despite his call for the formation of 'centre for theoretical gerontology', was still committed to pursuing a programme of experimental research. What was distinctive about this new programme of research was how it was driven by the aim to test specific hypothesis about the mechanisms of ageing.

From this perspective, it appears that the framing of the Group's work as focused on 'theoretical gerontology' was a localised tactic to justify its existence and survival, but did not preclude the continuation of experimental, laboratory research. The MRC's recommendation, and its implementation by UCL, meant however that Comfort's scientific legitimacy in designing and concerting experiments would be downgraded, as would be his capacity to speak on behalf of experimental gerontologists to funders and policy makers in the UK and abroad. From his perspective, the 'missionary apparatus' of the Group would have to include a clear and coherent programme of experimental research. Indeed, Comfort continued to work on the anti-oxidant experiment with the mouse model until 1972 (ACP: 53: Terry to Comfort, 1 November 1971), but had to interrupt the rest of the projects included in the 1969 MRC report.

During 1969, while negotiating the meaning of the MRC recommendation with the Department and University (MRC: Annan to Gray, 17 November 1969), Comfort became convinced that the only way to justify the existence of the Group at UCL was to provide it with a new focus and vision. Seeing the failure of the MRC Laboratory as linked to its proposed aim to focus on the narrow investigation of post-mitotic cell on ageing, Comfort reframed his laboratory as becoming a model organisation for work on experimental gerontology as he had envisaged it in the years before (see above). This work should not only be based on experiments with animal models but also, and importantly, be directly linked to the transformation of human 'adult vigour' and lifespan.

It is within this context that it is possible to understand why, in the middle of complicated local negotiations, Comfort chose to focus his attention on developing a framework for a new 'test of senescence'. He viewed this work as foundational – "the origins of experimental gerontology" (ACP: 26: Scientific Notes 1972) – following from his vision for the field developed in the years before. His approach to the subject comprised an attention to the technological, organisational and institutional aspects of the proposal that set it significantly apart from previous attempts to develop a measure of biological age, which had mostly focused on its scientific or statistical dimensions, leaving social and institutional aspects implicit (Moreira, 2017). In this regard, Comfort's 1969 *Lancet* paper can be considered a technocratic re-imagination of the management of health and ageing in Britain.

With swift publication helped by Comfort's role at the *Lancet* as commentator and reviewer, the quality of the paper does not appear to have been hindered by lack of peer review. The wide reaching context and implications of the paper are explicit, Comfort emplacing the proposed battery in a wider sociotechnical assemblage: the increase availability of longitudinal data on health and ageing; the routine use of standard measurements in the community, conducted by non-experts; the growing power of computers to process 'multivariate analysis'; automation of biochemistry analysis; and the "experimental necessity" stemming from emerging evidence of the effects of environmental

and pharmacological interventions on longevity in animal models (ACP: 26: Manuscript, 1969; Comfort 1969:1411). The inclusion of each of these elements was significant.

By 1969, longitudinal studies focused on ageing, launched in the 1950s, and those focused on community health, such as the Framingham Study, had demonstrated that it was possible to collect, process and calculate a variety of information from individuals at different points in time. Information had been collected through self-administered questionnaires or with recourse to standardised instruments operated by technicians or health care practitioners. This contrasted with an earlier situation, during the heyday of child development movement, when responsibility for collection and processing of data relied mostly on one investigator (Moreira and Palladino, 2011). The integration of statistical expertise in the newer forms of collaboration, and the increased availability of computers, facilitated the application of multivariate analysis, extending the amount of data that could be processed for comparing groups within a field experiment. Finally, and crucially, was Comfort's view that "it now appears certain that in the next 10-20 years it will become necessary to conduct […] studies of factors affecting the rate of ageing in Man [sic], more significantly, on drugs and manoeuvres purporting to delay it" (ACP: 26: 1969 Manuscript: 1)

It is worth remembering that by proposing a 'test of senescence' to be deployed in 'man', Comfort was seemingly retracting his earlier position that loss of information and increased noise in biological organisms with age made direct, individualised measurement of senescence next to impossible. In this, Comfort's drawing on James W. Hollingworth's research on the effects of radiation on health and the 'rate of ageing' within the Atomic Bomb Casualty Commission Adult Health Study (Hollingworth et al, 1965) was key for the deployment of continuity. Hollingworth and collleagues had, according to Comfort, established that it was possible to design a set of measurements that would closely correlate with the actuarial measurement of senescence - i.e. increased somatic vulnerability with age - that was also sensitive to 'environmental' conditions that were seen to accelerate the rate of ageing. The advantage of this work is that the battery had been established empirically, rather than by theoretical derivation – i.e. based on a particular theory of ageing -, resulting in a physiologically diverse instrument. This strongly aligned with Comfort's cybernetic view of ageing as a generalised 'loss of programme'. Comfort's proposed 'clock' was therefore not one driven by an internal mechanism but one resulting from the calibration between the distal timing of the 'force of mortality' and a proximal, practical method of gauging it.

It was a proxy measure of actuarial senescence justified "by reason of tedium" (ACP: 26: Comfort 1969 manuscript: 1), that is to say, by the fact that experiments measuring genuine senescence would require 30-40 years to complete. From this perspective, Comfort's battery aimed at hastening experimental time in gerontology, a problem he had experienced first-hand when working with guppies (above). It was an attempt to bring the future forward, of bringing experimental gerontology to bear in the present. This required detailed specification of the experimental procedure. In this, Comfort's aim was to evidence that the application of his method was possible outside heavily specialised research teams such the Atomic Bomb Casualty Commission Adult Health Study's.

To do this, he likened his proposed battery to that used by Leo Gitman in the Multiphasic Health Screening Center, at The Brookdale Hospital, New York (Gitman, 1969). Gitmans' battery included physiological measures such as blood pressure, and a variety of automated biochemical

quantifications. Gitman himself had modelled his multiphasic health screening procedure on Kaiser-Permanente's approach to health screening developed by Morris Collen. An explicit attempt to 'rationalise medicine' (Berg, 1997), Kaiser-Permanente's health examinations were invested in the promise of bringing about 'preventive medicine' (Collen, 1966), through the application of fordist principles of management - "assembly-line medicine"-, "the person screened proceed[ing] through a series of tests in smooth, continuous flow paths" (Gitman, 1969: 1270; also Estes et al, 1970). Similarly, Comfort's measure intended to prevent age associated illness by prolonging 'adult vigour', and doing so through the application of series of "doctorless tests" that should be as standardised and automated as possible (ACP: 16: Comfort manuscript: 4).

While the procedure was designed to maximise efficiency by minimising the use of clinical expertise, Comfort proposed that the 'screening centre' was best housed in a teaching hospital. This presumably, although not stated, would facilitate the training of staff and harnessing of screening labour, as well as the recruitment of volunteers motivated by the "incentive of a health check-up" (ACP: 16: 1969 Manuscript: 4). Comfort also saw this type of institution as one that would be receptive to experiment with the new form of public health 'facility' being suggested. Arguing that it was as "fundamental [an] advance in public health as a radio-telescope is in cosmology" (Comfort, 1969: 1414), the screening centre was to become the embodiment of a new form of bio-clinical management of individuals, one that prioritised the maintenance of health over the curing of age-associated diseases. Health screening centres, and the measurement of ageing rate, were central to the informational infrastructure of the gerontological utopia Comfort had outlined in the previous years.

Embedding promises (1972-1978)

In the first year of the 1970s, Comfort's alliances, which had been shifting since the mid-1960s, suffered a dramatic transformation, which led to him leaving UCL to the US. Although attention has been cast on how the publication of *Joy of Sex* made his position untenable in the British scientific establishment, the reality is that scepticism about Comfort's vision for gerontology on the British side contrasted with an American enthusiasm for it.

During 1972, Comfort's work at UCL was primarily focused on dismantling his lab. The new orientation of his 'group' – its missionary purpose – appeared, however, to be at odds with the direction of research on ageing in Britain. This became evident, for example, in the preparations for an MRC-led Conference on Cell Ageing during 1972-73. Organised to assess the 'state-of-the art' of research in Britain to inform the Biological Research Board strategy in that domain, the conference idea was to "commission reviews […] from active workers" in the field (MRC: Vickers to Neale, 21/06/1972). Although the initial proposed conference programme included Comfort as providing an introductory, general survey of theories of ageing, the organisers' "low opinion of Comfort" as experimental biologist (MRC: Vickers to Neale, 27/11/1972), no doubt propped by the 1969 assessment of his lab, progressively side-lined him, Bellamy (Zoology, Cardiff) eventually presenting on "the present status and future of experimental gerontology" (MRC: Conference on Cell Ageing Report, June 1972). In this, Bellamy presented a significantly different vision from Comfort's, positing that the relationship between development, growth and ageing, on which Comfort's lab had worked since the early 1950s, was a "possible connexion" worth examining (MRC: Bellamy, Future objectives of Experimental Gerontology, 24/05/1972).

This contrasted with the 'pull' Comfort experienced from the United States of America. Already in 1971, Comfort has been invited as an observer to the White House Conference on Ageing, where the launching of a major research initiative on ageing was discussed (Lockett, 1983). This advisory role, through his connection with the Senate Special Committee on Aging, was to continue until the creation of the National Institute of Aging in 1974 (ACP: 16: Church to Comfort, 20/11/1974). In 1972, Comfort visited the US twice to promote his approach to experimental gerontology, publicly praising "Americans [for] leading the revolt against short life spans" (ACP: 16: Koval, "Research aims at slowing biological clock", Modern Nursing Home: Sept 1972: 66). His ongoing experiments with Ethoxyquin on mice, done in close contact with Denham Harman – the US biochemist who had proposed to extend life span by controlling free radical reactions (Harman, 1969) - also had considerable more exposure in the US than in Britain (ACP: 53: Harman to Comfort, 1971).

This situation came to a head in July 1973, Comfort deciding to move to the US to integrate the Centre for Democratic Institutions at Santa Barbara, as a fellow. His main role in the Centre was to outline the political and institutional consequences of the sexual liberation movement he had advocated in the *Joy of Sex*, which was to be his main concern during 1973-74. But by the turn of 1975, Comfort was already publicly announcing his increased loss of interest in writing about sex and the aim to return to ageing and gerontology, offering his proposed battery to measure ageing rate to the NIA, "if that agency ever becomes operational" (ACP: 6: Daily Pilot, Irvine, 05/02/75). This decision was accelerated by the collapse of the Centre for Democratic Institutions in May 1975, Comfort discovering that the copyright revenue for the *Joy of Sex*, which he shared with the Centre, had been misused by its Director (ACP: 50: Comfort vs. Hutchins, 1976). In just a few months, Comfort had devised an Institute for Higher Studies, with John Wilkinson – translator of Ellul's *Technological Society* into English - and Harvey Weeler, a former colleague at the Centre for Democratic institutions.

This series of events meant that Comfort had to fully abandon his experimental programme to focus solely on anticipatory work, delineating the political justification for his gerontological utopia. His priority at this point was in tackling and challenging the "political institutions and social conventions" that make people 'old' (Comfort, 1976: 29), which he saw as being the cultural basis for resistance to longevity research and life-span extension programmes. In particular, he was concerned with the impact of the emerging environmental political movement, and its focus on growing populations, to the gerontological utopia, arguing that *Limits to Growth* relied on a view of older people as 'dependent' users of resources. His vision, as discussed above, entailed "years of extra vigour, not dependency" (Comfort, 1976: 112). This entailed, he argued, that it was then time to start discussing the social consequences of this transformation for the human biological life-span. The year before, Strehler (1975), changing from his previous, less optimistic position (see above), had laid the foundations of this anticipatory work with a paper on the 'implications of aging research for society'. Complaining of the paucity of sociological work on consequences of extended longevity, Strehler proposed that a likely prolongation of the adult phase of life by just 25% would lead to a new biosocial order underpinned by a re-structured life-course, with five generation families, multiple successive careers, and a new intergenerational economic contract.

This mostly positive scenario, assembled by biologists and their key allies in political circles, was sufficiently commanding to justify an examination of ethical and societal consequences by professional philosophers (also Neugarten and Havighurst, 1977). In 1976, the Institute of Society,

Ethics and the Life Sciences (later named Hastings Centre), supported by the National Science Foundation, organised a series of seminars and discussions with prominent philosophers such as Tristam Englehart. These resulted in the publication of 'Guidelines for research, development and delivery of life extending technologies', a "set of principles" aiming to frame deliberations about such technologies (Hastings Center Research Group, 1979). While rejecting decision making solely based on economic considerations, the Research Group on Death and Dying, which authored the guidelines, argued that reasoning should be guided by aiming to select between "competing legitimate aspirations and goals" (Idem: 79). In particular, they suggested that, "other things being equal", "efforts to alleviate pain, suffering and debilitation" should be prioritised over life-extension and the postponement of death, because those efforts were most likely to maximise the ultimate values of life and individual freedom (Idem: 79). Written from the individualist perspective that would come the characterise much of American bioethics, the guidelines presented a critique of life extension research and, implicitly, of the technocratic utopia that it was reliant on. For the Hastings Centre Research Group on Death and Dying, biological knowledge and economic efficiency should be controlled by the fundamental moral standard of human dignity.

This presented a different sort of challenge to experimental gerontology from the one advanced by neo-malthusian, environmentalist intellectuals (see above). While for Comfort or Strehler, ageing represented the outcome of a historical weakening of the forces of natural selection, variation and mutation being an underlying constant in shaping life forms, for bioethicists, human life had a special, irreducible ontological status. While Comfort viewed biologists as the ultimate experts in understanding and managing human life, bioethicists proposed that decisions to change human life span should rely on the interpretation they themselves provided about "the fundamental values of our society" (Veatch in House of Representatives, 1978: 76). This controversy was brought to the public stage in a hearing on 'Life Extension and Tomorrow's Elderly' held by the Select Committee on Aging of the House of Representatives on the 8th of February of 1978.

Questioning Comfort as one of the witnesses to the hearing, Marty Russo (Dem, Illinois) posed the question of the role of the public directly:

> *Mr. Russo: Do you think that there is public support to launch a full scale gerontological attack on ageing?*
>
> *Dr. Comfort: I think it depends on how you put the question to them. If you were to ask your constituents do you want to live to 110, most of them would say hell, no, I should be daft and in a nursing home. But if you said to them, would you like to take 80 years to reach 60, I think they might be more prepared to buy it from you. (House of Representatives, 1978: 21)*

For Comfort, the choice between the present situation and a future with extended 'adult vigour' was clear, as the question was not about the "abolition of old age" (Comfort in House of Representatives, 1978: 22) but the capacity to live longer in good health. The "possibility of resetting the clock" was a technical issue that did not require much deliberation, as the positive social and individual consequences would offset temporary disruptions to the social and economic fabric (Comfort in House of Representatives, 1978: 17).

To a very important extent, however, this answer did not address the key issue that the participants were concerned with, "the ultimate goal [of the hearing being] to develop a model for the entire

Congress to shape what human services we will need to cope with a maturing society" (Hughes in House of Representatives, 1978: 2). Indeed, much of the discussion in the Hearing focused on the role of geriatrics, research on age-related illness and other 'problems of old age'. Framing the issue as one addressing the proximal, policy implications of an ageing society meant that Comfort, and the other biologist standing as witness in the hearing, Leonard Hayflick, were unable to enrol participants in their vision of an alternative biosocial order – which the US pathologist and caloric restriction enthusiast Roy L. Walford (1983) would later call "the Long Living Society". Experimental gerontology was clearly not a solution to the present problems of the ageing society, not being interested in "detailing services that are needed now" (Comfort in House of Representatives, 1978: 52).

Bioethicists, on the other hand, provided the justification for why the present problems associated with old age – "pain, suffering and debilitation" - should be prioritised. In this respect, they were perfectly aligned with the political framing of the hearing and of the wider debate on the 'ageing society'. They also reinforced the NIA's focus on the more pressing issues to do with the biomedical aspects of ageing – with pathological ageing -, "current planning efforts for the development of enhanced health and related services for our older population [not being required] to take into serious account any imminent introduction of new technologies which would significantly increase the human life span" (Greulich in House of Representatives, 1978: 58). Life extension research was thus justifiably placed as a subsidiary, extra-mural area funded by the NIA. This meant that Comforts' vision for experimental gerontology became institutionally delegated to a lesser position within the organisation of ageing research, a "scientifically exciting" domain of research bearing only temporally distant technological and social promises.

Conclusion

In this paper, I have traced the dynamically complex epistemic and institutional process through which a seminal proposal to measure human ageing rate was generated and developed. The paper traced in detail how Comfort's vision of a new, experimental gerontology became intimately linked with his work on the measurement of senescence, as this was seen as key to bring to bear the social and technological promises of biology of ageing.

To understand how Comfort's metric of ageing rate came to be, the paper described first how Comfort's laboratory focused on what both biologists and policy makers considered to be one of the key problems of the time –the ageing society. In this process, Comfort's lab became associated with experimental and theoretical research that evidenced the cybernetic take on the 'modern evolutionary synthesis' approach to ageing, defining it as an inherently disorderly process. Between 1963 and 1968, Comfort's focus shifted from experimental work to outlining, drawing on the technocratic utopianism of Huxley, the aims and programme of experimental gerontology and how it was linked to the emergence of a new social and political order, where biological knowledge would guide the direction and implementation of policy to overcome the contradictions of the 'ageing society'. Taking the MRC 1969 evaluation and recommendations as a rejection of this vision, Comfort tackled what he saw as one of its underlying problem, developing a method for measuring the possible effects of age modifying technologies that could bear results within a reasonable time scale. Comfort's attention to both the scientific justification and the organisational infrastructure that could deploy the proposed 'test of senescence' aimed to secure the link between experimental gerontology and clinical and public health practice. In the years that followed, institutionally unable

to conduct experimental work, Comfort focused solely on delineating the political justification for his gerontological utopia in a context that he saw as more receptive. However, his engagement with policy making institutions in the US exposed a mismatch between the proximal needs of an 'ageing society' and experimental gerontology.

Just as we shouldn't attribute the establishment of a fact to a single actor (Latour, 1987), Comfort's inability to entrench his vision should be seen as the outcome of a configuration of conditions that were both political and scientific. Comfort himself realised that the difference between experimental gerontology's temporal horizon and research funders and policy makers' expectations was a major obstacle to his research. This was the key realisation that justified the development of a proxy test of senescence, anticipating the technological and social promises of gerontology. It was also a means to thwart the scepticism of some of his peers by proposing to 'put to the test', experimentally, the life extending interventions suggested by research on animal models. Further, he knew that biologists attachment to 'disease-focused' research was intimately linked to policy makers expectations about possible outcomes of biomedical research for life expectancy, dependency ratios, etc. His test of senescence aimed thus also to challenge both the scientific and political basis of the 'ageing society'.

His failure is significant not so much as an indication of the stability of the networks that composed biomedical research but most importantly because of how his proposal for a new approach to ageing and health was taken as an opportunity to re-affirm and reconfigure the normative and infrastructural basis of biomedicine. The ratification is evident, for example, in the reasoning behind the outcome of the 1978 Hearing of the House Representatives analysed above. The transformation comprises, importantly, James Fries' use of Comfort's own work to propose that preventative medicine and health maintenance should result in a 'compression of morbidity' (Fries, 1980), i.e. 'produce the squarer curve' that Comfort was explicitly trying to replace as an aim for biological research on ageing (see above). With the consolidation of the NIA's approach to ageing at the turn of the 1980s, hinged as it was on the aim to "derive new knowledge to advance our understanding of the underlying causes of the aging process and *help us separate disease from aging*" (Butler, 1980: 4: my emphasis), Comfort's approach to ageing was relegated in favour of the view put forward by his interlocutors in the 1954 CIBA Colloquium on Ageing (see above). This view, in turn, entailed committing to methodological approaches to measuring senescence that presupposed an 'orderliness' to organisms' ageing processes, which motivated the methodological critiques of biological age referred to in the Introduction. As Comfort's proposals make clear - and the institutional critiques of biological age also suggest-, attempting to develop a measure of ageing rate within the institutional apparatus of biomedicine was a contradiction in terms, and this is why it continued to be a frustrating quest in the decades to come.

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