Messengers of Stress: Towards a cortisol sociology

Abstract]

In 2008, Timmermans and Haas called for a sociology of disease to develop and challenge the sociology of health and illness. A sociology of disease, they argued, would take seriously the biological and physiological processes of disease in theorising health and illness. Building on two decades of Science and Technology Studies and feminist work on biological actors such as hormones and genes, we propose a cortisol sociology to push further at this argument. As a 'messenger of stress,' cortisol is key to understanding human and non-human health as a biosocial phenomenon. We argue that sociologists should engage with cortisol through critical yet open-minded reading of the relevant science and critical triangulation studies, and by tracking cortisol's movements from science into public worlds of biosensing and self-monitoring.

Keywords: Sociology, cortisol, stress, hormones, biosocial, biosensing, self-tracking

In 2008, Stefan Timmermans and Steven Haas called for a sociology of disease to extend and challenge the sociology of health and illness. Studying the patterns of publication in this journal, they argued that the sociology of health and illness typically ignores the biological processes of disease, side-lining the highest concerns of both clinicians and patients and their families. Ignoring the physical aspects of disease, they argued, means that 'the social processes social scientists describe remain clinically unanchored' (Timmermans and Haas 2008, 659). Leaving biological knowledge outside the realm of sociology, social scientists typically either 'accept clinical parameters at face value, tirelessly denounce "the construction" of factual knowledges or, more often, ignore such factors' (Timmermans and Haas 2008, 662).

The field of Science and Technology Studies (STS) provides important methodological impetus to the sociology of disease, as Timmermans and Haas (2008, 664-5) suggest in their presentation of Annemarie Mol's (2002) now-famous analysis of atherosclerosis. Building on the contributions of Bruno Latour, John Law, Michel Callon, Madeleine Akrich amongst others, Mol's praxiography provides an important route into understanding how clinicians, scientists and patients 'do' disease and how disease is enacted in particular encounters and spaces. Taking this a step further, Timmermans and Haas (2008, 665) suggest that sociologists use data on biomarkers to engage more directly with what happens in (diseased) bodies. Using existing biological data, or even learning to take measurements themselves, sociologists could, they contend, explore how 'the social world comes to be embodied within the biological' (Timmermans and Haas 2008: 267), thus testing the relevance of their theories and interventions into patients' social worlds.

At roughly the same time, a similar argument was being made within feminist theory, with scholars such as Elizabeth Wilson (2004) arguing that scholars of the body were ignoring the physiological and biological aspects of embodiment in an almost phobic

resistance to exploring forms of materiality that are traditionally in the purview of medicine and science. Bodies, in much feminist work, were theorised as culturally constructed, performed and/or inscribed: their physiological aspects were ignored, with scientific and biomedical descriptions of these subject to relentless critique (Roberts 2015: 35-41). This critical feminist work did not typically encourage scholars to collect biological data, but rather to pay close attention to published scientific texts in their attempts to theorise embodiment.

Working at the confluence of STS, the sociology of health, illness and disease and feminist theories of embodiment, Celia Roberts' (2007) exploration of sex hormones was an early attempt to theorise hormones as biological actors both in disease and health. Elaborating biomedical and scientific accounts of hormones as 'messengers,' she argued that hormones should be understood as exposing the impossibilities of distinguishing messengers and messages in the physiology and biology and lived experience of sex. Hormones, in other words, message 'sex' in a variety of ways, simultaneously and inextricably articulating material differences in bodies and carrying social meanings. Hormones as actors message across realms designated as 'social' and 'biological', disrupting analysts' intentions to demarcate zones of legitimate remit. Involved in long histories of medical and extra-clinical experimentation, sex hormones frequently participate in body-shaping projects, and are widely celebrated as powerful actors in personal-political projects around sex, gender and sexuality (see for example, Preciado 2008).

More recently, Roberts has turned to the so-called 'stress hormone', cortisol, exploring its figurations in scientific, medical and psychotherapeutic accounts of early-life trauma and chronic stress and how parents, workers and children are exhorted to act in relation to cortisol to manage stress in daily life (Mackenzie and Roberts 2017; Roberts, Mackenzie and Mort 2019). In this paper, we build links between this body of work on

hormones and Timmermans and Haas' proposal for a sociology of disease to explore a possible cortisol sociology.[i] Refusing the distancing effects of the 'of' in the phrase 'sociology of', we ask why should sociologists be interested in cortisol and how might they study it? What are the risks of moving into the biological body in this way, and how might these risks be averted? Should the sociology of health, illness and disease go that far into the body?

Why is cortisol important?

Cortisol is a glucocorticoid, a form of steroid hormone, produced in the adrenal glands (situated above the kidneys) when stimulated by the anterior lobe of the pituitary gland in the brain, itself responding to activities of the hypothalamus. As a 'chemical messenger', cortisol is involved in regulating several essential functions of the human body, including immune response, inflammation, blood pressure, blood-glucose levels, metabolism and energy production (Society for Endocrinology 2017). Like other steroidal hormones, cortisol is involved in complex feedback loops between the brain and other organs. In humans it typically follows a diurnal rhythm, peaking early in the morning and sloping off towards the evening. This is significant for research and for cortisol's messaging: 'Cortisol's diurnal variation may be an important element of its regulatory actions; indeed, cortisol is one pathway by which central circadian rhythms are signalled to multiple peripheral biological systems' (Adam et al. 2017, 26).

In both scientific and wider discourses, cortisol's role in the body's stress response system (known as the hypothalamic-pituitary-adrenal or HPA axis) means it is predominantly and extensively referred to as *the* stress hormone, despite the implication of many other hormones active in stress reactions. Over the last four decades, cortisol has become 'one of the most frequently employed biomarkers in psychobiological research' that attempts to

understand the relationship between stress and negative health outcomes, including increased mortality (Adam et al 2017, 25). Cortisol levels are generally said to rise under conditions of short-term stress, remaining elevated for long periods in some cases. Long-term historical stress, however, can lead to atypically low cortisol levels and/or flattened diurnal slopes. Both high and low cortisol levels and flattened slopes are connected to poor physical health. At the extreme ends of this spectrum lie Cushing's disease and Addison's disease, associated with too much and too little cortisol respectively.

High cortisol levels are associated with the 'fight or flight' response, constituted by increased heart rate, increase in gastric motility and a sensation of panic and/or aggression. Regular experiences of 'flight or fight' are associated with over-eating and problems with memory and cognition. Over the long-term, both high and chronically low cortisol are linked to increased risk of heart disease, depression and illness-related mortality (Allen et al 2014; Adam et al 2017).

The association of cortisol with stress and ill-health has a long history. Building on late 19th century accounts of homeostasis and the neurological effects of modernity, and investigations of post-WWI shell shock, 'stress' entered Euro-American biomedical research in the 1920s and 30s, most notably through the work of Walter Cannon and Hans Selye. In the early decades of the 20th century, Cannon focussed on the physiology of shock, trying to establish how psycho-social experience could affect physical health. 'Stress' in his accounts was 'a factor that could either precipitate or accentuate mental and physical instability, and that demanded resistance or resilience' (Jackson 2013, 73).

In the 1930s, as understandings of hormones as messengers materialised (Oudshoorn 1994), Selye developed these ideas through a series of animal experiments. His co-authored paper in the *Proceedings of the Royal Society of London* contained his first use of the term

'stress' (Selye and Mckeown 1935). These experiments subjected rats to various forms of trauma, including fasting, pain and the injection of drugs such as adrenaline, and measured the physiological outcomes, particularly on the brain but also on the spleen, liver and digestive tract, on muscle tone, the reproductive system and adrenal function (Jackson 2013, 81–82). Over time, Selye was able to show that 'persistent stress could cause these animals to develop various diseases similar to those seen in humans, such as heart attacks, stroke, kidney disease and rheumatoid arthritis' (Marksberry 2011, npn).

Distinguishing stress (a set of physiological responses) from external stressors, Selye articulated the ways in which adrenal secretions such as cortisol were implicated in human health. Building on evolutionary theories, he described the stress response as an 'adaption to our surroundings,' arguing that such ability to adapt 'is one of the most important physiologic reactions to life'; indeed, he believed that 'the capacity of adjustment to external stimuli is the most characteristic feature of live matter' (Selye 1946, 189 cited in Jackson 2013, 83). Over his career, Selye became concerned with the long-term effects of relentless environmental stressors, increasingly emphasising the role of hormones in provoking pathology and regulating metabolic resistance to injury (Jackson 2013, 86–87; 98). Historian Mark Jackson argues that via Selye, 'the physiology of stability under stress that had been conceived by Cannon and Henderson and their peers was gradually transformed into a biochemistry of life' (Jackson 2013, 98).

Across the middle of the 20th century, this biochemistry of life evolved into 'a science of control' (Jackson 2013, 104). Selye was convinced that hormonal processes should become sites of intervention in the name of health. In the 1940s, the US military eagerly took up these ideas, hoping that cortical preparations could be used to reduce stress-induced mental and physical fatigue (Jackson 2013, 124). Other scientists, including Karl W. Deutsch and Norbert Wiener, made conceptual links between hormonal systems and theories of

communication and control, arguing that cortical hormones should be understood as 'messengers' in cybernetic systems that were analogous to modern societies (Jackson 2013, 135–36). Hormones became enrolled in moral accounts of security and responsibility relating to self-monitoring and openness to intervention that arguably continue to this day. In the 1950s, Selye expanded his understanding of disease into 'a fully fledged philosophy of life' (Jackson 2013, 152), distinguishing good stress (eustress) from bad stress and affirming the necessity of 'mastering' stress to attain health (Jackson 2013, 178).

Today, biomedical research continues to attempt to clarify the relationship between stress and negative health outcomes. In 2017, for example, Abdallah, Averill, and Krystal (2017, 1) launched the Sage journal *Chronic Stress*, reporting that 'The detrimental effects of chronic stress are increasingly evident in preclinical and clinical research.' Although cortisol is often described as a 'promising biomarker' in this field (Law et al. 2013: 1607), a 2017 review concludes that 'Findings have… been inconsistent, and researchers have not systematically summarized the existing research, or fully explicated the meaning of the DCS [diurnal cortisol slope] or the potential mechanisms by which it may be related to mental and physical health outcomes' (Adam et al. 2017, 26).

The temporal complexities of cortisol pose problems for measurement. As most humans wake in the morning and sleep during the night, cortisol is usually measured by the Cortisol Awakening Response (CAR) test, using saliva samples taken at wakening and for the next hour (Steptoe and Serwinski 2016). Shift workers, flight personnel, parents of young children and insomniacs (amongst others), however, deviate from this norm. Many other temporal factors are also thought to effect an individual's cortisol levels, including age, time of waking, time of the year, season, time of the month, anticipation, time in menstrual cycle, developmental stage in children and, for foster children, age at time of placement and

duration of placement (Allen et al 2014; Law et al 2013; Taylor and Corbett 2014; van Andel et al 2014).

Conventionally, researchers and clinicians rely on sampling saliva, urine or blood to test cortisol. Two additional problems trouble this research. Firstly, whilst saliva and urine can be painlessly donated, the stress of any form of sampling, particularly having blood taken, may skew results. Secondly, each of these fluids only index cortisol levels at the time of sample. Measuring cortisol concentration in hair provides one solution to both difficulties. Cortisol levels are captured in hair structures, with each centimetre of hair growth equating to a month, so hair strand analysis can track changes over several months (Koren et al 2002; Maurel et al 1986). Complex issues of difference trouble the practice of hair strand analysis however (Wennig 2000, 5). Henderson et al (1998), for example, tested for racial difference in hair-strand-based drug testing, with results suggesting that the criminalisation of Black people may be in part due to the fact that their hair absorbs and stores more drugs than White and Asian people's hair, whilst Rippe et al (2016, 56) report a long list of variables affecting hair cortisol levels including 'high amounts of sun' and 'recent hair washing,' as well as class, ethnicity, sex, and family income. Despite these complexities, medical researchers continue to use cortisol as a biomarker of both acute and prolonged stress when trying to articulate connections between physiological stress and ill health.

Towards a cortisol sociology

Since the 1980s, sociologists have drawn on Selyian notions of stress to affirm a core tenet of social science: that 'social context matters' when it comes to health (Hinkle 1987, 566). Working within the frames of the sociology of health and illness rather than the sociology of disease, however, they have largely avoided exploring the actions of hormones in bodies or critically engaging with the science of stress. While a 2020 search for the word

'stress' in the journal *Social Science & Medicine* produced 8288 results and in the *Sociology of Health and Illness,* 1233 results, such studies typically measure stress through qualitative and quantitative social science methods (including interviews, surveys and psychological tests) rather than hormonal assays.

In 2004, however, sociologist of racial stratification Douglas Massey introduced the scientific concept of 'allostatic load' (borrowed from McEwan and Lasley 2002) to describe the long-term effects of living in racially segregated poverty on mental and physical health (including heart disease, brain function and immunity) via disrupted cortisol levels (Massey 2004, 19-2). Massey argued for a biosocial model of stratification, writing that

> What the [stratification] field needs most at this point is a dataset that contains biosocial markers indicating allostatic load gathered from a large multi-racial sample whose individual, family and neighborhood characteristics are well-defined and measured at various points in time (Massey 2004, 21).

Timmermans and Haas (2008, 669) refer to this piece as an exemplary foray into the sociology of disease (see also Freund, 2010). Since then several scholars have articulated the promise of cortisol for sociology, arguing: that it is 'novel' (Taylor 2012, 437) and 'innovative' (Damaske, Smyth, and Zawadzki 2014, 130); that it produces more objective, truthful, accurate and valid data on stress than self-report data collected in interviews, psychological scales and questionnaires (Damaske, Smyth, and Zawadzki 2014; Gersten 2008; Taylor 2012); that it is easy to do, requires little training, and is cheap (Taylor 2012, 440; Smyth et al 2013, 608); and that it will corroborate existing social science about 'social determinants of biological outcomes' (Taylor 2012, 434).

Despite these positive affirmations, a review conducted in 2012 found that 'There are very few sociologists using cortisol in their research' (Taylor 2012: 440). A 2020 search for

the word 'cortisol,' however, produced 248 results in *Social Science and Medicine* (*SSM*) and 6 in *Sociology of Health and Illness* (*SHI*), indicating the more biomedical orientation of the former journal. In the *SSM* articles, cortisol measurements are typically used as objective, factual indicators of stress; only two articles take a critical approach to biological data. The *SHI* articles, in contrast, do not go anywhere near measuring cortisol. Lowe, Lee and Mcvarish (2015), for example, are highly critical of the ways in which biological data, including cortisol levels, are entering into discourses of childhood abuse and neglect; whilst Elstad (2008) promotes a purely social account of the effects of stress on health. In *SHI*, only Timmermans and Haas (2008) are positive about cortisol's potential for sociology: to date, their 12-year-old plea appears to have gone unheard in this journal.[ii]

Whilst there is a small group of health sociologists willing to engage with cortisol, then, most remain focussed on the core elements of the sociology of health and illness – that is, their social aspects. Sociologists working with cortisol use it to provide objective evidence of the physical effects of social suffering and to track the ways in which social life can impact human health. Although articulating connections between the biological and the social, this work does not attempt to trouble this distinction: instead, it claims that 'Incorporating biology into models of social stratification and health positions social scientists to explicate the critically important role of social factors in biological function and response that affect health' (Harris and Schorpp 2018: 19).

In contrast, we are interested in a cortisol sociology that troubles the biological/social distinction. What can sociology learn from cortisol science that does not simply add physiological measurements to what we already know? Conversely, yet equally importantly, what might critical sociologists offer those working in the life sciences on stress and cortisol? What would such a cortisol sociology look like?

Cortisol sociology would engage critically and open-mindedly with life science research

Traditionally, many social scientists have taken a highly critical approach to scientific knowledge of the body, pointing out in detail where problematic assumptions are made, particularly in relation to the nature of 'the social' (Timmermans and Haas 2008; Rose and Abi-Rached 2013; Brossard, Cruwys, Zhou and Helleren-Simpson 2020). Other social scientists embrace as true those elements of the life sciences they find useful, ignoring the arguments of STS scholars and historians and philosophers of science about the situated nature of scientific knowledge claims (Rose 2013: 4). To engage effectively with cortisol's messaging actions, we want to suggest an alternative way through – a route that both listens carefully to scientific research and understands science as a set of situated, social practices. Methodologically, this means reading the scientific literature for points of disagreement, contestation and potential openness; analysing the 'findings, feelings and figurations' (Roberts 2015) articulated in cortisol texts. These places of contestation and openness, we suggest, constitute zones of possibility where structuring categories of thought – most importantly here, 'the social' and 'the biological' – are productively challenged.

Tuning into scientific debates about cortisol, rather than assuming that 'cortisol = stress,' we immediately encounter a potentially productive issue: that some scientists argue that, for several reasons, cortisol may not actually be a reliable biomarker of stress. First, the heterogeneity of study design and methods used make it difficult make any strong conclusions about associations between different variables and stress (Campbell and Ehlert 2012; Hunter, Minnis, and Wilson 2011; Kristenson, Garvin, and Lundberg 2011; van Andel et al. 2014). Second, as described above, there are multiple ways of measuring cortisol from single point levels to slopes and rhythms over time. Third, these complexities are further compounded by the fact that although cortisol measurements may help us understand how stress impacts on bodies, they can never adequately index the multiple, inter-related ways

stress is registered physiologically, which Joëls and Baram (2009, 459) describe as the 'neuro-symphony of stress' (see also Obayashi 2013).

Science also shows that cortisol measurements have a complex relation to individuals' felt experiences of stress. The Trier Social Stress Test (TSST), developed by Kirschbaum, Pirke, and Hellhammer (1993), is a lab-based method for producing a psychosocial stressor (being negatively judged on performance in a job interview) that reliably produces changes in cortisol levels in test subjects. In their review of TSST studies, however, Campbell and Ehlert (2012, 1111) found only a 25% correlation between physiological and psychological responses to stress. It is also difficult to disentangle cause and effect in stress science. Physical reactions to external stressors are multiple and are likely to cause further stress to the individual, and cortisol patterns may refer to historic rather than present life circumstances. In both the life sciences and social sciences there is an increasing awareness of the importance of temporality in understanding the link between stress in the past and negative future health outcomes (Pearlin et al. 2015). Although much research on cortisol concerns early life stress, knowledge about typical levels of cortisol in children and how these change as children develop is scant: 'Almost none of the prominent theoretical models in stress physiology are truly developmental, and future work must incorporate how systems interact with the environment across the lifespan in normal and atypical development' (Doom and Gunnar 2013, 1359).

Attempting to address these complexities, scientific work on the effects of cortisol provides potentially productive models for sociologists interested in biosocial accounts of stress. After reviewing the literature, Adam et al, for example, suggest a 'cascading effects explanation' in which multiple sources of cortisol dysregulation are connected to physiological outcomes that themselves alter cortisol patterns:

> transactional and cascading changes across multiple stress-sensitive biological systems mutually reinforce each other. In this explanation, there could be multiple initial sources of dysregulation. Regardless of the initial source or system of dysregulation, interacting and cascading changes ultimately lead to multi-systemic biological dysregulation, of which a flatter DCS [diurnal cortisol slope] is both an indicator and a precipitating and reinforcing factor (Adam et al. 2017, 36).

As biological systems are interrelated and transactional, they argue, social and psychological experiences can 'jointly contribute' to flatter DCS and multiple forms of negative health outcomes (Adam et al. 2017, 36). This model of 'reciprocal and cascading interactions', we suggest, resonates promisingly with the complex biosocial embodiments articulated in sociology, STS and feminist theory. Adam et al's argument puts 'social experiences' on a par with genes, appetite, cortisol and sleep, thus troubling conventional biological/social distinctions.

Cortisol sociology would recalibrate stress biomarkers through critical triangulation

A very small number of sociologists work with biomedical and other scientists on projects that triangulate rich accounts of participants' social lives with measurements of cortisol (or other stress biomarkers). Building on Massey's research, Karb and colleagues, a team of sociologists and medical scientists, for example, contend that in order to better understand the 'ecology of stress' (see also Hill and Angel 2005; Hobfoll 1988; Matheson et al. 2006), research should 'integrate both environmental and biological mechanisms to explain health disparities' (Karb et al. 2012, 1038). Current research, they argue, focusses on describing psychosocial characteristics (class, race, etc) and the individual-level stressors (acute stressors, such as job interviews or exams) that influence health outcomes via 'the

dysregulation of stress-relation biological pathways such as cortisol secretion' (ibid.) In their view, 'to more fully understand the aetiology of cortisol dysfunction, it is necessary to examine characteristics of the multiple environments in which individuals are embedded. Social structures determine, in part, the exposure of individuals to stressors as well as stress-buffering resources' (2012, 1040). To do this, Karb et al undertook a complicated study with 308 participants in Chicago that measured: participants' age, education, relationships, and mental health; environmental aspects of neighbourhoods, such as levels of crime, perceived and reported stress and levels of social support; and diurnal cortisol slopes. Their findings demonstrate 'a significant association between neighbourhood social and physical characteristics and patterns of diurnal cortisol secretion' in which the greater the perceived and observed stressors, the flatter the diurnal cortisol slope, thus supporting the existing hypothesis that chronic stress flattens cortisol slopes, rather than raising cortisol levels (Karb et al. 2012, 1045). Importantly, like Adam et al, they conclude that 'social factors are not merely "downstream" from biological factors, but are themselves capable of shaping the development of biological systems' (Karb et al. 2012, 1046).

This work has strong resonance with Youdell, Harwood and Linley's interdisciplinary work on stress in school education, which combines ethnographic study of classroom interactions and textual analysis of policy and other documents with verbal and visual accounts of participants' feelings and biological measurements of stressed states (through outbreath analysis and electroencephalogram [EEC] brain scanning). Youdell, Harwood and Linley's critical triangulation of methods does not work towards a quick answer, but rather aims to keep open the question of what 'stress' is and how it affects human life:

> It is not our aim to synthesise these accounts of stress but to approach 'stress' as produced across domains – highlighting the entangled nature of these various

> accounts, including as they inform and are instantiated in experiences of 'stress'. As such we work across divergent ways of encountering and understanding what is described as 'stress' (Youdell, Harwood, and Lindley 2018, 221).

Ultimately, the value of this kind of research will depend on how data are analysed and presented (see also Rose and Abi-Rached 2013: 232). Little will be gained if differences between forms of data remain unexplored, or if their divergent histories of value are ignored: children's accounts of how stressed they feel at school have very different cultural and scientific valence compared to heart rate calculations, police crime data or EEC results (see also Ftizgerald, Rose and Singh 2016). Critical triangulation opens up ontological and epistemological questions about the object of study: here, about the nature of stress; the messaging actions of cortisol within the flight or fight response; and the social capacity of humans to testify to their own experience in written or spoken form. Given the challenges of cortisol measurement outlined above, researchers should not figure biological measurements as simple facts or truthful indicators of objective 'stress', but rather as a potentially interesting, and inherently fluid, part of complex biosocial intra-actions (Barad 2007).

Highlighting the biological aspects of human experience can be politically and ethically risky. As Sara Shostak (2013) points out in relation to scientific research into molecular biomarkers of exposure to environmental toxins, it opens space for claims regarding physiological susceptibility and resilience in which particular individuals or groups are figured as more easily affected by external factors than others (see also Warin, Koval and Maroni 2019). Such claims can produce new forms of responsibilisation: in Shostak's case, for poor and minoritised people living in chemically contaminated environments; in Warin et al's case, for Indigenous Australians surviving intergenerational racism. Mackenzie and Roberts' analysis of 'brain-based parenting' training for the parents of children who have

experienced early life trauma and who are understood as having atypical cortisol is another example (Mackenzie and Roberts 2017: 140-143). Interdisciplinary projects on cortisol must remain mindful of the ways in which particular people or groups can be responsibilised to take care of their physiology in the absence of meaningful social change. In our view, this risk should not preclude paying attention to cortisol in theorising the complex connections between psychological and lived experience, structural (dis)advantage and bodily states, however. Indeed, critically triangulated research already confirms something interesting about cortisol: that it does not necessarily increase when stress is pervasive and long-term. This counter-intuitive finding may have important implications for individual and public health strategies and should be explored in more depth.

Cortisol sociology would track cortisol's messaging in everyday life

STS scholarship demonstrates that science is not (only) a rarified set of practices undertaken in laboratories, but also extends into lay worlds. In order to understand hormones' dynamic messaging, cortisol sociology would also engage with its public life as 'the stress hormone,' tracking its movements from the laboratory and clinic into various media and everyday lives. Such exploration would articulate the biosocial nature of cortisol and its entanglement with emerging formations of subjectivity, embodiment and platform capitalism (Roberts, Mackenzie and Mort 2019).

The key question for the bulk of scientific research on stress is 'What role does cortisol play in the connection between stress and physical health?'; only a small amount of this work asks 'How do we reduce stress?' But as scientific research on stress travels out into the public world, articles, blogs and popular science, diet books and websites exhort us to 'beat your stress hormone' (Svoboda 2011) via, for example, herbalism, meditation, massage and

connecting with nature. Attempting to find a new angle on ‘stress,’ these articles point directly to cortisol as something readers should learn to know and manage. This is indicated in titles such as ‘Suppress Destructive Cortisol’ (Goldshein 2017) and ‘Cortisol: Why “The Stress Hormone” Is Public Enemy No. 1’ (Bergland 2013), and ‘Cortisol: The 'Stress Hormone' That's Making You Ill’ (Simmonds 2016). Sometimes managing cortisol is about productivity rather than health. In the *Financial Review*, for example, people working in financial markets are advised to get to know their cortisol so they can trade more effectively (Solon 2015).

In these kinds of public discourse on cortisol, the causes of stress melt away. Poverty, discrimination, early life trauma and exposure to violence remain invisible. A yawning gap appears between the subjects of the relevant scientific research – oppressed, abused, racially marginalised people and experimentally-stressed animals – and the readers of lifestyle magazines and newspapers wanting to reduce felt stress for health or economic advantage. Cortisol becomes something to know and manipulate; a process for individual intervention and control. The differential burden that this work might involve for different individuals or groups is obscured.

The figuration of cortisol as an object of manipulation is deeply entwined with the development of personalized health monitoring devices and biosensing platforms (Roberts, Mackenzie and Mort 2019). As yet, however, there are no commercially available biosensors to directly monitor cortisol levels (Kaushik et al 2014; Bahadır and Sezgintürk 2015; Rice et al. 2019). Commercial services in both the US and the UK offer to test hair, saliva or blood samples sent to labs, but these provide only very limited information due to the limited time scale of sample collection. In the advertising of such tests, cortisol’s diurnal and longer fluctuations are downplayed. Consumers looking to ‘improve their sports performance’ and willing to spend £39 on a blood test by *Forth*, for example, will receive just one measure of

(waking) cortisol, from which they are told they will be able to 'check your adrenal function, check whether your body may be under too much stress and check whether you may be overtraining' (Forth 2018).

In contrast to the one-off and distant nature of saliva and blood tests, measuring stress through heart-rate variability (HRV) and/or Galvanic Skin Response (skin sweatiness associated with arousal) is relatively easily done on a continuous basis through a watch-like device. Heart-rate variability (the temporal gap between heartbeats) is increasingly used to articulate raised cortisol and/or 'stress' as well as cardio fitness. 'The Thinking Man' reading the *Telegraph*, for example, is encouraged to build HRV monitoring into his fitness programme and to learn to 'optimise' his heart rate and breathing to 'create a consistent HRV' in order to gain physical and emotional benefits, including 'reduced cortisol levels, decreases in high blood pressure as well as mood improvements and improved physical stability' (Laidler 2017).

It is important to note that the results of biosensing information about cortisol may become of interest to others, including teachers and employers, who may, as the *Financial Review* suggests, want to know about workers' stress levels so they can be sent home when overwhelmed (not as an act of care but in order to protect employers' assets) (Solon 2015). Such information may also be of interest to parents and carers: Van Andel et al (2014) suggest that information about cortisol levels in fostered children might help carers to understand and look after these children more effectively. At an individual or family level, tracking individuals' cortisol levels may help to address mental and physical health issues. Coming to know what atypical cortisol feels like to a child, or looks and feels like to a parent living with that child, may be an important element in living with the long-term effects of early-life or intergenerational trauma (Mackenzie and Roberts 2017). This is not to suggest, however, that sociological research (or indeed social policy or related interventions) should

narrow its focus to individual bodies, or even relations. To the contrary, we wholeheartedly agree with Youdell, Harwood and Lindley (2013, 236) when they write,

> By looking at stress and learning through multiple lenses – including those offered by a range of biosciences – we bring back into the frame of potential thinking, analysis and practice the possibility that stress is not a disease of the mal-adjusted individual but is something that *flows through social spaces, is produced through interacting social and biological forces and can be apprehended across scales* from the distribution of outcomes in high stake tests to the flows of VOCs in breath (emphasis added).

Sociological understanding of the 'social spaces' and biosensing platforms through which cortisol flows is absolutely essential to understanding its complex messaging actions. Cortisol sociology, in other words, would not take 'cortisol' to be a stable actor, but rather a 'messenger multiple' (Mol 2002) in particular assemblages or worlds.

Messengers of stress

Cortisol is a significant actor in scientific and popular figurations of stress and in attempts to both understand and ameliorate the long- and short-term effects of human and non-human animal suffering. In both scientific and popular literatures, it is figured as a messenger of stress, carrying news of external trouble through the entire body, with multiple effects on its function and health and the person's psychological and social life. Cortisol patterns are also figured as a place of memory, where early-life experience becomes embodied and then repeated, even when the disturbing stressor has ended. In this sense, cortisol is also a message. Like sex hormones, cortisol *messages* across the biological and the social, raising significant questions about conventional distinctions and demarcations in the study of health, illness and disease.

Sociology has much to offer the study of cortisol. Sociologists can apply their well-honed skills to highlight moments of reductive discourse in both scientific and lay arenas. As noted above, some accounts of cortisol run the risk of individualising responsibility for addressing atypical cortisol patterns and their effects, and burdening those who already have a lot to bear with a difficult biophysical management task. It is important to stay alert to and resist such figurations but also not to close our ears to what scientists have to say about the significance of biological actors in human life. The STS literature on hormones (Latour and Woolgar 1979; Fausto-Sterling 2000; Oudshoorn 1994; Roberts 2007; Sieben 2011; Pinto et al. 2012), neurons (Wilson 2004; Fine 2010; Rose and Abi-Rached 2013; Schmitz and Höppner 2014; Callard and Fitzgerald 2015) and genes (M'Charek 2005; Reardon 2005; Freese and Shostak 2009; Pickersgill et al. 2013; Timmermans and Shostak 2015) are hugely instructive here. This literature reminds us to pay attention to the historical and present practices that constitute contemporary science and not to take any particular claim as decontexualised truth. Additionally, we have argued here that tracing cortisol's travels outside strictly scientific arenas, into biosensing, paid work and parenting for example, should be part of cortisol sociology.

Timmermans and Haas' (2008) call for a sociology of disease focussed on paying attention to the biological aspects of embodiment in order to address what is of greatest concern to clinicians and patients. They also emphasised that studying biomarkers like cortisol or heart rate variation may help sociologists to test their theories and related interventions: Does moving into a less racially-segregated housing estate produce less ill health, for example? Ultimately, they concluded that studying biomarkers could help sociologists in their quest to understand 'the fascinating interstices of embodied social life' (Timmermans and Haas 2008: 672). In the twelve years since the publication of their piece, little headway has been made in pursuing this agenda. Students of sociology are not regularly

taught physiology or trained to take bio-measurements, as they suggested (Timmermans and Haas 2008: 672) and most sociology remains uninterested in, even hostile to, the collection and inclusion of biomarker data.

We think there are many good reasons to be cautious about including cortisol measurements in sociology. Indeed, our call to move towards a cortisol sociology is not oriented towards inclusion of the biological as a legitimate domain: we do not want a sociology *of* cortisol in that sense. Learning from existing STS work on hormones, we suggest *engaging with* cortisol as a messenger of stress by tracing the findings, feelings and figurations articulated in its messaging actions. Cortisol sociology, in our imagining, would be both critically attentive to the 'transactional and cascading' flows that cortisol science articulates and, acknowledging that 'the biological' (as an object of knowledge) is at least as complex as 'the social', invent modes of research that trouble this distinction.

Methodologically, we are concerned about the tendency towards objectivist readings of biomarker data in some triangulation studies and instead look towards more experimental research that puts qualitative and biomarker data and textual analysis into critical conversation. We are inspired by work in design and STS involving experimental engagements with biosensing technologies and ethnographic recordings of daily life (Gabrys, Pritchard and Houston 2019; Wilkie 2020) but note that many of these involve ethnographic accounts of citizen science projects rather than direct engagements with biosensing data. Some STS colleagues are also collaborating with artists and scientists to exciting effect: the 'Genders: Shaping and breaking the binary' project led by Nina Wakeford and Anne Pollock is an exciting example (https://www.kcl.ac.uk/gender-translations-bringing-together-disciplines-to-explore-gender-and-the-world); Louise Ann Wilson's (2017) interventions across conventional art/science/social science divides in the field of human reproduction is another. Importantly, we are not suggesting that all research teams must be interdisciplinary;

what matters, rather, is that key categories – 'the social', 'the biological' - are problematised. As Fitzgerald, Rose and Singh (2016) note, the notion that sociology should not deal with 'the biological' is relatively recent. Cortisol sociology is an experiment-in-the-making that we hope will hail diverse actors to develop new ways to engage with the complexities of biosocial life without reaffirming conventional demarcations of expertise.

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[i] Our argument is based on two systematic literature reviews. The first, a general review of scientific literatures on cortisol, prepared by Oscar Maldonado Castaneda, used network analysis to document literature that used 'cortisol' as a keyword from 1950-2015. The second review, prepared in 2017 by Brigit McWade and updated in 2020, was a more focussed search on the use of hair-strand testing for cortisol levels. Search terms included 'cortisol', and 'stress', 'biomarker', 'biosensor', 'continual personal health monitoring', 'hair', and 'hair cortisol concentration'. All studies using this method in humans were selected, 2003-2016. References in these papers were followed to collect a wider sample of literature relevant from across disciplines, including archaeology, forensic science, sport science, developmental psychology, laboratory chemistry and techniques, and biosensing design and development. In addition, we collected online articles, blogs and websites that engaged with cortisol and stress – including private companies offering cortisol level testing.

[ii] According to Web of Science, only three papers in *SHI* have cited Timmermans and Haas (2008), including Timmermans and Buchbinder (2010). Twelve papers in *SSM* have cited it.