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Leadership Evolution for Planetary Health: A Genomics Perspective

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Abstract: We are living in the Anthropocene period, where human activity has become the dominant influence on climate and the environment. Addressing the question of how nature and societies will evolve in the Anthropocene is one of the grand challenges of our time. This challenge requires a new form of leadership, one capable of transmuting the eroding relationship between business, society and nature. Yet at this critical time, leadership theory is at a crossroads, with many arguing that leadership, as a field of study, should be abandoned. Operating in parallel to this Anthropocene challenge is an increasing understanding of the complexity of the genome, including the inherent plasticity of our genomic hierarchies, and the influence of the genome on health, disease and evolution. This has demanded a change in thinking to view the genome from an evolutionary systems perspective. To address the imbalance presented by the Anthropocene, we propose using a genomic lens as the basis for thinking about leadership evolution. In arguing this, we aim to provide the pathway for an improved synergistic relationship between business, society and nature, one that can guide the future of humanity in the unstable world we have created.

Keywords: leadership; genome; epigenetics; evolution; adaptation

1. Introduction

The human imprint on the global environment has become so large and active that it rivals some of the great forces of nature in its impact on the functioning of the Earth. We are living in a new paradigm, one that many describe as the Anthropocene, viewed as the period during which human activity has been the dominant influence on climate and the environment [1]. The Anthropocene represents a new phase in the history of both humankind and of the Earth, when natural forces and human forces became intertwined, so that the fate of one determines the fate of the other [2]. The Anthropocene thus presents a grand challenge of how the problematic relationship between humans and nature can evolve [3].

When we ask what caused the Anthropocene, who is responsible for the onset of this epoch, and even what the proper designation of this epoch should be, many authors lay its origins “squarely

at the door of a system: capitalism or the global economic system" [4] [p. 6]. This capitalist model is argued to have contributed to the breaching of several ecological boundaries, in relation to climate change, biodiversity loss and nutrient enrichment, at the same time damaging the natural systems that sustain it. Capitalism is also leading to increasing inequality, in turn creating social tensions that make it still more exposed. That the now dominant capitalist economic system is unsustainable is not in doubt. As the negative consequences of current growth strategies escalate, what to do in response becomes an ever more vital and urgent question [4].

As humans move towards the second quarter of the twenty-first century, there is a need to address this escalating problem by identifying a new economic model guiding a new business model [5]. However, for any new model to be effective requires a new form of leadership, one capable of focusing on the relationship between business, society and nature. Indeed, it is claimed that the demands on, and need for a new definition of, leadership in such a profoundly difficult time are unprecedented [6]. Future business leaders, guiding and supporting others, will need to identify radical new approaches to the relationship between business, society and nature, in order to advance beyond the Anthropocene era [7]. Ultimately, new leaders need to be capable of creating visions for a new relationship between business and society, one that values a worldview [8]. These leaders need to be able to guide business through the difficult and daunting task of moving towards sustainable and effective management of the planetary health [9]. Yet at this critical time in our evolution, leadership theory, conceptualisation, and methodology are also at a crossroads; indeed, many argue that leadership as a field of study should be abandoned [10]. While existing theory focuses on the characteristics, roles and power relations between leaders and followers, there is little focus on the potential of leadership to develop an evolutionary response to this increasing global complexity. It is time for leadership to evolve to meet this challenge.

Operating in parallel to this Anthropocene challenge is change relating to the theory of evolutionary biology. This has occurred alongside increased understanding of the complexity of the genome, including the inherent plasticity of our genomic hierarchies, and the influence of the genome on health, disease and evolution [11,12]. While it has long been understood that human genomes hold a record of the evolutionary forces that have shaped our species, advances in genomics have allowed a deepening of our understanding of human genome evolution and its relationship to nature (e.g., through natural selection), as well as factors shaping human health and disease. These advances have revealed many previously underappreciated factors that influence the adaptive nature and evolutionary capacity of the human genome [13]. Recent statistical and experimental advances have revealed significant complexity in classical topics in human population genetics [14]. Heng et al. [11] argue that it is time to drastically change our thinking, to depart from the traditional genetic framework to the genomic organisational level. This new conceptual framework asks that we make the transition from the gene-centric view to the genomic theory, the key to which is viewing the genome from a systems perspective.

This conceptual paper presents the proposal that findings from genomics can contribute to the evolution of leadership, and through this organisational evolution, for this new paradigm. In so arguing, we propose the need for fundamental changes to support an evolutionary process to enable the adaptive capacity inherent in our genomic plasticity to be utilised. Based in a biological view of evolution, we identify the potential for a foundational paradigm shift to a more developed leadership and business model; models capable of guiding humanity and protecting planetary health.

2. A Historical Perspective of Leadership

Leadership theory, in both its conceptualisation and the methodology used to explore it in practice, is complex, and has resulted in an array of definitions across a spectrum from the individual to the collective. Early leadership studies focused upon inherited individual traits [15]. However, as this theory emerged, it became clear that certain skills and behaviours required of leaders could be identified. Accordingly, leadership theory was expanded to acknowledge traits, skills and behaviours

of leaders [16]. This also enabled an exploration of how leadership skills and behaviours could be acquired. Further expansion of leadership theory resulted in recognition of the influence of situations, contingencies and environments on leadership [17,18]. This resulted in leadership theory being advanced to acknowledge the social exchanges that occur between leaders and followers that enable leaders to wield power and influence over followers [19]. This is the world of the transformational and charismatic leader [20]. From here, leadership theory moved to focus not just on leaders, but also on follower interaction [21]. In turn, a more values-based conceptualisation of leadership began to emerge as the need to create selfless leaders became apparent. Leadership began to seek approaches that invested in people by genuinely caring about them and their success. This was the era of the ethical [22] and servant [23] leadership theories. This led to leadership success being characterised as reliant upon the efforts of followers over self-interest [23]. For example, a decade into the new millennium, Day and Antonakis defined leadership in terms of: “(a) an influencing process—and its resultant outcomes—that occurs between a leader and followers, and (b) how this influencing process is explained by the leader’s dispositional characteristics and behaviors, follower perceptions and attributions of the leader, and the context in which the influencing process occurs” [24] [p. 5]. While they admitted that this definition is still leader-centric, they argued that it encapsulated the interaction between leader and follower, as well as the leaders’ effect with regard to the resulting broader outcomes.

The next advancement in leadership thinking aimed to go beyond that of the individual leader. These advances view leadership as an activity or practice [25], with examples such as Raelin in using the concept of leadership-as-practice to identify “a shared process that has collaborative tendencies” [26] [p. 196]. Leadership-as-practice includes the moral, emotional, and relational aspects of leadership rather than just its rational, objective, and technical ones [27]. Leadership-as-practice is “more concerned about where, how and why leadership work is being organised and accomplished than about who is offering visions for others to do the work” [26] [p. 196]. Alongside this move to view leadership more as an activity or practice rather than inherent in a single leader, has been a move to see leadership more as engagement [28] and going “beyond the ego” to embrace approaches that are more authentic and radical [22] [p. 1]. At the same time more collective, shared and distributed approaches to leadership are being explored [29].

More recent explorations of inclusive approaches to leadership suggests the need to develop more nuanced adaptive mechanisms that suit future rather than past environment [30]. In their explanation of what they termed adaptive leadership, Heifetz et al. [31] identify “practice of mobilising people to tackle tough challenges and thrive” [31] [p. 14]. Adaptive leadership, they argue, highlights the link between leadership, adaptation, systems and change. This link is similarly evident in evolutionary psychologists’ arguments that the environment has changed much more rapidly than humans’ capacity to adapt to these changes. These authors highlight the need to explore the practical relationship between leadership, adaptation, systems and change, rooting these ideas within scientific explanation of evolution of human life.

In contrast, rather than seeing an adaptive and evolutionary leadership development, van Vugt and Ronay [30] argue we have developed to a point described as a *mismatch* between modern and ancestral environments, where followers are psychologically developed for ancestral environments yet modern leadership practices are based on very different psychological patterns. Hagen and Hammerstein [32] and van Vugt and Ronay [30] argue there is a discrepancy between modern and ancestral environments that has resulted in an evolutionary mismatch between human ancestral patterns of social grouping, mating and leadership, and contemporary business leadership practices (e.g., top-down control, centralised decision-making driving power and politics).

Industrial ecologists have commenced discussion and debate about this lack of coherent evolution. For example, Bansal and Hoffman [33] and Andrew and Johansen [34] identify organisations where leadership focuses on the modern macro, global business environment. This is in contrast to the ancestral environment, where leadership focus was on the local, where humans lived in smaller groups more closely connected to the natural environment. This mismatch between modern and ancestral

environments not only affects approaches to leadership, but also perceptions of organisations within the broader environment. Such a broader challenge requires leadership to go “beyond the ego”, challenging organisations to think of their role in the broader context that includes responsibility to the social and natural environment. This includes attempting to create more organic versions of leadership, while also focusing on the moral and relational aspects [35]. Indeed, there is evidence that scholars are exploring the deeper evolutionary roots of the organisation, with a focus on closer integration with patterns of the ancestral environment.

To address this mismatch we need new patterns of leadership, and these need to be developed taking into account ancestral understanding of collaboration and networking, but also of the relationship to the land. Indigenous discourse views leadership as intrinsic, in which leaders sacrifice their own interests to their followers, with leaders leading by example [36]. These indigenous approaches to leadership emphasise interpersonal relationships [37], mutual respect and removal of hierarchy. Based on these approaches, it is important to re-focus leadership to view it as a co-constructed process that evolves over time [38]. In this way, the current psychological mismatch between modern organisations and the ancestral environment can emerge from where it is currently trapped, and lead to the evolution of leadership theory to a more values-based, ethical approach. This provides a particular opportunity to address the challenges presented in the Anthropocene, where the relationship between business, society and the natural environment requires a changing perspective from existing economic and business mindsets. This requires a new conceptualisation of leadership that takes it further along an ongoing evolutionary path that will see it explored not only within organisations, but also between organisations and society, and between organisations and the natural environment.

While this introduction to theories of leadership is brief, it does demonstrate significant development in theories of what leadership is, how it is defined and how it occurs in practice. This development has identified leadership as being conceptualised across a spectrum, from individual to collective, from inherited traits to learnt skills and behaviours, and from control to influence. To progress the leadership discourse, there is need for a more expansive dialogue to find effective solutions to the leadership crisis. To address the challenges presented through the Anthropocene, there needs to be a closer integration of scholars from the fields of social and biological sciences in order to produce a more holistic, more adaptive, more evolved approach to leadership. We propose using a genomic lens to create a shift in leadership thinking to exploit our inherent biological adaptive capacity to address the planetary health issues presented by the Anthropocene. The paper presents a conceptual argument that findings from genomics can contribute to the evolution of leadership. To do so, we argue the need for fundamental changes that enables evolution to utilise the adaptive capacity inherent in our genomic plasticity. The next section explores synergies between theory associated with genomics and that of leadership.

3. Genomics, Leadership Theory and Evolution

Using the scientific lens of genomics, it is possible to explore evolution in leadership to better adapt organisations to a changing landscape [39,40]. This enables an exploration of insights from genomic mechanisms as to how leaders can enable organisations to evolve, to adapt, and to thrive. This section presents a discussion of biological evolution, adaptation and environment before focusing on the role of genomics in shaping leadership. A latter section will focus on the post-biological evolution and the inter-dimensional systems-thinking interplay in order to offer suggestions for further research into an advancing leadership.

Using this analysis, we suggest that a more developed leadership needs a paradigm shift in thinking to focus on the adaptive capacity of their followers and the leader’s responsibility in enabling their followers to thrive. For this to occur, it is critical to recognise that businesses and organisations are a collective of people coming together to deliver products or services [41]. For business to evolve is for leaders and followers to evolve. For business to thrive is for leaders and followers to thrive.

For this to occur, leadership needs to focus on the health and well-being of both themselves and their employees, in their relationship to each other, and to the natural environment.

3.1. *The Nature of Evolution-Enabling Evolution*

In the current business world and its leadership paradigm, the concept of evolution has come to mean development of business practices to adapt to change in the modern globalised business world [42]. Writings discuss the mechanisms by which leaders in organisations can enable evolution to facilitate their progress forward [43,44]. In the capitalist model, this is with a view to increasing profitability [45], often at a cost to the natural environment. Yet traditionally, evolution is placed within biology, with the term evolution referring to the changes in inheritable information (within populations) over time, and the dynamics of population origins and extinctions [46]. This process is viewed as a change in the gene pool of a population from generation to generation [47]. It is within this biological view of evolution that we explore the potential to create the foundational paradigm shift to a more developed leadership. We argue that by enabling biological evolution through the nature of the relationship between leaders, employees, and the natural environment, organisations capable of thriving in rapidly-changing landscapes (that is, adaptive organisations) can be created. To explain this, we focus on the two most well-known traditions of thinking into biological evolution - Lamarckism and Darwinism.

In Lamarckian terms, evolution is the process whereby changes made by an organism during its life in order to adapt to its environment are passed on to offspring. It is also known as the “heritability of acquired characteristics” or “soft inheritance” [48]. Lamarck was often credited with advancing modern evolutionary theory by proposing a mechanism by which the gradual change of species might take place. Lamarck incorporated the idea of use versus disuse, theorising that individuals lose characteristics they do not require or develop characteristics that are useful. Based on this, he also argued that acquired traits are heritable [49].

Darwin’s theory of evolution similarly argued that inheritable characteristics influence subsequent generations. However, in contrast, he postulated that randomly acquired traits in organisms are selected by pressures in the environment. The most widely recognised Darwinian evolutionary process is that of natural selection, which stresses a purely naturalistic (undirected) “descent with modification”. That is, complex creatures naturally evolve from more simple ancestors over time. As random genetic mutations occur within an organism’s genetic code, the beneficial mutations are preserved because they aid survival, hence survival of the fittest. The resultant changes allow an organism to better adapt to its environment to help it survive and have more offspring [50].

An important contrast between the Lamarckian and Darwinian views of inheritance is that Lamarck posited that organisms, such as humans, have some capability to adapt within a generation and pass such adaptations on to their offspring. Whereas Darwin proposed that adaptation occurs over many generations and is shaped by the environment. Despite these differences, a common feature of these theories is the concept of adaptation, or the process that makes organisms better suited to their “rugged fitness landscapes” [51]. Primarily explored as a biological process, adaptation may cause either the gain of a new feature or the loss of an ancestral feature. In Darwinian terms, adaptation is viewed as a gradual process, a slow change in progress, with the hand of time marking the “long lapse of ages” [51]. However, subsequent models of evolution for adaptation have challenged this perspective by identifying periods of rapid phenotypic (i.e., observable characteristics) evolution and stasis in some lineages [52]. For Lamarck, the process of adaptation is through acquired modifications and short-term adaptive changes to ensure fitness for the environment [53].

Outside these two views, for the post-biological evolutionists, the process of adaptation is reliant on multiple systems of heredity [54], hypothesised as soft inheritance processes for adaptation that play a Lamarckian role in the overall evolutionary dynamic [55]. Evolutionary theorists explore the concept of evolution as adaptation of species to environment, where the environment is of nature, “air, gravity and wild blue berries” [56]. For evolutionary psychologists, this focuses on exploring the ways humans

have evolved a rich repertoire of psychological mechanisms to reap the benefits of group living within the natural environment [57]. Anthropologists exploring early patterns of human behaviour tend to focus on the capacity of humans to adapt to these natural environments. Yet, a century ago, biologist Sir John Arthur Thompson proposed that human evolutionary connections to natural environments were being eroded by urbanisation [58]. More recently, Lubchenco reinforced this by indicating that “the concept of what constitutes the environment is rapidly changing” [59] [p. 491]. This links to the van Vugt and Ronay [30] and Hagen and Hammerstein [32] discussions on the current mismatch between modern and ancestral environments. These discussions have broad implications for the capacity for Darwinian or Lamarckian evolution to occur, not just in leadership, but also in wider organisational and community life. For the purpose of this paper, we start with a focus on the link between evolution and adaptation that is emerging from genomics research.

3.2. *The Role of The Genome in Evolution and Adaptation*

The word “epigenesis” was coined by Aristotle over 2200 years ago [60]. He believed that all complex creatures grow from a simple fertilised egg or seed through to a mature organism via stages of development and differentiation—out of the simple comes the complex. This idea is widely accepted today.

In the early 1800s, Lamarck proposed that the way an organism adapts to its environment will be passed down the generations. Two generations later, Darwin built on Lamarck’s proposition to propose that there are minute granules (“gemmules”) that are thrown off by our tissues. These gemmules, he proposed, can multiply and travel to our eggs or sperm sex cells and be passed to future generations [61]. By the late 1800s, Darwin presented his view that evolution occurs by natural selection through random changes in our DNA that enable us to evolve and adapt over millennia. Subsequently, another biologist (Waddington) refashioned “epigenesis” to “epigenetics”, and used this to describe the way in which our genes interact with their environment to make us what we are [62]. In Waddington’s world epigenetics refers to the “factors on top of our genes” [63]. Since then, the debate between the influence of nature (genes) or nurture (environment) has underpinned much discourse, including that of the comparable influence of each on health and behaviour. Ridley [48], building on Waddington, suggests that the answer is a combination of the two.

More recently, Darwin’s concept of natural selection has been fused with Mendel’s model for how genes and traits are passed from parents to their children [64]. This fusion, along with epigenetic changes, is being viewed as a mediator of the gene–environment interaction [65]. While genetic changes are still understood in terms of gene mutations, deletions, inversions and translocations, they are now expanded to include sequence changes—referred to as copy number variation [66]. Epigenetic modification describes the set of small molecules that sit “on top of our genes” and choreograph when and how our genes act. This, in turn, directs our development from the zygote to the grave. Epigenetic molecules can be encoded by our DNA to act in response to a range of environmental as well as protein and non-coding RNA (ncRNA) effectors [67,68]. These epigenetic modifications can be added or removed in response to these effectors contributing to our inherent genomic plasticity—nature via nurture [48]. This creates a flexible epigenome that allows us to adjust to changes in the world around us and to learn from our experiences. Unique sets of genes are induced or silenced epigenetically during different stages of life, causing the development and maturation of the individual through orchestrated events in combination with input from the environment. Epigenetic studies are providing a general mechanism for the way in which exposure and experience can stably reprogram genes and function [65]. However, it is important to note that this increased adaptability can vary between individuals. Epigenetic modification permits organisms to enter new environments, where they experience selection pressures that move some individuals in different phylogenetic directions than their less-flexible peers. For example, individuals that display a high degree of behavioural plasticity (defined as the ability to modify behaviour as a result of environmental input) are better able to adapt to novel environments than less plastic individuals [69,70].

The outcome is that epigenetic research has identified a range of mechanisms by which epigenetic modification impact genome function, and through this, phenotypic expression. Three mechanisms key to the focus of this paper are: (1) adaptive response to daily exposure and experiences; (2) epigenetic modifications resultant from experiences in the womb and early childhood; and (3) inheritance of epigenetic modifications from parent and grandparent generation (transgenerational and intergenerational epigenetic inheritance). Before discussing the role of epigenetics in the modern business, it is important that a discussion of these mechanisms is presented.

3.3. Adaptive Response to Daily Exposure and Experiences

Studies have demonstrated direct and indirect epigenetic modification resultant from life experiences. Epigenetics is involved in many normal cellular processes, such as cellular differentiation [71] and circadian rhythm control of biological clocks [56]. More specific examples of epigenetic adaption, including nutritional interventions in adulthood (e.g., calorie restriction), have been shown to induce epigenetic changes that have the potential to alleviate age-related diseases [72]. In rat studies, this is demonstrated through the effects of adolescent social stress on cognitive inflexibility and epigenetic modifications [73].

3.4. Epigenetic Modifications Resultant from Experiences in the Womb and Early Childhood

These epigenetic changes underpin the idea that our experiences in the womb and early childhood can program our future health. These changes most likely lie behind a recently recognised phenomenon called the Developmental Origins of Health and Disease, known as 'DOHaD' which links maternal health to in-utero growth and, through this, to the lifetime risk for the development of chronic diseases [74]. An oft-cited example of this is that of 60-year old humans who were in their mother's womb at the time of the Dutch Famine during the Second World War. These individuals were found to not only have poorer cardiovascular health than their siblings, but also an epigenetic legacy of this experience stamped on a handful of their genes [75]. Other animal studies reveal stories related to early juvenile epigenetic changes. For example, in rats it has been found that a mother's licking and grooming behaviour can influence subsequent stress levels in offspring, mediated by an epigenetic change to a gene involved in stress response. Newborn rat pups whose mothers spend time licking and grooming them grew into calmer adults, whilst pups who receive little maternal attention tended to grow into more anxious adults. Grooming altered the pattern of epigenetic marks, which in turn altered gene activity of the stress regulator gene. Critically, when neglected rats were treated with a drug that altered these epigenetic marks, both their anxiety and the accompanying epigenetic changes could be reversed [76].

3.5. Inheritance of Epigenetic Modifications from Parent and Grandparent Generations (Transgenerational Epigenetic Inheritance)

Epigenetic mechanisms include inheritance processes independent of the classical Mendelian inheritance. An example is imprinting, an epigenetic process that involves epigenetic marks that are established ('imprinted') in the germline (sperm or egg cells) of the parents and then maintained through fertilisation and post-zygotic cell divisions in the embryo. Imprinting means that the gene from one parent is silenced, while the gene from the other parent is expressed. The mechanisms for imprinting are not completely understood, but they involve epigenetic modifications that are usually erased and then reset during the creation of eggs and sperm [77]. While imprinting is an essential epigenetic modification, imprinting errors can result in genetic disorders, such as Prader-Willi syndrome, and Angelman syndrome [78,79]. This is an important genome modification process as it provides a mechanism by which gene expression is controlled and by which transgenerational epigenetic modification errors can occur [80].

In combination, these three mechanisms describe innate and genetically-determined epigenetic processes that can occur during early development, and similar organised processes that adapt the epigenetic profile through life in response to signals from experience and external exposure to create

an “experience-dependent” epigenome. These epigenetic mechanisms serve as genome adaptation mechanisms that adapt the functioning of the genome to signals derived from experience and the environment [81]. Such findings led Klironomos, Berg and Collins [82] to hypothesise that heritable epigenetic change can affect rates of “fitness” increase, as well as patterns of genotypic (genes inherited) and phenotypic (observable characteristics) change during adaptation. In particular, they suggest that when natural selection acts on pure epigenetic variation in addition to genetic variation, populations adapt faster, and adaptive phenotypes can arise before any genetic changes.

Before leaving the discussion of epigenetic modifications as evolutionary adaptive mechanisms, it is important to note that adaptation in one context can become maladaptive in a different or latter context [83]. This can signify an adaptation that, whilst reasonable at the time, has become less and less suitable, and more of a problem or hindrance in its own right, as time goes on. This is because it is possible for an adaptation to be poorly selected or become less appropriate or even become, on balance, more of a dysfunction than a positive adaptation, over time [84]. Biological wear and tear can lead to maladaptive physiological responses resultant from epigenetic changes that increase disease risk and undermine health. For example, childhood poverty may “reset” the immune system in a manner that increases stress-related impairments in immune function, rates of infectious and chronic diseases, or blood pressure and cardiovascular disease incidence [85]. Insulin sensitivity in offspring of females exposed to food scarcity is considered adaptive, as it prepares offspring to deal with unfavourable conditions with limited food supply. However, if not reversed, can leave the individual maladapted with an inappropriate response for favourable conditions [86]. Over time, the cumulative wear and tear (often referred to as allostatic load) [87], caused by exposure to chronic stress, results in physiological changes to the body with adverse consequences for health and well-being. Epigenetic changes in response to acute stress can be considered adaptive, but maladaptive as a responses to chronic stress [88]. This indicates that sustained reliance on short-term adaptive mechanisms can work against a healthy epigenetic process. Recent research also demonstrates capacity for epigenetic modification to directly influence genetic mutations resulting from crosstalk between the genome and the epigenome [89]. These genetic mutations can then be selected for or against as part of an evolutionary process.

Finally, an extension of the field of epigenetics is the study of the role of ncRNA in genome orchestration. One of the long-standing models of genome function holds that genetic information normally flows from DNA to RNA to protein. This has led to the assumption that genes generally code for proteins and that proteins fulfil most of the structural, catalytic and regulatory functions in cells. However, this model is being challenged by observations in the research of ncRNAs. Here, ncRNAs (RNA that does not directly code for a protein) have been shown to play a broader orchestration role than a direct transcription (i.e., DNA is copied into RNA to make protein) role [90]. Findings to date demonstrate wide-ranging roles for ncRNAs acting as part of a genomic regulatory system that interfaces between the environment and the genome. This can be seen in research showing ncRNAs as epigenetic modulators [91], and can be linked to evolution through adaptation of human cognition [92]. The vast majority of the genomic output of complex organisms is constituted of ncRNAs, so while their role is relatively unknown, it is likely their contribution to genome-environment interaction will be significant. While the researchers into the role of ncRNA identify this field of study as separate to that of epigenetics [90], others place it within the epigenetic discourse [93]. For the purpose of this paper, ncRNA will be encompassed within the broader concept of epigenetic processes.

Whilst the research in genetics and the emerging fields of epigenetics is extensive, the research is primarily focused on a health deficit model, skewed towards deleterious mutations [94], variants as disease predictors [95] and aberrant epigenetic programming of genes [96]. This deficit model has resulted in research focusing on identifying and reducing deleterious conditions and predispositions that can undermine adaptive capacity. This has led to more limited research on exploring how adaptive capacity may be maximised through genetic and epigenetic mechanisms. Some relevant research being explored includes genetic mutations for positive traits (e.g., psychological well-being, psychological flexibility, resilience). There is also research into health pillars (e.g., diet, exercise, mindfulness, sleep)

as health indicators for epigenetic well-being [85]. One such research initiative demonstrated that nutrients can reverse or change epigenetic phenomena, “thereby modifying the expression of critical genes associated with physiologic and pathologic processes, including embryonic development, aging, and carcinogenesis” [97] [p. 8]. Research into ncRNA is less well understood, but its contribution to disease and wellness is well evidenced [98].

In summary, Lamarck and Darwin have identified some of the key mechanisms underpinning evolution. These discussions suggest that the gene-environment interactions are the normal process by which exposure to environments modulate the genome to ensure adequate adaptation of genome function to these environments. Changes at the genetic level are considered more long-term adaptive changes. Changes at the epigenetic level are more short-term adaptive responses, which, in certain circumstances, can have long-term effects. While such flexibility gives rise to beneficial adaptability to environmental conditions, it likewise allows weaknesses to integrate and exert negative and diseased outcomes on both individual and evolutionary scales [99]. When not managed well, these genetic changes and epigenetic modifications can contribute to disease. These changes are being implicated in a broad range of neurological, physiological and behavioural disorders argued to result from response to environmental factors. These include autism and other intellectual disability [100], cancer [101], and cardiovascular disease [102]. This had led to new areas of research looking into the factors that maintain genetic and epigenetic health (herein described as *genomic health*).

As this relates to leadership theory, these discussions highlight the inherent biological evolutionary capabilities individuals possess that allow them to adapt to a changing environment in ways that allow them to thrive. However, these biological capabilities, when taken too far outside the natural context, lose their adaptive capacity. To adapt and to thrive via our biological evolutionary capacity is to maintain genomic health. This requires maintaining individual health, as well as a healthy relationship with others and the environment in which we exist. For leaders in the workplace, this relates to the genomic health of themselves and their employees, both individually, and in relationship to each other and the environment in which they work. The implication from this understanding of biological evolutionary capabilities is the need to ensure that leadership theory incorporates an understanding of the potential evolutionary impact of leader decisions, actions and behaviours on genomic health.

4. Genomics Research and The Leadership Debate

The use of genomics research to inform the discourse on leadership has been limited to date. There have been some recent attempts to apply insights from genetics research to inform the leadership debate [39], but these have largely focused on early leadership theories. These theories focused on the inheritance of leadership traits [103–106] or leadership behaviours [94,107,108] considered as the key to good leadership. This led to debate as to whether good leaders were “born” or could acquire needed skills and behaviours [109]. Further research into the genetics of leadership has explored the relationship between genetically inherited physical characteristics, such as height [110] and facies [111,112], and the success of leaders. There are also studies that research the genetic involvement in leadership role occupancy as well as leadership approaches [20,113]. Finally, there are studies that highlight the moderating influence of gender on heritability of emerging leaders [109,114].

Genetics research has also attempted to address the question of the role genes play in modulating social behaviour. So-called “sociogenomics” is an attempt to integrate molecular biology, genomics, neuroscience, behavioural biology and evolutionary biology. This research aims to identify genes that influence social behaviour and genes that are implicated in social evolution. Findings in animal studies that may have relevance to the leadership discussion include research into mating, foraging, social hierarchies, and dominance interaction [115].

Genetics research provides insights into the impact of leadership, as expressed through the organisation, into employee health and well-being. This research has demonstrated links between occupational chemical toxicity, DNA fragmentation and cancer prevalence [116]. Workplace stress has been linked to increased levels of oxidative stress [117], which is in turn linked to increased DNA

fragmentation and changes in genetically facilitated metabolic pathways. These changes have been linked to neurodegenerative, autoimmune and complex life diseases [118]. Other relevant genome research has linked stress to genome changes (including DNA fragmentation) and an associated impact on fertility [119], as well as early abortion and risk of childhood cancers in offspring [120].

This current leadership discourse focuses on adaptation of traits and behaviours, based on the assumption that the humans can evolve in pace with the changing context. Yet Darwinian evolutionary theory would argue this to be a slow biological evolutionary process; we may not have the adaptive mechanisms to rapidly changing environments [30]. Thus, using Darwinian theory, leadership evolution can only occur over a long time. This argument is supported by data that suggests that the Neanderthal and modern human genomes are at least 99.5% identical [121], thus “we should not be surprised if we discover that we are not as different from our extinct relatives as we believe” [121] [p. 552]. Given this, if leadership is to adapt more quickly to a more agile approach, there is need to apply an epigenetic lens to explore the potential for more rapid psychological evolution.

Epigenetic modifications are yet to play a key role in research into leadership. Given the epigenome’s inherent plasticity, and the capacity for epigenetic modifications to provide shorter-term biological adaptation, this field could well be even more important in the context of rapidly changing modern business environments. Studies in this area are likely to become relevant to the evolution of leadership discourse. The importance of the broader regulatory systems (e.g., ncRNA) to facilitate this inherent adaptability is also likely to become apparent.

This becomes an even more important issue when the potential for adaptation to become maladaptive through epigenetics changes is recognised. Negative impacts have been recorded in studies that demonstrate a link between chronic stress, cognitive function and mental health issues [122], with mouse studies confirming epigenetic causation. In modern business environments, for both the organisation and its leadership, this suggests potential links between workplace culture and practices and employees’ physical and psychological health issues. The field of epigenetics challenges the need to examine the in-utero and early childhood impact of epigenetic changes relevant to pregnant women in the workplace. Studies have demonstrated prenatal risks relevant to workplace health and safety, for example Perera and Herbtzman [123] presented evidence that “prenatal exposure to diverse environmental chemicals dysregulates the fetal epigenome, with potential consequences for subsequent developmental disorders and disease manifesting in childhood, over the life course, or even trans-generationally” [p. 363]. These studies include pollutants which, while not specifically a workplace pollutant, are relevant to a workplace environment, and thus present a workplace risk. These authors also discuss the interplay between environmental pollutants, nutritional status and the epigenome. Links can be drawn between nutritional status and workplace practices (e.g., hours of work, break times) [124], again arguing that the workplace can contribute to prenatal risk through its practices. Keverne and Curley demonstrate changes to epigenetic mechanisms activated during fetal development in response to environmental stimuli, such as maternal care and social interactions, linked to changes in fetal brain plasticity [125]. Negative impacts have been shown between stress and prenatal aetiology of Autism Spectrum Disorders (ASD), with Kogan et al. [126] proposing epigenetic origins for ASD resulting from general immune and metabolic disturbances that affect the brain with links to oxidative stress [127]. This has led some authors to question the nature of our moral epigenetic responsibility [128], and more specifically within the workplace, to ask “Can workplace stress cause trans-generational ripples of employer liability? What are the possible impacts of epigenetics on health and well-being liability?” [129] [p. 1].

Beyond epigenetics, current research is looking to explore the relationship between genomic systems (including the ncRNA level of the genomic hierarchy), disease and evolution [93,130]. As an example, an association has been shown between paternal (father’s) stress and increased levels of microRNAs (a form of ncRNA) in sperm of mice and brain development changes in offspring [131,132]. The research is proposing a possible link between high levels of microRNA and a range of psychiatric conditions in offspring, including anxiety and schizophrenia. Research is also

exploring the interplay between the individual's functional genomic systems, the body's microbiome (i.e., the stable community of microorganisms in a particular environment including body niches) and the external environment [133]. Such research is linking an individual's health with their microbiota (i.e., the microorganisms of the individual's body) and with a range of diseases [134,135]. Again, stress features in this discussion, with the microbiome being shown to act as a regulator of stress and inflammation [136]. Research is showing clear links between stress, the individual's gut microbiome, and disease [137,138]. Research is also looking at the association between the genome, the microbiome and major public health issues (e.g., antibiotic drug resistance) [139]. Despite this expanding field of investigation, very little of this has been discussed within the occupational health and safety literature. The only evidence to date of this area of study being explored within the organisational setting is work looking at the link to building design [140].

Given the array of research initiatives aimed at understanding contributors to disease, through the genomic lens, one can assume the connection between the leadership, the workplace, the genome, and its associated impact on employee health and well-being (both physical and psychological) is still to unfold. The implications for leadership and leadership theory are significant. In terms of informing a discussion on developing leadership, the insights from genomics indicate that genetic traits and behaviours provide limited insights into the new world of leadership. They also indicate that organisations as they exist in the modern business environment are key contributors to diseases. If there is to be evolution to adapt and thrive, there needs to be a fundamental shift in leadership thinking to drive a new business model, one focused on the health and well-being of both leaders and employees, in their relationship to each other and the natural environment.

5. Developing Leadership-Evolving Business

In introducing a genomic lens, we have proposed the need for a fundamental shift in thinking about leadership and the nature of the modern business model. This is a shift such that the focus moves from the individual (or even the collective) and the power and control dynamic to a focus on developing the health and well-being of leaders and employees, as well as enhancing their relationship to each other and the natural environment. The biological models and their inherent adaptive nature can form the basis of this new evolutionary business model. We discuss the potential for biological models to be used to guide the development of a new business model by: (1) looking at the current metaphorical use (metaphorical); (2) in direct (literal) application within the existing modern business environment; and (3) in direct (literal) application, but re-orientating business toward a relationship with the natural environment.

5.1. Metaphorical

To date, biological models have largely been used metaphorically by organisations to explain the emergence and evolution of organisations and human systems. At the broader biological level, some examples include the use of animate systems (e.g. exchange of energy and environment to maintain equilibrium) [141], the human body with everything connected, such as tissues and organs [10], the organisation as a complex adaptive system [142], and more recently the concept of the organisational ecosystem [143]. As it relates to the evolution metaphors, examples include the concepts of natural selection and adaptation [141] as well as the concept of creating goodness of fit between the organisation and the conditions in their external environment [41]. At the genetic level there is the use of the organisational DNA as well as genes and their unique combination to create functional agility [141]. This use of metaphors can also include biological disease to organisational situations [e.g., corporate nervosa] [144].

These metaphors refer to evolving organisations to adapt to the changing environment [141], yet the nature of the environment is not explained. One could reasonably assume this refers to the organisational environment that Daft [41] defines as being composed of forces or institutions that surround the

organisation and affect performance, operations, and resources. For the purposes of this paper, the organisation's environment will subsequently be referred to as the modern business environment.

5.2. *Literal*

5.2.1. In the modern business environment

To adventure beyond the metaphorical is to ask how biological evolution can be used literally to explore modern business, in particular, in its use of the adaptive genomic mechanisms. In focusing on the concept of the organisation within the current modern business environment, three areas that can be studied are:

- (1) The use of genetics or epigenetics to identify and create leaders capable of adapting themselves and their leadership to the changing modern business environment.
- (2) The use of genetic or epigenetic mechanisms to facilitate adaptation of others to the changing modern business environment.
- (3) Creating a workplace that supports genomic health to facilitate adaptive capacity.

Genetics research relevant to this leadership discussion could focus on behaviours and traits critical to the changing organisational landscape. With an increasing focus by organisations on creativity, adaptability, resilience, and the need for strong collaboration, relevant discussions could include aspects such as personality traits that support increased interpersonal skills (e.g., genetics of agreeableness) [145], characteristics that foster openness to change [146], promote resilience [147] and increase adaptability (e.g., genetics studies into psychological flexibility) [148], as well as genetics of creativity [149] and the need to cope with stress (e.g., genetic studies into stress response profiles) [150]. The socio-genomic research also offers potential insights into the genetics of social behaviours adaptive to the changing landscape [115]. However, because genetic variation is a moderate component of such traits, care would need to be taken to consider other factors, such as epigenetics and previous environments (e.g., training), when selecting leadership candidates.

In terms of epigenetics research, this would argue the need to foster the activation of epigenetic mechanisms to facilitate flexibility and responsiveness [69]. Epigenetic capacity is reliant on physical and psychological well-being with research showing strong links between diet, stress, physical activity and epigenetic health. This links to the pillars of health, as previously discussed, to ensure both leaders and staff have the health status to maximise their epigenetic adaptive capacity. It also explores the link between exposure to natural environment, health, and through this, epigenetic health. This can be seen in research utilising satellite technology, which has demonstrated clear associations between the natural environment and a wide variety of positive health outcomes [151].

Combined, a more developed leadership requires organisations to focus on identifying a leadership that thrives within a changing modern business environment. Similarly it also focuses on identifying a leadership that can nurture adaptive capacity by creating a workforce that thrives within a changing modern business environment. This can be achieved through recruitment and fostering of leaders and their staff with inherited adaptive capabilities described previously. More broadly, a more developed leadership role-modeling these adaptive capabilities can influence this adaptive capacity. It can be created through an adaptive culture that fosters physical and psychological well-being. Leadership and culture is closely intertwined with strategy and structure, so choices around these organisational elements will be important. All of this needs to be reinforced through good systems and processes, as well as suitably crafted human resource policies and practices.

As a cautionary note, from an evolutionary perspective, this approach to organisational evolution in a modern business environment must be set against its impact on the broader evolutionary impact. Many authors would argue the current trajectory of the human-determined progression, Diamond's [152] world of guns, germs and steel, is devastating from a global evolutionary perspective [153]. This leaves us to consider the maladaptive nature of the human imposed form of evolution.

5.2.2. In relationship with the natural environment

By broadening the scope to address the interaction between the workplace, the environment and genomic health, another area that can be studied is the fostering of a better match between the organisation, its modern business environment and the natural environment to promote genomic health and planetary health.

From the review of the existing organisational literature, we have discussed different types of relationships between the modern business and the natural environment. We have argued that links between exposure to the natural environment, health, and through this, genomic health [151], are important in cultivating employee well-being in the workplace. We have also discussed the need for a new business model to address planetary health issues [1–4]. There is additional literature emerging that provides causal links between *planetary distress* and *personal distress*, leading to a range of physiological and psychological health issues [154]. Given the interdependence of the planet and humanity, we suggest that better integrating the workplace with the natural environment can foster new business models that reciprocally promote genomic health for employees and planetary health.

We argue that the nature of the relationship with the natural environment is a choice businesses are making. This choice will determine the degree to which the business can activate innate adaptive capacity to thrive. It also determines the impact of business on employee well-being and on planetary health by fostering (or not) the relationship between modern business, society and nature. The degree of development of leadership is considered a strong contributor to this choice. The modern businesses can exist as:

1. Separate entities, largely mutually exclusive (often exploitative) of any relationship to the natural environment;
2. Separate entities attempting to become more organic, thus recognising they have a relationship with the natural environment;
3. Separate entities that recognise their ethical responsibility to the natural environment;
4. Interdependent entities that are reflective of, and in an inter-dependent relationship with, the natural environment.

We offer a nomenclature based on these perspectives to explore how this relationship might progress. In describing these perspectives, it is argued that our genomic capacity is enhanced when there is alignment with nature, as this best supports wellness in our biological capabilities.

The use of a nomenclature to explore the relationship between organisations and the natural environment is not new [155]. Work by Hunt and Auster [156] describes five categories of corporate environmental management programs: (1) the beginner; (2) the firefighter; (3) the concerned citizen; (4) the pragmatist; and (5) the proactivist. Roome [157] also suggested a classification system based on levels of proactivity in terms of environmental management: (1) noncompliance; (2) compliance; (3) compliance plus; (4) commercial and environmental excellence; and (5) the leading edge. This can be seen a reflective of Carroll's [158] pyramid of corporate social responsibility [CSR], with its stages of: (1) economic; (2) legal; (3) political; (4) ethical; and (5) philanthropic.

We offer our own nomenclature based on advancing the relationship between the organisation, its modern business environment and the natural environment. These evolutionary perspectives are viewed as forming a continuum along which organisations increasingly move towards more natural biological models of existence. In addition to considering their relationship to the natural environment, organisations can alter their size and structure to take advantage of the ancestral patterns. This is exemplified by W.L. Gore's organisational structure [159]. The W.L. Gore organisational structure reflects the social structure and leadership of ancestral humans who lived as hunter-gatherers in small-scale, egalitarian societies. Unit sizes remain around 150–200 employees, beyond which the unit splits, occupying space in separate buildings. There are no managers or workers at Gore, as every employee is an associate. Staff have a key role in choosing a new CEO. "All important

company decisions are democratic, consensual, and peer-reviewed" [158] [p. 1]. This can be viewed as reconnecting the organisation with its identity as a community of people.

This leads us to proffer suggestions for a more developed leadership based on the perspective identified. This will depend on where along the continuum the organisation positions itself in relation to its natural environment. Each of the four perspectives offered draws on different leadership aspects leaving level of development of leadership dependent on perspective.

1. **Parallel:** In this, the organisation and its leadership continue to view their modern business environment as separate to the natural environment but are becoming increasingly cognisant of the natural environment. Here, evolution requires a continued focus on the organisation's environmental responsibility through practices such as engaging in acts of CSR. This is a relationship well represented in the business literature. For leadership to support this evolutionary perspective requires focus on much of the current views of leadership (e.g., transformational, situational). However, there is an increasing need to rely on the interpersonal and adaptive capacity of its leadership to facilitate adaptation to the changing modern business environment.
2. **Partially integrated:** In this, the organisation and its leadership shift to view their modern business environment as being in relationship with the natural environment. Evolution requires a focus on partnering with the natural environment. For leadership to support this evolutionary perspective requires focus on much of the current views of leadership (e.g., transformational, situational). However, there is an increasing need to rely on the interpersonal and adaptive capacity of its leadership, as well as the ethical and servant capacity of its leadership. This is key to leaders taking up their role as leaders of a community working in partnership with, and as guardians of, the natural environment.
3. **Nested:** In this, the organisation and its leadership shift to view their modern business environment as being nested within the natural environment. Evolution requires a focus on redesigning organisations to be more biological, to reflect their natural environment. For leadership to support this evolutionary perspective requires a shift in focus of its leadership to being increasingly interpersonal and adaptive, but more importantly to the ethical and servant capacity of its leadership. This could also be facilitated by introduction of more indigenous leadership approaches. This will allow leaders take up their role as elders of a community and servants to the needs of the natural environment.
4. **Co-evolving:** In this, the organisation and its leadership shift to view their modern business environment as being integrated along with the natural environment into a meta-system. The nature and role of a meta-system needs to be determined as do the meta-governance structures of this meta-system. For leadership to support this evolutionary perspective requires a leadership capable of identifying and crafting a broader meta-construct into which business and the biological fit. This could be akin to Lubchenco [59] concept of the biosphere. The leadership broadens its scope from the role within the organisation to a leadership role within the meta-system. They need to be able to ask the questions around purpose, values, and norms of this meta-system. They need to participate in the meta-governance structure tasked with evolving within, and as participants of, the meta-system.

As these evolutionary perspectives relate to genetic mutations and epigenetic modifications (including ncRNA), the closer to the relationship between the modern business and the natural environments, the greater the capacity to use these biological processes to support health, well-being and adaptability thus enabling evolution.

6. Conclusions

Inherent in biology are the evolutionary mechanisms that enable a species to adapt and thrive. In this paper, we have focused on the genomic mechanisms of genes and epigenetic modifications (including ncRNA) as examples of these evolutionary mechanisms.

In a rapidly-changing modern business environment, it is imperative that these evolutionary mechanisms are maximised to capitalise on our inherent adaptive capacity. However, we argue that in the modern business environment, these mechanisms are being stretched such that they are now becoming maladaptive in their expression, impacting negatively on health and well-being. This underlines the importance of genomic health as an issue of organisational and leadership responsibility. This relates to factors relevant to the individual's health and well-being (e.g., sleep, diet, exercise) as well as the relationships both between individuals and between the organisation and the natural environment.

Therefore, using this analysis, we suggest that before leadership can evolve further, there needs to be a fundamental shift in leadership thinking to focus on the health and well-being of both employees and leaders, in their relationship to each other and the natural environment. Genomics can offer the opportunity to better understand how we can create organisational and business environments to enable us to thrive rather than just cope. A more developed leadership requires understanding of the genomic concepts to help improve genomic health through organisational elements (e.g., structure, culture, strategy). This can be reinforced through the various evolutionary perspectives offered as they relate to the organisation's relationship with the natural environment.

It is through this genomic lens that the potential barrier to the evolutionary nature of leadership can be removed. Only then can the mismatch that currently limits leadership evolving be overcome, making the way for a new leadership paradigm. A more developed leadership and a more progressive business model is essential if we are to address the planetary health challenges and find a pathway to life beyond the Anthropocene.

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