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Visiting Iniquity Upon the Generations

Epigenetics, Systems Biology, and Theologies of Inherited Sin

Developments in evolutionary biology expressed in the Extended Evolutionary Synthesis (EES) present new opportunities for theological engagement with biology. Emphases of the EES have the potential to transform our understanding of key realities that define creaturely life such as agency and inheritance, and this holds implications for theologies of inherited sin. This essay examines two areas of research within evolutionary biology that fit within the EES – epigenetics and systems biology. Reflecting on new information from these areas of evolutionary theory demonstrates the reality that we are constituted through networks of relationships, all the way down to the molecular level. The essay demonstrates that the effects of sin and its propagation involve every aspect of being human, including the biological. The symbiosis of nature and culture that forms us as human beings allows for an understanding of inherited sin that sees humans as both victims and perpetrators of sin, and it embeds an understanding of human sinfulness in the context of the rest of the natural world, acknowledging the interdependence of creation.

Keywords: Inherited sin, Epigenetics, Systems biology, Extended evolutionary synthesis

1. Introduction

Since the publication of Charles Darwin's *On the Origin of Species* in 1859, there has been a great deal of interest on the part of theologians in developing a coherent synthesis between theologies of inherited sin and scientific accounts of human life. Recent developments in evolutionary biology expressed in the Extended Evolutionary Synthesis (EES) present crucial new opportunities for theological engagement with biology as some of the emphases of the EES have the potential to transform our understanding of key realities that define creaturely life such as agency and inheritance, which will carry implications for theologies of inherited sin. This essay examines two areas of research within evolutionary biology that fit within the EES – epigenetics and systems biology. Reflecting on new information from these

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areas of evolutionary theory demonstrates the reality that we are constituted through networks of relationships, all the way down to the molecular level, and so any understanding of sin must situate the individual 'I' as a negotiation of the 'we' that constitutes and sustains it. The view of inherited sin presented in this essay avoids reducing sin to biological imperfection, or conversely, abstracting it into the spiritual realm in a way that neglects attention to the material implications of sin. It demonstrates that the effects of sin and its propagation involve every aspect of being human, all the way down to the biological. This view of the symbiosis of nature and culture that forms us as human beings allows for an understanding of inherited sin that sees humans as both victims and perpetrators of sin, and further, it embeds an understanding of human sinfulness in the context of the rest of the natural world, acknowledging the interdependence of creation.

The notion of inherited sin continues to carry immense explanatory power for the human situation in the twenty-first century. The effects of sin manifest in unique ways based on the particularities of our bodies, and the particularities of these bodies are the result of inherited biological and cultural processes, as well as environmental niches, which were formed long before us and which we inherit. As developments in the EES demonstrate, some of our woundedness is the result of biological forces and environments that we do not control, and of which we are not always even aware. However, we also constantly mediate and adapt the world we have received from those who have gone before, and we shape the biological and cultural world that will be passed on. Thus, we are not completely at the mercy of our bio-cultural inheritance, but we also mold our world as active agents.

We begin then by providing a brief sketch of developments in evolutionary thinking that have led to the EES before turning to discuss the central contours of epigenetics and systems biology. These scientific investigations are followed by an assessment of some key areas relevant for theology that are implicated by these new insights from biology. The biological investigations in this essay illuminate the interdependencies that define creaturely life, the persistent entanglement of nature and culture, the centrality of desire to human identity and behavior, and the role played by biology in the transmission of sin.

2. Developments in Evolutionary Theory

Natural selection, according to Darwin, is a process that "acts only by the accumulation of slight modifications of structure or instinct, each prof-

itable to the individual under its conditions of life" (Darwin [1859] 2008, 174), and it is a force that works continually on organisms to ensure that they are adapted to their environments. The most well-adapted organisms have the highest chance of survival and reproduction. Through reproduction, beneficial variations in species are passed on to the next generation, and so species gradually adapt over long periods of time. Darwin developed his theory of natural selection and inherited variation without any knowledge of genetics, and despite the refusal of some later interpreters of his theory to consider the possibility that adaptation could emerge from interactions between the organism and the environment, Darwin himself expressed openness to the idea (Pigliucci and Müller 2010, 5). To explain the inheritance of acquired traits, Darwin relied upon a theory known as 'pangenesis' in which hypothetical 'gemmules' are produced by cells in an organism, and these 'gemmules' determine the organisms' traits. As Alister McGrath summarizes,

> Each cell of an organism, and even every part of each cell, was understood to produce gemmules of a specific type … These were able to circulate throughout the body and enter the reproductive system. Every sperm and egg contained these hypothetical gemmules, and they were thus transmitted to the next generation (McGrath 2011, 152).

Darwin's theory of pangenesis was highly speculative and not able to be verified at the time, and so his inability to provide a convincing understanding of inheritance remained a vulnerability of his newly articulated theory of natural selection.

Darwin believed that all living creatures descended from common ancestors and that natural and sexual selection were the primary drivers of evolutionary change (Pigliucci and Müller 2010, 5; see also Koonin 2009, 1). According to Massimo Pigliucci, Darwin 'flirted with' the ideas of Jean-Baptiste Lamarck, who argued that environmental factors could cause changes in an organism, and that these adaptations caused by the organism-environment interaction were transmittable to future generations – a process evolutionary biologists now refer to as "soft inheritance" (5). Though Darwin was open to 'Lamarckism,' it fell into disrepute within scientific circles. The rejection of Lamarckism[1] became only more entrenched when, almost a century after *The Origin of Species* had been published, the principles of genetic inheritance discovered by the Augustinian friar and scientist Gregor Mendel and Darwin's principles of natural selection were combined into a unified theory that was termed the 'Modern Synthesis' (Huxley 1942).

1 For helpful analyses of the reception of Lamarck's work, see Gissis and Jablonka 2011.

Proponents of the Modern Synthesis have emphasized the following principles: random mutations cause genetic variations in species, populations evolve by "changes in gene frequency brought about by random genetic drift, gene flow, and especially natural selection," and most genetic variations have "individually slight phenotypic effects so that phenotypic changes are gradual" (Futuyma 1986, 12). Recall that a *genotype* is the genetic 'information' that an organism carries within its genome, and a *phenotype* is the composite of an organism's observable traits – including its behaviors, the shape of its body, its development, and its biochemical properties. The Modern Synthesis is a 'gene-centric' theory. Central to the Modern Synthesis have been both the belief that all inherited variations can be expressed in terms of genetic differences, and the rejection of anything that seems 'Lamarckian,' or that would postulate a theory of 'soft inheritance' (Jablonka and Lamb 2010, 137). Within this framework, genes came to be portrayed as the masterminds[2] of evolutionary change, as if genes possess some form of agency and organisms are at the mercy of their given genomes.

The Extended Evolutionary Synthesis has brought a growing appreciation for the fact that constituent elements of an organism, such as genes, are formed by and function within systems over time[3], and that they can only be properly understood from within their given contexts. Genes have many possible phenotypic effects, and the ones that ultimately manifest are largely dependent upon environmental factors[4]. Furthermore, phenotypes are 'plastic,' which means that a phenotype produced by a specific genotype can also change in response to its environment, and it seems that these accommodations to the environment may also be heritable (Sterelny 2009).

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2 As an example, note Dawkins' claim "Now they swarm in huge colonies, safe inside gigantic lumbering robots, sealed off from the outside world, communicating with it by torturous indirect routes, manipulating it by remote control. They are in you and me; they created us, body and mind; and their preservation is the ultimate rationale for our existence. They have come a long way, those replicators. Now they go by the name of genes, and we are their survival machines" (Dawkins 1989, 19–20).

3 As Gould notes: "Bodies cannot be atomized into parts, each constructed by an individual gene. Hundreds of genes contribute to the building of most body parts and their action is channeled through a kaleidoscopic series of environmental influences" (Gould 1992, 91).

4 It is important to note that some genes are 'monomorphic,' meaning they generally do not vary in terms of how they are expressed from one person to the next. For example, monomorphic genes lead to humans having two eyes situated on the front of their face. Other genes, however, have 'polymorphisms' [technically speaking, they have "two or more different possible alleles (alternate forms of a gene)"], which means that these genes can create genetic variation among humans (different eye or hair color, personality tendencies, etc.). Cf. Salk and Hyde 2012, 397.

There is not, then, a one-directional movement of causation from DNA to the phenotype, but rather, as Evan Thompson notes, "The causal chain between DNA sequences and phenotypic characteristics is too indirect, complex, and multifaceted for there to be any robust one-to-one relationship between them. Hence, no phenotypic characteristic can be said to be 'coded for' by DNA sequences" (Thompson 2010, 181). Genetic variation exists among different humans, but also within the same human over the span of a lifetime. This significantly complicates previous understandings of the role of genes as determinants of an organism's traits and behaviors. Genes do not determine phenotypes on their own, rather, recent developments in evolutionary biology emphasize "the role of constructive processes in development and evolution and reciprocal portrayals of causation" (Laland et al. 2015, 1), and these new emphases are expressed in the Extended Evolutionary Synthesis.

3. Epigenetics: A Broader View of Inheritance

A defining feature of the Extended Evolutionary Synthesis is the development of research into "epigenetics," defined by Eva Jablonka as "heritable changes in the expression of genes that are not dependent on changes in an organism's DNA" (Jablonka 2016, 46). As with systems biology (discussed below), epigenetics is not a novel concept but it has experienced a renewal of interest in recent years. C. H. Waddington coined the term "epigenetics" in 1942 to refer to the "bridge between the genotype and phenotype in development" (Heard 2014, 96). Broadly speaking, research in epigenetics involves examining the mechanisms that bring about "inducible, persistent, developmental changes" (Jablonka and Lamb 2010, 144) within organisms and this often involves consideration of the mechanisms of epigenetic inheritance as well. Epigenetic inheritance, according to Jablonka and Lamb, can occur at the cellular level within an organism, but it can also occur between organisms through various types of interactions. All organisms are capable of being shaped by epigenetic transgenerational inheritance; however, whether or not organisms are, and the extent to which they are, are determined by environmental and genomic contextual factors.

The idea expressed by epigenetics is that organisms pass on more than just their genes – they also pass on 'molecular switches,' or cues for how genes should be expressed. Epigenetic changes typically happen within an organism because of contextual influences that could include intra-organism

factors like specific enzymes or hormones that would provoke gene expression or silence, and contextual influences can also include factors outside the organism like parent to offspring interactions, social learning, symbolic communications, and the changes that an organism makes to its own environment or to the environments of other organisms (Jablonka and Lamb 2010, 144). Developments in epigenetics research indicate that the changes in patterns of an organism's gene expression in response to environmental factors leave 'epigenetic signatures,' or marks, on the genome, and that these marks can be inherited.

For example, some studies of the offspring of Holocaust survivors indicate that, in addition to the environmental and cultural elements that might have an impact, these descendants are also born with alterations to their biological stress response systems that reflect similar epigenetic signatures to the ones developed by their ancestors who endured the initial trauma, and that these inherited epigenetic signatures may leave them more vulnerable to experiencing negative effects of stress (Bowers and Yehuda 2016). Another study often cited to demonstrate the possibility of epigenetic inheritance is by Painter et al. from 2008 entitled "Transgenerational Effects of Prenatal Exposure to the Dutch Famine on Neonatal Adiposity and Health in Later Life". This study examined the grandchildren of a cohort of men and women who were malnourished for a prolonged period of time during the Dutch famine of World War II, and it found that they demonstrated more persistent negative health effects such as obesity and chronic disease than their peers who descended from Dutch people who escaped the famine. This suggests that realities like trauma, poor socio-economic conditions, and other environmental stresses can have multi-generational repercussions for the health and well-being of populations.

This means that, in the words of one leading researcher in this area, some people "have a lot more to overcome because their biology has given their condition a firmer reality" (Yehuda 2015), especially members of human groups who have endured extensive prolonged trauma. While epigenetics provides insights into how trauma can persist biologically for generations, it also provides reasons for hope since resilience and healing are also partially inheritable. "Biological and molecular healing" (Yehuda 2015) can also be passed on to future generations via the mechanisms of epigenetics. Some implications of this developing research in epigenetics for theologies of inherited sin are expressed below[5].

5 It is worth noting that epigenetics is still very much a developing field within evolutionary biology, and there is currently a great deal of debate among scientists about many aspects of epigenetic research including the mechanisms of epigenetics

4. Systems Biology and the Development of Desire

Assessing recent developments within the field of evolutionary biology, Eva Jablonka and Marion Lamb argue that "in the long term, the development that will have the greatest impact on evolutionary ideas is the shift to systems thinking in biology" (Jablonka and Lamb 2014, 381). As with epigenetics, systems biology is not a wholly new approach in the field of biology. Indeed, scholars such as C. H. Waddington (1905–1975) emphasized that the relationship between genes and phenotypes should be understood as interacting in a networking of interlocking systems, and Waddington is credited with being a "founding father" of systems biology (381). However, systems biology has experienced a resurgence in recent years with the expansion of evolutionary thinking reflected in the Extended Evolutionary Synthesis. Denis Noble from Oxford University has been a major contributor to the expansion of research in systems biology as well. As he states in his *The Music of Life: Biology Beyond the Genome*,

> In recent decades, however, biologists have tended to focus quite narrowly on the individual components of living organisms. What properties does each component have … Now, we are ready to ask some bigger questions. These are about systems (Noble 2006, 9).

Systems biology emphasizes the inadequacies of approaches that divide up complex phenomena and organisms into smaller parts and examine these smaller parts in isolation in order to understand whole organisms or phenomena. Rather, systems biologists argue, it is crucial to evaluate how each of the various components within an organism work in combination with each other and change over time. As Noble argues,

> Molecular biology requires a certain way of thinking. It is about the naming and behavior of the parts. We reduce each whole to its component parts and define them exhaustively. Biologists are now perfectly used to that thinking and the interested lay public has caught up too. So we are now ready to move on. Systems biology is where we are moving to. Only, it requires a different mind-set. It is about putting together rather than taking apart, integration rather than reduction (9).

In other words, within systems biology the emphasis is on emergent properties and the behaviors of networks of smaller parts, rather than on individual elements in isolation (Jablonka and Lamb 2014, 382). Systems biology certainly resonates with many of the emphases of epigenetics which

and the extent to which epigenetically induced traits can be inherited beyond a single generation. Eva Jablonka, Marion Lamb, Kevin Laland and others have written extensively about the current state of evidence for transgenerational epigenetic inheritance.

were discussed above, especially in its portrayal of genes as existing within the middle of a matrix of influences that shape their expression.

In addition to Noble and others, a key researcher in the area of systems biology is Anne Fausto-Sterling, the Nancy Duke Lewis Professor Emerita of Biology and Gender Studies at Brown University. For the purposes of this essay, her challenging of the nature/nurture dichotomy, her articulation of four key principles for systems biology, and her investigations into the physiological development of desire are especially relevant.

a) Four Principles of Systems Biology

The body, Fausto-Sterling argues, is a "collection of systems found within the world" (Fausto-Sterling 2012, 404). She posits that the body is an entity that exists "in the middle." Our bodies are "sustained within the world, responding to it, but also reshaping it" (404). Understanding the body as a collection of systems that are constantly integrating new information, and that fluctuate in their stability and coherence, she argues, renders the notion of predisposing biology or determinative culture nonsensical. We are born into complex webs of influences that are impossible to untangle. Embodiment, in this framework, is a multi-tiered collection of processes that shifts and adapts over the course of a lifetime. Bodies and behaviors cannot be reduced to genes, hormones, or social constructions. She argues that we should view human traits and behaviors not as fixed, but rather as the result of "a dynamic interplay between body and experience" (Fausto-Sterling, Cole and Lamare 2012, 1693). We are in part shaped by the genetic, epigenetic, and environmental legacies of those who came before us, but we are also continually adapting over the course of lived lives in response to choices we make and the influences of those around us who help to shape our environments. Fausto-Sterling argues that studying the relationships between interacting systems such as "the macro system of human history and evolution, to the meso level of individual experience and behavior, down to the micro world of genetic regulation within individual cells" (Fausto-Sterling 2008, 676) demonstrates that it is impossible to separate nature and nurture. It is time, she argues, to abandon the notion of a nature/nurture dualism and to establish new models for understanding human life that more adequately account for the multiple interacting systems that cohere in each of us.

Fausto-Sterling describes systems biology in terms of four key concepts. The first concept is that "behavior, engaged in over time, influences nervous system structure" (Fausto-Sterling, Cole and Lamare 2012, 1693). For example, statistically it appears that parents tend to interact in different

patterns with newborn sons than they do with newborn daughters. These differences include things like patterns of affectionate touch, frequency of verbal communication, and tone of vocalization (1693). Some of these differences in parental-infant interactions are expressed even while the child is still in the womb. Parent-newborn interactions, especially when they are continuous over time, shape the nervous system of the infant, and this contributes to all manner of later differences in biological characteristics and behaviors that can come to be perceived as 'innate.' Affectionate touch from caregivers contributes to an infant's ability to learn to regulate temperature, to sleep, and to self-sooth. It also lowers newborn levels of stress hormones and metabolism, and it contributes to healthier immune function. Skin-to-skin contact, argues Fausto-Sterling, is also "essential to the embodiment of emotions and the development of the self" (Fausto-Sterling 2012, 408). Thus, in this first concept within a systems approach to biology, we see the persistent entanglement of biology and culture.

The second principle of systems biology, according to Fausto-Sterling, is the notion that "behaviors and other physiological states are softly assembled" (Fausto-Sterling, Cole and Lamare 2012, 1696). A 'softly-assembled' behavior is one that is relatively, but not permanently, stable and that provides a foundation for experimentation and potential development of other 'softly assembled' behaviors. These 'softly assembled' behaviors and states are also influenced by environmental inputs. For example, they can be reinforced or discouraged by parental reactions. Thus, she argues that again nature and culture are impossible to separate since physiological states might prompt some behaviors which are then 'softly assembled' and either rewarded or discouraged by caregivers.

The third principle of systems biology, according to Fausto-Sterling, is the fact that "the body integrates perception, action, and cognition" (Fausto-Sterling, Cole and Lamare 2012, 1696). She reports that infants in the womb and after birth are inundated with sensory information, which causes their nervous systems to expand and develop rapidly. "Through its sensory and motor abilities," she argues, "the exterior layers of the body bring the world into the central nervous system" (Fausto-Sterling 2012, 405). Experiences and social interactions collide with the explosive expansion of neural branching and connectivity, as well as chemical signaling happening within the developing nervous system of the baby. All of this activity influences the development of the brain's "limbic system," which, she notes, "integrates emotional states with stored memories of physical sensations" (Fausto-Sterling, Cole and Lamare 2012, 1697). These processes influence later abilities to make social connections, develop self-awareness, regulate emotions,

and make interpretations about emotive experiences. This plasticity does not end with infancy, but rather, it continues throughout the development of a life. Thus, Fausto-Sterling argues, "far from being destiny, anatomy is dynamic history" (Fausto-Sterling 2005, 1511). Our bodies give us clues about our ancestors, our parents, our homes of origin, our social contexts, and our habits, but since they are constantly integrating new sensory data and inputs (partly due to choices that we make), they also defy predictability.

The fourth principle of systems biology as expressed by Fausto-Sterling is what she describes as a "new respect for individuality" (Fausto-Sterling, Cole and Lamare 2012, 1698). She argues that biologists should be interested in the question of "how large group differences emerge over time from a starting point of large individual variability but small group differences" (1698). Newborns exhibit vast amounts of individual variability in behaviors, brain sizes, and motor functioning. However, the degree of variability in these elements diminishes as infants grow up.

Each element of a systems approach to biology described by Fausto-Sterling supports her aim of eliding the distinction between nature and nurture in order to develop a more helpful model for understanding what it means to be human. Developing a systems approach to creaturely life requires us to accept that genes, hormones, limbic systems, cells, and organs found in the body play a role in shaping individual and group behaviors, while also recognizing that biology intersects at all times with environmental and social forces, such that causal influences can never be definitively untangled.

b) The Development of Desire

Many of the elements of systems biology described above will be helpful for our development of a biological-theological approach to inherited sin, as we discuss in more depth in the next section. However, one additional area of Fausto-Sterling's research is also relevant for our purposes, and this is her insight into the development of desire. Because of its centrality to human life, desire plays a fundamental role in sin, human flourishing, and in the economy of salvation. It will be crucial, then, to have a framework for understanding the development of desire from the perspective of biology as well as theology.

In a move consistent with her tendency to view human life through the lens of systems biology, Fausto-Sterling describes desire as a developmental process, rather than as a permanent state (Fausto-Sterling 2007,

50). Understanding desire in its fullness requires acknowledgement of the many components that cohere together to produce states of desire with varying levels of stability in the human person. The levels of organization involved in the development of desire range from "the subcellular to the sociocultural" (56), she notes. She reflects the emphases of the Extended Evolutionary Synthesis and especially epigenetics in her placing the influence of genes squarely in the middle of a matrix of causal influences. Gene expression, she argues, is a "reaction to a particular environment or experience" (56). Genes should not be considered 'causal' agents in any linear or straightforward way. She emphasizes as well the centrality of neural plasticity to the development of desire. As we develop from infants to adults, our brains grow as well, and our nerve cells "make and lose and remake and stabilize multiple connections in response to experiences and behaviors" (56), which helps us to understand how we come to experience embodied desires.

Memories that become integrated into the body are central to the experience of desire. As we discussed above, sense experiences influence the development of the brain's "limbic system," which, Fausto-Sterling notes, "integrates emotional states with stored memories of physical sensations" (Fausto-Sterling, Cole and Lamare 2012, 1697). Repeated experiences or behaviors cause our bodies to, in a sense, 'memorize' feelings. Particular pleasures, repulsions, longings, and desires, especially if they are frequent, become incorporated into the body. She describes this incorporation as desires becoming "sedimented in the body" (Fausto-Sterling 2007, 55) such that they become resistant to change. These sedimented desires become habitual and thus unconscious. Dynamic systems can be "self-stabilizing" (55). However, there are a multitude of factors, including physiological, psychological, hormonal, and social that can cause these usually stable systems to destabilize and become "chaotic" (55). Usually the systems will re-stabilize after a period of integration, and after this re-stabilizing, desires may remain the same as they were before the destabilizing event, or they may change.

Though desire is often unconscious and habitual, Fausto-Sterling argues that through the human capacity for self-reflection and story-telling, we can actively contribute to making desire at least partially a feature of our conscious thought, and this making conscious of the previously unconscious can "in turn modify incorporated knowledge" (55) or influence the ongoing sedimentation of various desires. This description of the development of desire helps to illuminate the complexity of desire as, on the one hand, a series of systems that we inherit based on processes of incorporation and

sedimentation that happen long before we are consciously aware. Thus, to a certain extent, the shaping of our desires is out of our control. On the other hand, we can, she argues, partially impact the development of desire by our choices of repeated bodily practices and social influences, and we can intentionally strive to become more aware of the sedimented desires within, which is one way of also contributing to their ongoing development and adaptation. Much of the workings of desire depend upon processes that are out of our control, however, we are not passive recipients of our inherited desires. Rather, we participate actively – without having complete mastery over them – in shaping the future directions and developments of our desires. Biology, she argues, is not "permanence" and social construction does not entail complete plasticity (Fausto-Sterling 2007, 51). Biology is both recalcitrant and plastic, and social construction can be determinative even as it is alterable.

5. Epigenetics, Systems Biology, and Inherited Sin

Epigenetics and systems biology both reveal the extent to which the Extended Evolutionary Synthesis is a movement away from the gene-centered picture suggested by the Modern Synthesis. The EES seeks a richer and more complex account of the interactions between genes and environments across the life span of individual organisms, species, and species across generations. It shows the nuanced interplay between nature and culture, and the impossibility of ever separating these realities. Culture is shot through with nature, and nature is always already cultural. On the one hand, epigenetics and systems biology both reveal that organisms are shaped by forces and environments that they do not entirely control, and of which they are not always even aware. They expand our understanding of the complexity of the ways in which our biological and cultural pasts are always part of us – all the way down to the level of our genes and the various possibilities for their expression, as well as in our sedimented memories of desire. The persistence of the past into the present means that some begin life with more to overcome, biologically and culturally. On the other hand, they also reveal that organisms are not only inert and passive entities acted upon by evolutionary forces. Rather, organisms also impact the environments and other organisms around them, thereby shaping the direction and pace of evolutionary movement. Through our active living in the world, through our aesthetic tastes and romantic loves, our dreaming and our longing, through our religion and our myth-making, we constantly mediate and

adapt the world we have received from those who have gone before, and we shape the biological and cultural world that will be passed on. The Extended Evolutionary Synthesis is changing how we think about what it means to be humans embedded in an evolutionary milieu, and the dynamic picture it paints has relevance for how we think about theological categories such as sin, agency, desire, and the importance of corporeal practices.

a) Inherited Sin

The reality of the body revealed by epigenetics and systems biology as a dynamic space 'in between' can in many ways lend support to theologies of sin that have insisted that sin is somehow inherited. As we have seen, from the moment of conception, we are formed within a dynamic matrix of biological and social/cultural forces. There is no time at which the biological is not also cultural, and there is no 'pure nature' that is later influenced by culture. Rather, from the moment we begin to exist, we receive biological and cultural inheritances that contribute to our flourishing, but that also 'infect' us with biases, traumas, prejudices, and injustices that originated long before our choosing. As Catherine Keller notes,

> I did not choose my ancestors' slaveholding, my nation's aggressions. Yet such preconditions have shaped, privileged and deformed 'me' – like a contagious disease, as Augustine would say (yes we are all connected). If one earthling falls into alienation, into greed, into domination – that sin will infect its relations and this in part constitute all who follow. A relation is a repetition: recapitulation (Keller 2003, 80).

In this sense, sin is 'original' to each of us since there is never a time at which we are able to escape the formative power of the culture/nature dynamism of evolution. Additionally, in a qualified sense, we can argue that sin is propagated 'biologically,' if we again affirm that biology and culture work as a synergy in the human subject.

This approach to inherited sin rejects the suggestion made by some that sin arises from 'nature,' or is simply a theological way of describing the destructive influence of some aspects of our biological inheritance. For example, Patricia Williams argues, "human beings are self-interested, selfish, and conflicted because of their general genetic makeup" (Williams 2000, 799). It likewise rejects the suggestion made by others that sin is transmitted only through cultural inheritance and not biology. For example, although he affirms that recent developments in evolutionary theory undermine the nature/culture divide, and he affirms the "deeply enculturated nature of human existence" (van den Toren 2018, 176), Benno van den Toren nevertheless argues that

current evolutionary theory rather unexpectedly provides a new theoretical framework that helps us deepen our understanding that human sinfulness is *not part of human nature* yet is unavoidably inherited from our parents and from the communities in which we are raised (179, emphasis mine).

Thus, for van den Toren, cultural socialization, and not biology, is the mechanism for the transmission of sin. This serves to reify a nature/culture dichotomy, despite his acknowledgement of the inadequacy of the nature/culture dualism. This essay draws from epigenetics and systems biology in order to press more deeply into the synergy of nature and culture and insist that we can never separate nature and culture, and so sin is transmitted through a matrix of influences both 'cultural' and 'biological,' although the deeper point to acknowledge is the inadequacy of frameworks dependent upon a nature/culture dualism for explaining the origins of sin. Human culture and socialization are thoroughly biological developments, and human biology is permeated and shaped by human culture.

One way, then, in which we can retain a notion of 'original sin' in the twenty-first century in light of all that we know about the dynamic interplay of nature and culture in evolution is to see the human person as a product of an evolutionary past that continues to exert causal influence, as an entity shaped by multiple interacting systems, with a certain degree of agency, but not unbounded possibility, with our agency always already limited and shaped by the matrix of interdependencies in which we live. The past decisions made by our ancestors, our early childhood experiences, and the forces that came before us – the sinful and the good and everything in between – are always with us, although we are also not completely determined by these histories. Although this essay argues that biology plays a role in transmitting the effects of sin, this is not to say that every biological vulnerability or imperfection that we experience within ourselves is a result of sin – our own or that of our ancestors. This would lead to the abysmal, and inaccurate, conclusion that poor health can be simplistically correlated with one's level of sinfulness or victimization. Instead, this essay makes a more general point, namely, that since culture and nature are inextricably intertwined, biology can (and likely does) play a role in manifesting and transmitting the effects of sin. However, this should not be conflated with the idea that all biological imperfections are necessarily sinful or the result of sin.

b) Agency

As adumbrated above, epigenetics and systems biology should also transform our conceptions of creaturely agency, which is also relevant for

theologies of inherited sin. It is not tenable to posit any conception of sin and culpability dependent upon a notion of the human person as an autonomous 'I.' The various "sticky webs of connections" (Bennett 2004, 365) that form each of us also entangle us in various ways in immense "webs of reciprocity in evil" (Duffy 1988, 616) that we cannot escape through our own efforts. Yet, as we have seen, this matrix of causal influences that forms our 'self' also includes as one factor our own active decisions and choices, and so we can also – to a certain extent – make choices for good or for ill. As Keller states,

> We go along, we do not resist, we seek to secure our existence. The repetitions become habitual, often compulsive, carried along by global patterns of assumption – economic, sexual, racial, religious. Amidst these structures, our agency may be unconscious. But it is never simply absent (Keller 2003, 80).

The EES can thus assist us in developing a notion of sin that accounts for the wide array of influences, forces, and systems that collide to influence human behavior, and to resist the temptation to think of culpability in a simplistically individualistic sense. Indeed, as Elizabeth Grosz argues, it is more accurate to describe creaturely life in terms of excessive agency rather than a lack of agency. She states,

> Subjects, groups, do not lack agency; on the contrary, they may, perhaps, have too much agency, too many agents and forces within them, to be construed as self-identical, free, untrammeled, capable of knowing or controlling themselves. This is not to claim that subjects are not free, or not agents, but that their agency is mitigated and complicated by those larger conditions that subjects do not control (Grosz 2005, 6).

We are radically interconnected and interdependent, even across species, and all the way down to the molecular level. A conception of the human person as an autonomous 'I' that persists especially in Western contexts and that has caused so much difficulty for the notion of sin as inherited is now being transformed by a greater appreciation for the embeddedness of the human species in the evolutionary world, and the complexity and diversity of the processes that shape human consciousness and identity. In this light, the notion of 'inherited sin' is a helpful resource as we seek to understand the history of our species. As Stephen Duffy has argued, "before being able to choose," we are, "merely by being historically situated" (Duffy 1988, 616), inextricably caught in conflictual and sinful structures that shape us. In our unity with one another, we share our culpability and restoration, our sickness and healing. Keller is thus correct in her argument that sin is thus "discreation, that is, creaturely relations that deny and exploit their own interrelations" (Keller 2003, 80). However, we would extend Keller's insight to

say that sin is not only a denial or exploitation of creaturely relations, but that the concept of sin also describes pathology in the ways in which we relate to God. As Alistair McFadyen argues, "the language of sin carries an inbuilt reference to God, naming the pathological as the denial of and opposition to God" (McFadyen 2000, 11).

c) The Centrality of Desire

Reflection on desire is central to some of the most influential theologies of sin in the Christian tradition. The insights of Fausto-Sterling and systems biology affirm the view expressed by many theologians that desire is a central determinative feature of human life and behavior. Fausto-Sterling's work also helps to unveil the complexity of the dynamic development of desire, and the extent to which desire, and sedimented memories of desire, establish our identities. Sedimented and unconscious desires, while not permanently determinative, exert strong influences over our behavior and self-understanding. Fausto-Sterling's insight that desire is a force that is both given and constructed can contribute to a framework for understanding inherited sin. Her illumination of the means by which desire becomes sedimented helps to explain the recalcitrance and relative stability (but not permanence) of destructive individual, familial, and societal desires. Destructive desires such as the desires to dominate or possess others (Augustine's *libido dominandi* or Raymund Schwager's Girardian notion of 'acquisitive mimesis')[6], to exclude and alienate, to enact violence and to be cruel can become sedimented in individuals and groups. Fausto-Sterling's work illuminates how deeply ingrained in our bodies desires become, and thus, they are not easily uprooted and transformed. We cannot shift them solely through our own efforts, especially because so many of the desires that drive us are unconscious. However, her work also reveals that we can play a role in making our unconscious desires conscious, and we can participate in the ongoing development of the trajectory of our desires. Fausto-Sterling shows once again that agency is multi-tiered – we exist enmeshed in multitudes of webs of connection and a "matrix of interdependencies" (Bennett 2004, 365) that shape us for good and for ill, but we also play a role in constructing ourselves.

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6 Augustine argues in "De Genesi Ad Litteram," "*Primum esse et maximum vitium tumoris ad ruinam sua potestate velle uti, cuius uitii nomen est inoboedientia*" (The fundamental and greatest sin is the distention by which one desires to have independence to his own ruin, and the name of this sin is disobedience) (Augustine [414] 2000, VIII.6). For Schwager's notion of sin as 'acquisitive mimesis' see Schwager 2006, 18.

In some theologies of sin that have emphasized the centrality of desire, desire is depicted as a problematic force to be mastered and subdued by reason. For example, while it would not be accurate to depict Augustine as straightforwardly negative toward desire, he does portray desire as a potentially dangerous force that should be rightly ruled by the mind[7]. As he notes in *De Opere Monachorum,* "What therefore, in one person are mind and concupiscence (for the one rules, the other is ruled, the one dominates and the other is subdued), that in two human beings, man and woman is represented according to the sex of the body" (Augustine [400] 2000, 32.40). In contrast to this, systems biology can help us to appreciate that while desire is a crucial feature of human life that shapes our identities and behaviors, it can never be 'mastered,' especially since many of our desires are unconscious. Even if it were possible to totally subdue desire, this would ultimately diminish creaturely flourishing. Vibrant desire is essential to almost every area of life considered important by humans – love, relationships, meaningful work, artistic expression. Furthermore, as Darwin noted, the unruliness and unpredictability of desire play important roles in the ongoing processes of sexual selection, which are central to the movements of evolution. Our inability to be completely in control of the direction and shape of our desires is not something to be lamented, even though it has the potential to be a source of suffering. Recognizing the nature of desire as excessive and eruptive reminds us that we do not make ourselves who we are through our own autonomy and self-determination. Rather, much of human life is learning to become attentive – awakening – to what we have received from others, including our desires – for good or for ill, and then working with and through our desires to continue to grow in ways that promote creaturely flourishing.

The EES helps us to appreciate the fact that we are, to a large extent, shaped by histories and forces that we did not choose and which we cannot control through our own efforts. It helps us to see that causation is plural and nonlinear. The dysfunctions and 'discreations' that wound creaturely life and distort desire were not definitively caused by one thing. Rather, histories of sedimented distortions of desire with many varying levels of agency

7 It is not right to depict Augustine as negative toward desire because for him, it is not what we think, but what or who we love, that determines who we are. *Voluntas* in Augustine's thought, as John Rist argues, does "some of the work of the word and concept 'eros' – the love of the good and the Beautiful, and the perversions of that love. Hence, we should not be surprised that *voluntas* is often interchangeable with *amor* and in its perfect form identified with it: that is, as the Holy Spirit" (Rist 2001, 36) For Augustine, love also "determines the Christian virtues" (Rist 1994, 119).

and complex intersections of factors have coalesced to produce our histories. A theological vocabulary enables us to name this as 'sin.' Every human is simultaneously a victim and a perpetrator, although not necessarily in equal amounts. As we have learned from epigenetics, even at the biological level, 'some people have a lot more to overcome' than others (Yehuda 2015).

d) The Importance of Corporeal Practices

The final insight to highlight from epigenetics and systems biology for theologies of sin is their emphasis on the importance of the embodied activities of everyday life for the ongoing evolution of our species. The small, mundane, bodily practices we participate in, individually and collectively, are pivotal in shaping the trajectory of evolutionary processes. For example, a myriad of different characteristics, behaviors, and desires in individuals are shaped by the small, repeated, corporeal practices that occur within family life, such as play and affectionate touch. Repeated practices or experiences cause our bodies to sediment desires. These sedimented desires then become incorporated into the body and shape one's sense of self. Additionally, as epigenetics has revealed, prolonged and repeated habits and exposure to positive or negative environmental influences can impact the epigenome, which can be inherited.

The focus found in epigenetics and systems biology on the importance of corporeal practices affirms the theological insight that spiritual disciplines, liturgies, and ecclesial rituals are fundamental to human life, and that we can intentionally use these practices to partner with the Holy Spirit to orient our desires to be more aligned with love, selflessness, solidarity, and other Christian virtues. Liturgies and spiritual practices can provide structured spaces in which we can become more attuned to our desires, we can make our unconscious desires conscious, and we can work to redirect destructive desires. Thus, the emphasis on the importance of corporeal practices found in the EES finds some consonance with John Paul II's insistence that it is not only theologies of the body, but also "pedagogies of the body" (John Paul II 2006, 274), that are needed. Repeated corporeal practices, liturgies, and habits will play important roles in effecting transformation, but ultimately, we cannot transform ourselves by force of will or by cooperating with the processes of becoming that are inherent to evolution. Rather, within the context of a Christian theological framework, we would emphasize that it is only through the experience of redemption in Christ that the human person receives the gift of the Holy Spirit, which enables him or her to live life in a genuinely new way. Transformation is both a gift and a task. As Graham

Ward argues, "The contents of the faith are the start of a biblical, liturgical, and ecclesial formation led in and through a life of embodied practices all of which can be summed up in prayer" (Ward 2016, 117). Formation – individual, familial, and ecclesial – will be necessary to reorient our desires toward love and away from 'discreation.' However, this is not a 'mastering' of desire, but rather, a redirecting and a renewal of desire.

We are constrained by what we have inherited, sometimes in destructive ways, but we are also in a continual process of evolution, and we participate actively in its ongoing elaboration through our corporeal habits and practices. God's creation of the world is a continual process of becoming, a continual proliferation of difference that is sustained by the presence of God but also influenced by the dynamic energy of human beings. The EES can help us to appreciate the ways in which our collective, ecclesial, and individual bodily habits and practices play roles in shaping the unpredictable future of our species.

6. Conclusion

Developments in epigenetics and systems biology offer support for the notion that sin is, in a sense, 'inherited' and inescapable. They help provide a framework for understanding why sedimented distortions and 'discreations' are not easily uprooted, but rather, they are stubbornly recalcitrant across generations. Theologies of inherited sin that emphasize the unity of the human race, the fact that biology plays a role in the transmission of sin, and that desire is central to human identity are all affirmed by these developments in evolutionary biology. We are interconnected, interdependent, and constituted by various webs of connection that have forming power over us, which we did not choose. We belong to one another, and thus the notion of inherited sin provides a crucial framework for perceiving the reality that sin is not only manifested in discreet, individual, conscious acts; rather, it permeates our ecological niches, our interrelations, and our 'sedimented desires.' This project locates sin in neither 'nature' nor 'culture,' but argues that nature and culture are inseparable, entangled forces that shape creaturely becoming. As Serene Jones argues, sin "inhabits us just as we willingly inhabit it" (Jones 2005, 301).

Epigenetics and systems biology illuminate the nature of the body as both a memorial to the past and a site of development that is open to the future. They provide important tools for conceptualizing creaturely life as a blend of 'givenness' and construction (both social and individual). They enable us to

recognize that causation is not linear, but is, rather, "complex, recursive, and multi-linear" (Frost 2011, 71). They demonstrate that every creature exists in the midst of a matrix of "interdependencies" (78), and thus they work against the myths of both essentialism and determinism, but also the fantasies of autonomy and self-creation. We are constrained by our bodies, our ecological niches, our evolutionary pasts, but these very constraints are also the means of their partial overcoming. As Jane Bennett notes, humans are always "in composition with nonhumanity, never outside of a sticky web of connections" (Bennett 2004, 365). Our bodies are products of an accumulation of events, forces, and processes in our evolutionary past that we do not control. We carry in our bodies the effects of choices made by our ancestors, the effects of traumas and triumphs they experienced, and the influences of the families and communities in which we were raised. On the other hand, the past we carry within us is not static, but it is constantly providing resources that we use in the present to develop new behaviors and trajectories, both for us as individuals, for our communities, and for our species.

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