# Neo-Aristotelian Ethical Naturalism and the Challenge of Genome Editing

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# *Neo-Aristotelian Ethical Naturalism and the Challenge of Genome Editing*

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### *Introduction*

Neo-Aristotelian virtue ethics is one of the most theoretically well-developed approaches to virtue currently on offer. From that perspective, questions as to whether virtues are global or local, universal or culturally relative are answered as follows: genuine virtues are global, and they are universal because they are grounded in human nature. Three claims are crucial: (1) People naturally seek the good (eudaimonia); (2) the virtues contribute to and partially constitute eudaimonia; and (3) the realization of eudaimonia through the virtues and external goods is the fulfillment of human nature.

Thus far, the central challenge to the universality of virtues has been based on the fact of cultural diversity. The diversity of cultures entails a multiplicity of goods and virtues, such that compelling arguments must be made to relate all of these goods and virtues back to a universal standard of moral goodness grounded in human nature. If those arguments fail, it seems that moral relativism, according to which goods and virtues are relativized to specific cultures, is a fallback position (as is moral skepticism; see Stangl 2018). The presupposition of this ongoing debate is that nature and culture combine in the articulation of goods and virtues, with nature stably anchoring goods and virtues and culture producing variability in them within limits set by nature. We now have reason to believe the presupposition about natural stability will be falsified in the near future. Technology, specifically, germline genome editing, is well on the way to providing humanity with the means of effecting heritable changes in human nature, thereby changing human goods and virtues, not from cultural influences but from the natural side of the nature/culture equation.

This essay explores challenges presented by genome editing to the dominant conception of neo-Aristotelian ethical naturalism and its conception of human goods and virtues. In part I, I sketch the dominant conception, which is espoused by Philippa Foot, Rosalind Hursthouse, and Michael Thompson. In part II, I offer a brief overview of relevant developments in genome editing, and explore possible implications for the neo-Aristotelian framework in part III.

### *I. Neo-Aristotelian Ethical Naturalism in Brief*[1]

The Hursthouse-Foot-Thompson conception constitutes a more or less unified approach, featuring points of influence, overlap, and coherence. Though Hursthouse makes contributions to it, I will focus primarily on Foot and Thompson, as their views are more relevant to the main concerns of this essay.

The central idea of this conception of naturalism is that evaluations of the moral goodness and badness of humans have the same conceptual structure as evaluations of the goodness and badness of plants and animals. Early adumbrations of this approach can be found in work by Elizabeth Anscombe and Peter Geach, and was developed in papers by Foot in which she argues against moral subjectivism, especially R. M. Hare's version of prescriptivism.[2] Foot (2002b, 199) invokes Anscombe's notion of an 'Aristotelian necessity': "that which is necessary because and insofar as good hangs on it." We use this idea, Foot (2002b, 199) contends, " . . . when we say that it is necessary for plants to have water, for birds to build nests, for wolves to hunt in packs, and for lionesses to teach their cubs to kill." These judgments provide standards by means of which we can identify individuals that are good of their kind and those that are defective. Since it is the nature of wolves to hunt together in packs and the nature of dancing bees to lead other bees to sources of nectar, we can say that a free-riding wolf, one who does not participate in the hunt but partakes of the spoils, and a dancing bee who finds nectar but does not alert other bees to its whereabouts, are defective. They are just as defective in these social aspects as are members of species who suffer from individual defects, for example, who lack sight, hearing, or the power of movement (see Foot 2002b, 200).

Foot (2002b, 200) claims: "I am therefore, quite seriously, likening the basis of moral evaluation to that of the evaluation of behaviour in animals." She goes on to stress the extent to which human communication and reason complicate these evaluations, not least by creating a diversity of goods exceeding those available to plants and other animals in extent and complexity. Yet the passage just quoted expresses the central thesis of the Hursthouse-Foot-Thompson approach to ethical naturalism. Foot expands on this, as does Hursthouse (see Foot 2001; Hursthouse 1999 and 2004). Both draw on an important paper by Michael Thompson (1995), "The Representation of Life," which develops a conceptual structure for naturalistic evaluations of plants, animals, and humans (see, for example, Hursthouse 1999, 203; Foot 2002b, 199 and 2001, chapters 2 and 3). Thompson has amplified his approach in his later work (see Thompson 2003, 2004, 2008, and 2013).

Thompson (2004, 47) is interested in characterizing representations and knowledge of things as alive, and specifically, the human life form. A starting point for understanding his view is his development of the abstract concept of a 'natural kind' into the notion of a life-form. A life-form is the idea of a living kind or species (Thompson 1995, 266). This abstract representation, which in the case of a particular species, is built up partly from empirical observations of the lives of members of that species, but go beyond them, is necessary if one is to understand both the individual members as well as the species itself (Thompson 2004, 47ff). Knowledge of life forms enables us to make life-form attributions, the general form of which is: "X is a bearer of life form S, or X is a member of species S …", and natural historical judgments (Thompson 2004, 58, italics his; see also 2004, 49 and 1995, 280ff). Natural historical judgments describe life-forms, and, though they tend to be formed in the present tense, are in fact atemporal. (We will revisit Thompson's atemporality claim later in this essay.) They take the form: "'The S is (or has, or does) F'," as in "'The domestic cat has four legs, two eyes, two ears, and guts in its belly'" (see Thompson 1995, 281). Thompson (1995, 281) calls such sentences 'Aristotelian categoricals,' by which he means that they are statements of facts about species on which depends the good of individual species members. If Tibbles the cat, for example, has only three legs, but not four, he

is lacking in a feature on which his good as a member of the feline species depends (see Thompson 2008, 65). In more technical terms, natural historical judgments provide the basis for 'judgments of natural standard,' that is, species-relative judgments of natural goodness and natural defect (see Thompson 2004, 55ff and 1995, 295-296). Natural-historical judgments are normative in allowing for inferences of the type: 'The S is F,' 'this S is not F,' therefore, 'this S is defective in not being an F' (see Thompson 1995, 295). Through this type of inference, we arrive at judgments of the natural goodness or defectiveness of individual members of species.

This scheme applies to Foot's work insofar as operations of the will or practical reason in humans are species-dependent and thus, can be judged as good or bad according to a natural standard. Our species is the kind of life-form whose natural history shows us capable of acting well, for reasons that we see as good (see Thompson 2004, 59ff and 1995, 250-251). Thus, when we fail to see reasons as good and do not act upon them, or see them as good yet fail to act, we are displaying defects, and if someone fails chronically in these ways, she can be judged a defective member of the human species. These judgments have the same conceptual structure and follow the same logic as attributions of goodness and defect to other species.

As noted above, Foot, like Thompson, finds normativity in nature, and adopts his conceptual structure of judgments of natural goodness and badness, contending that the meanings of the terms 'good' and 'bad' are the same when used in judgments of natural goodness and defect of plants and animals as when applied to humans, and that this is true despite the diversity of human goods (see Thompson 1995; Foot 2001, 35, 39, 44, 47). Moreover, she argues that the happiness of humanity consists in the enjoyment of good things, by which she means pursuing and attaining right ends, thus ruling out a life of wickedness as a way of achieving happiness (Foot 2001, 96-97).

We can use contemporary scientific terms to capture key aspects of this explanation, while recognizing that human nature on neo-Aristotelian accounts does not reduce to scientism. Science informs these conceptions, and provides them with content about human cognitive, emotional, and motivational capacities and traits, but does not exhaust them. Virtue ethicists frame and inflect the scientific content in different ways. For all of these accounts, however, scientific facts are an indispensable core constituent of human nature.

Thus, it is consistent with Aristotelian ethical naturalism to say that, barring genetic defects or anomalies, humans have the same genome or genetic inheritance. Our genetic inheritance is expressed in different ways, depending on variations in our environment. As Guo (2005, 46) puts it:

Many human traits and behaviors result from both genetic and environmental factors. Moreover, genetic and environmental influences on a trait are not simply additive. Genes "interact" with the environment. That is, genes provide the potential for a trait, but environmental conditions determine whether that potential will be realized. The same genetic codes may be expressed at different levels in different environments.

Guo (2005, 46) provides this rather striking example:

Compare, for example, Asian immigrants in the United States to U.S.–born Asian Americans.

U.S.–born Asians are twice as likely as immigrants to suffer from prostate cancer, and Asian-American adolescents born in the United States are more than twice as likely to be obese as Asian-American adolescents who recently immigrated to the United States. U.S.–born Asians and immigrant Asians are likely to have similar genetic predispositions for prostate cancer and obesity. The differences between the two groups in the prevalence of these disorders are, therefore, likely to be caused by environmental conditions such as lifestyle and diet

Add to this picture the phenomenon of epigenetic changes. These are ". . . heritable changes in gene expression (active versus inactive genes) that do not involve changes to the underlying DNA sequence (https://www.whatisepigenetics.com/fundamentals/.)[iii]

To recap, nature and nurture – genes and environment – interact to produce expressions in traits and behavior. The effects of environment are sometimes dramatic, as can be seen in Guo (2005)'s example of the changing proclivities to prostate cancer and obesity of Asians born in the U.S. compared with those who weren't. Enter epigenetics. The underlying DNA sequence is that which remains stable, yet trait expressions are heritable. Presumably, U.S.-born Asians pass on their increased proclivities to disease to their offspring. Yet, provided the underlying DNA sequence remains unchanged, human nature anchors these changes.

This general account could be used to explain how the neo-Aristotelian naturalistic framework can explain the cultural diversity of goods and virtues. Nature interacts with culture in various ways to produce a diversity of goods and virtues, but nature is unchanging and always, at bottom, anchors this cultural diversity. But what happens if the underlying DNA sequence is changed? Changes in the human genome, in my view, would necessarily force changes in neo-Aristotelian ethical naturalism as described in part I, and would have implications for associated accounts of the human good and virtues.

### *II. A Primer on Genome Editing*[iv]

In 2017, the Committee on Human Gene Editing (CHGE) of the National Academies of Sciences, Engineering, and Medicine published a comprehensive report entitled, Human Genome Editing: Science, Ethics, and Governance. The authors write: "Genome editing is a powerful new tool for making precise additions, deletions, and alterations to the genome – an organism's complete set of genetic material" (CHGE, 15). They use the term 'genome editing' instead of 'gene editing' because " . . . the editing could be targeted to sequences that are not parts of genes themselves, such as areas that regulate gene expression" (CHGE, 15, n. 1). The Committee writes that new approaches to genome editing, such as the use of meganucleases; zinc finger nucleases (ZFNs); transcription activator-like effector nucleases (TALENs); and most recently, the CRISPR/Cas9 make genome editing more precise, efficient, flexible, and less expensive to use than previous systems (CHGE, 15).

Here I focus on CRISPR. A concise explanation of CRISPR is found on the website of the Broad Institute of MIT and Harvard, which researches genomics in order to improve human health:[v]

"CRISPR" (pronounced "crisper") stands for Clustered Regularly Interspaced Short Palindromic Repeats, which are the hallmark of a bacterial defense system that forms the basis for CRISPR-Cas9 genome editing technology. In the field of genome engineering, the term "CRISPR" or "CRISPR-Cas9" is often used loosely to refer to the various CRISPR-Cas9 and -CPF1, (and other) systems that can be programmed to target specific stretches of genetic code and to edit DNA at precise locations, as well as for other purposes, such as for new diagnostic tools. With these systems, researchers can permanently modify genes in living cells and organisms and, in the future, may make it possible to correct mutations at precise locations in the human genome in order to treat genetic causes of disease. Other systems are now available, such as CRISPR-Cas13's, that target RNA . . . (https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/questions-and-answers-about-crispr).

Jennifer Doudna, of the University of California at Berkeley, is one of the scientists who pioneered the development of the CRISPR system. In an interesting and wide-ranging popular book chronicling its discovery, Doudna and her colleague Samuel H. Sternberg (2017) explain multiple ways in which CRISPR functions as a kind of "molecular scissors" to cut or edit gene sequences in various ways (Doudna and Sternberg 2017, chapter 4). They also explain how deactivating CRISPR provides a way for scientists not to permanently edit a genome's DNA, but to change ". . . the way that its DNA gets interpreted, translated, and expressed" (Doudna and Sternberg 2017, 108). Thus, gene expression control – turning genes on or off or dialing them up or down – is another function that can be performed by CRISPR, though in its deactivated form (Doudna and Sternberg 2017, 109).

CRISPR has been used in plants and non-human animals. It has joined the ranks of techniques used to induce DNA mutations in plants, resulting in GMOs or 'genetically modified organisms' (Doudna and Sternberg 2017, 119ff). Among other kinds of interventions, it has been used to modify the DNA of some breeds of animals, such as cattle, pigs, and dogs, to produce leaner, more heavily muscled breeds (Doudna and Sternberg 2017, 130ff). Genome-edited lab animals have also been engineered using CRISPR, as have designer pets and mutated creatures that have not previously existed, thereby raising concerns about animal welfare (Doudna and Sternberg 2017, 138, 143, 144). Recently, genetically edited same-sex mice have given birth to their own mouse pups. Only pups born to two mothers survived and gave birth to pups of their own (Wei-Haas, 2018). Scientists are using CRISPR in "de-extinction" science, which attempts to bring back extinct native species, such as the woolly mammoth, using DNA samples from preserved specimens (Doudna and Sternberg 2017, 144-145). CRISPR has also been used in experiments aimed at "driving" new genes, along with their associated traits, " . . . into wild populations at unprecedented speeds, a kind of unstoppable, cascading chain reaction" (Doudna and Sternberg 2017, 148). For example, in an effort to extinguish malaria, some scientists have sought to cull entire populations of mosquitoes by releasing gene drives that can hinder reproduction (Doudna and Sternberg 2017, 149ff; Regalado May/June 2016). MIT scientist Kevin Esvelt is developing what he calls a 'daisy drive': unlike a standard CRISPR gene drive, a CRISPR daisy drive engineers changes to be passed on for a limited number of generations, not indefinitely. The daisy drive has yet to be field-tested (Marcus 2018a, C3). Finally, CRISPR is being used as a technology to further xenotransplantation – the transplantation of organs from non-human animals into humans. It is being used to "shut down" genes in pigs that would provoke immune rejection of transplanted organs by the human body, and to ". . . eliminate the risk that porcine viruses embedded in the pig genome could . . . infect humans during transplantation" (Doudna and Sternberg 2017, 141; see also Kolata 2017).

Mention of its use in xenotransplantation leads us to CRISPR's implications for humans. Two kinds of CRISPR interventions are possible: changes to somatic cells, such as muscle, heart, liver, etc., the DNA of which cannot be transmitted to offspring, and germ cell interventions. The DNA of germ cells is heritable. Germ cells ". . . make up the germline of the organism – the stream of genetic material that is passed from one generation to the next" (Doudna and Sternberg 2017, 158). Somatic and germ cell CRISPR interventions are of two kinds: those that seek to repair deficiencies, and those that seek to enhance human capabilities. To be sure, the repair of a deficiency can also be seen as an enhancement in a specific case, insofar as it brings an individual's capacity up to a baseline level. So, for example, if a Parkinson's sufferer has genome-editing therapy and because of that, the elimination of tremors, he or

she could be said to be both repaired and enhanced.[vi] However, in the literature on enhancement, 'enhancement' is typically seen as raising individual capacities beyond normal human baselines.

It seems difficult to deny the value of somatic interventions using CRISPR to treat individual patients, some of whom suffer from serious genetic diseases (see Regalado November/December 2016; Doudna and Sternberg 2017, chapter 6; CHGE, chapter 4). A recent study shows genome editing's promise for treating cancer and infectious diseases (Kolata, 2018), and now, a modified version of CRISPR is being used in 'base editing,' with potential applicability to blood disorders, neurological disorders, hereditary deafness, and hereditary blindness (Mullin January/February 2018, 23). The value of using genome editing for somatic enhancements is less clear. Even more controversial issues attend germline genome editing. Hypertrophic cardiomyopathy, a disease affecting about one in 500 people, can cause sudden heart failure in young athletes. It is caused by a mutation in a gene called $MYBPC_3$. A study using CRISPR to edit the mutation out of egg cells that had been fertilized with mutated sperm and another which injected mutated sperm and CRISPR simultaneously into egg cells resulted in mutation-free embryos (see Belluck August 2, 2017; Ma, et. al. 2017). In addition, it is worth noting that a Boston-based company, Veritas Genetics, now charges to decode the complete sequencing of newborns in China (see Regaldo September/October 2017). These developments give rise to the concern that "designer babies" – babies whose genome is selected not only to eliminate disease-causing genetic mutations but also to yield desirable traits – will be next (see Belluck, August 4, 2017; Regalado May/June 2015).

A cautionary word about advances in genome editing is in order. Apparently referring to the study referenced above, Marcus (2018b, C5) reports that in August, 2018, " . . . three reports were published by scientists arguing over whether researchers successfully used Crispr to edit out a single gene mutation in human embryos linked to a deadly heart disease." Marcus (2018b, C5) also quotes Dr. Michael Snyder, the chair of the genetics department at Stanford University School of Medicine, as saying that manipulating complicated traits such as intelligence and athletic ability would likely require thousands of gene changes and are not imminent. Snyder also notes that questions such as whether and who decides to engage in these manipulations will need to be addressed.

Genome editing is controversial and many scientists counsel caution. The study using CRISPR to eliminate the mutation that causes hypertrophic cardiomyopathy is in accordance with recommendations laid down by the Committee on Human Genome Editing (see CHGE, 134-135; Harmon, 2017). These guidelines restrict genome editing to disease-prevention and follow a consideration of ethical issues, including what it can mean to change human nature, human dignity and fears of eugenics, social justice questions in the distribution of costly gene-editing technologies, and arguments that see therapeutic genome editing as putting science on a slippery slope toward being used for non-therapeutic enhancements (see CHGE, 124-130). In the last two chapters of their book, Doudna and Sternberg (2017, chapters 7 and 8) describe numerous meetings that were convened among top scientists and journalists to discuss the ethical implications of genome editing and involve the public in informed discussions. As early as 2015, some scientists sought a ban on germline-editing (see Lanphier, et. al. 2015; Wade, 2015). In the same year, a group including Doudna and Sternberg published guidelines for moving forward (see Baltimore, et. al., 2015, 2-3). Harvard Medical School's Personal Genetics Education Project has launched a Genetics Consortium to educate people across the country (Marcus, 2018, C5), and from November 27-29, 2018, the Second International Summit on Genome Editing was held at the University of Hong Kong.

Yet on November 27, 2018, the same day as the start of the conference, The Wall Street Journal reported that "A Chinese scientist claims to have produced the world's first genetically modified babies, stirring alarm among doctors who warn such experiments using nascent DNA-editing technology pose too many health and ethical risks" (Rana and Fan 2018, A9). The work, which was not vetted by other scientists and has not been published, apparently consisted of altering the genes of embryos to resist HIV infection. The article suggests that the embryos resulted from a healthy mother and an HIV-infected father, were genetically altered in a lab, then re-implanted in the mother's womb. Twin girls were born. The same article reports that ". . . China is the only country known to have tested Crispr on humans, mostly to treat adult patients in advanced stages of cancer" (Rana and Fan 2018, A9).[vii] The scientist, He Jiankui, defended his work to skeptical scientists at the conference, some of whom censured him harshly (Stein, 2018). He also claimed at the conference that ". . . a second woman had been implanted with a gene-edited embryo," but did not elaborate (Rana 2018, A9). As reported on npr.com, "A group of 122 Chinese scientists issued a statement calling He's actions 'crazy' and his claims a huge blow to the global reputation and development of Chinese science" (Stein, 2018). On Thursday, November 29, 2018, the Chinese government ordered a halt to He's work (see "China Halts Work by Team on Gene-Edited Babies").

Long before the furor so recently raised by He's work, one commentator, Antonio Regalado (November/December 2016, 82), raised a key ethical issue in the CRISPR debate: "The potential to precisely and easily 'edit' any genome using CRISPR is changing the way we think about nature." He also asked (May/June 2016, 57), "Does any country, agency, or individual have the right to change nature in ways that could affect everyone?" Not only does CRISPR challenge how we think about human nature, but also human nature itself could be changed through it and other genome-editing technologies. And changing human nature could change what count as human goods and virtues.

### *III. Some Possible Implications of Genome Editing for Neo-Aristotelian Ethical Naturalism*

I will examine possible implications of genome editing for neo-Aristotelian ethical naturalism in four areas: (1) how we think about nature, including human nature; (2) how judgments about goodness and badness of the sort endorsed by Thompson stand to be affected; (3) how human goods could change; and (4) how human virtues could change.[viii]

(1) Thinking about nature and human nature. As Regalado (November/December 2016, 82) notes, the use of CRISPR is changing how we think about nature. Scientists who use genome editing, at least, now think of nature as deeply under human control. Perhaps the most dramatic examples of this are the use of gene drives to cull entire populations of mosquitoes in an effort to control malaria, and de-extinction science. One issue with the use of gene drives is the possible negative effects that destroying entire populations of insects might have on ecosystems. The deeper issue, of course, is that no one really knows the short-term or long-term effects that germline genome manipulations will have on species themselves, or on the larger ecosystems of which they're parts. Moreover, if germline genome editing changes groups of species, resulting in more muscular individual cattle, pigs, dogs, etc., what effects will result if members of those groups breed with individual animals whose genes have not been altered?

These questions of the effects of germline genome editing on ecosystems and species are at the practical level, but conceptual issues can also be raised. Have scientists created entirely new species through germline genome editing, or mutations of existing species? Where is the line between natural and artificial, if there is a clear boundary at all? If germline genome editing is used to treat diseases in humans or to effect heritable enhancements, human nature is being changed in artificial ways. One might interject that human nature has always been changing in artificial ways through the heritable cultural shaping of traits, i.e., epigenetics. But germline genome editing is different – it is the deliberate manipulation of the stable DNA sequences that have hitherto provided the anchor for human nature, epigenetics notwithstanding. The anchor for human and nonhuman nature can now be changed through human intervention, thus blurring distinctions between natural and artificial.

What are the implications for Thompson's view? Thompson's starting point for his version of ethical naturalism is the abstract concept of a 'natural kind.' This is the concept that he seeks to develop into the notion of a life-form -- the idea of a living species. As noted earlier, the abstract representation of a life-form is built up in the case of a particular species partly from empirical observations of the lives of its members. Germline genome editing complicates this picture in at least two respects. First, it raises the prospect that in addition to what we might call 'pure' natural kinds, by which I mean species that are purely natural and have not been subjected to germline genome editing, we must admit what we might call 'impure' natural kinds, by which I mean natural kinds that have been artificially changed through alterations of DNA sequences. But if so, impure life-forms will also result, for the empirical charactertistics that partly generate abstract representations of genetically altered species will necessarily differ from those of the original species. So, along with the pure species or life-form, 'cow,' we would have the impure species 'heavily-muscled' cow, and other variations, such as the impure species of 'cow genetically engineered to be born without horns and to pass the trait of hornlessness on to offspring' (see Choi 2016). Second, we have the prospect of what I will call 'mixed' species or life-forms. These are species or life-forms in which some members have been altered through germline-genome editing and have been allowed to mate with other, non-altered individuals. This can occur when, for example, heavily muscled cattle, pigs, or dogs are allowed to breed with members of species that have not been engineered for greater muscularity.

In other words, no longer having purely natural species or natural kinds forces alterations that reverberate throughout the conceptual framework of ethical naturalism that Thompson constructs. At the most general level, this requires the introduction of two new categories of species or life-forms: impure natural species and mixed species.

(2) Thompson's judgments of goodness and badness. The blurring of distinctions between natural and artificial also has implications for the sorts of judgments that Thompson wishes to be able to make. This is also true for Foot's account, though I here focus on Thompson.

(a) Life-form attributions. Let us begin with his account of life-form attributions. Earlier we noted their general form: 'X is a bearer of life form S, or X is a member of species S …' At the very least, such attributions would have to be made more precise, for example, 'X is a bearer of pure/impure/mixed life-form S, or X is a member of pure/impure/mixed species S. Presumably, the empirical characteristics of pure life-forms or species are already known, so they need not be specified in life-form attributions. Thus, if we say, "Fido is a member of the canine species," this implicitly

conveys well-known information about the species 'dog,' such that we need not go on to specify the empirical characteristics which justify the attribution, for example, that Fido has four legs, a tail, a certain number of teeth, certain kinds of capacities for movement, hearing, smell, and sight, and so on. However, if we seek to make an impure life-form attribution, we would need to add characteristics so as to specify more precisely what we mean if our attribution is to be informative and not misleading. We would need to say, for example, "Bossy is a member of a bovine species that has been genomically edited for greater muscularity," or "Flossy is a member of a bovine species that has been genomically edited for hornlessness." It is unclear what kind of information would need to be included in a life-form attribution for a member of a mixed species, perhaps something like, "Porky is a member of a porcine species in which interbreeding has occurred between non-genomically altered individuals and individuals that have been genomically altered not to have tails." One might not consider this a dire challenge for Thompson, as it results only in the need to make rather clumsy life-form attributions.

(b) Natural historical judgments. Matters become more serious when we turn to natural historical judgments, which describe life-forms. As noted earlier, they take the form: 'The S is (or has, or does) F;' for example, 'The domestic dog has four legs, two eyes, a certain number of teeth, a certain hearing and visual range, etc.' One might be tempted to suggest that natural historical judgments can be altered along the lines suggested for life-form attributions. But unlike life-form attributions, which can truly be made of individual members of impure natural or mixed species, natural historical judgments cannot truly be made of impure natural or mixed species. This is because impure natural or mixed species do not have natural histories in the same sense in which purely natural species do.

Natural historical judgments purport to summarize the 'natural history' of a species – to convey, in abbreviated form, the characteristics that members of a species typically possess, and have evolved to possess, over the course of millennia. Life-form attributions do not do this – they indicate a token-type relationship. Thompson predicates atemporality of natural historical judgments, even though their form is in the present tense. The atemporality of natural historical judgments is not meant to deny that natural species have evolved over the course of millennia, and certainly, the judgments can include references to temporality having to do with species-specific life cycles, as in, "The yellow finch breeds in spring, attracting its mate with such and such song. . ." (Thompson 2008, 65). The atemporality predicated of natural historical judgments is meant to signal that species are temporally stable in a way that life-form attributions are not. Moreover, the temporal instability of species members, along with other facts about them, cannot be made conceptually salient without the knowledge conveyed in natural historical judgments. Thompson (2008, 65) illustrates this point by noting that 'Elsa the bear bore three cubs this last spring'—a past tense life-form attribution -- can be regarded as providing an example of what is conveyed in the present tense in the general natural historical judgment: 'The mature female bear bears two to four cubs in the spring.'

When we attempt to craft parallels to natural historical judgments for impure natural species and mixed species, we run aground both conceptually and with respect to atemporality, for in neither case is there, strictly speaking, a purely 'natural history' belonging to the species in question. In the case of impure species we might seek to make 'artificial historical' judgments in which we convey information about the genetic modifications made to the species. However, all we would have, at this point in their development, is a cluster of life-form attributions that could presumably be used as a partial basis for "building up" -- along with life-form attributions to members of relevant natural species -- an abstract

representation of an impure species. For example, our abstract representation of the impure species 'hornless cow,' would be built up of various life-form attributions to specific cows that were genetically engineered to be born without horns. But these life-form attributions could only be used as the basis of an abstract representation of the species 'hornless cow,' by contrast with life-form attributions to specific cows born naturally with horns, as well as with the abstract representation of the species 'cow,' which includes the property of being born with horns. Conceptually speaking, any 'artificial historical' judgments that might be made about impure species would not parallel natural historical judgments made about pure species, but instead, would be parasitic upon or derivative from them for at least some conceptual content. In other words, an 'artificial historical' judgment about hornless cows would be nonsensical unless understood against the background of our conceptual understanding of the natural history of cows and life-form attributions of members of the species 'cow.' Moreover, life-form attributions to members of the impure species, 'hornless cow,' are so recent that 'artificial historical' judgments made on their basis cannot approximate the atemporality of natural historical judgments.

The upshot for Thompson's framework is this. In his original scheme, natural historical judgments always nicely correspond to life-form attributions. However, given the complexities introduced by germline genome editing, this is no longer the case. Life-form attributions become more complex, encompassing attributions to bearers of purely natural, impurely natural, and mixed life-forms. Natural historical judgments correspond to only one subset of life-form attributions, those referring to purely natural species. Attempts to parallel natural historical judgments with what I've called 'artificial historical' judgments show that the two are not a par, either conceptually or with respect to the property of atemporality. I have not discussed mixed species, for I am unclear what to make of them.

(c) Species-relative judgments of natural goodness and natural defect. Recall that Thompson (1995, 281) calls natural historical judgments, 'Aristotelian categoricals,' and that these judgments provide the basis for species-relative judgments of natural goodness and natural defect (see Thompson 2004, 55ff; also Thompson 1995, 295-296). Changes wrought by germline genome editing complicate this picture. Consider the following syllogism resulting in a judgment of natural defect:

1. The cow is naturally born with horns.

2. This natural cow (cow that was not genetically engineered) was born without horns.

3. Being born without a natural feature is a defect.

4. Consequently, this natural cow born without horns, a feature naturally possessed by cows, has a natural defect, namely, the lack of horns.

This argument makes sense until we consider the rationale for genetically engineering cows without horns. The genetically engineered cow is altered to be born without horns for its own good and that of its keepers (see Choi 2016). Horns add nothing of value to the life of the cow, cows with horns sometimes harm themselves and others (both non-human animals and humans), and the process of removing horns is painful for the cow. If so, it is better for cows to be born without horns than with horns. If this line of reasoning is correct, it should not be considered a natural defect for a natural cow to be born without horns. Instead, it should be considered a natural advantage. But if so, genetic engineering has actually removed a natural defect from the cow (its horns) and provided cows so engineered with an advantage.

At the heart of this argument is a challenge to ethical naturalism. Ethical naturalism presupposes that having natural attributes of the type identified in natural historical judgments is good, and that not having them is bad or a defect. But, as we see in the case of cows born with horns, this is not always the case. What is natural to a species is not always a good to its possessor. Sometimes a natural attribute can cause pain or trouble for an animal, and in that case, to genetically alter the species to remove the attribute does not amount to eliminating a good, but instead, to eradicating a defect or impediment.

From my remarks thus far, it should be clear that genome engineering threatens to put Thompson's scheme into disarray. Let us turn now to a discussion of broader issues.

(3) The landscape of human goods and defects. It should be clear from the discussion of part II that germline genome editing has the potential to radically alter what are typically considered to be human goods and defects. It has the potential to eradicate many, if not all, genetically caused heritable diseases and defects. It is difficult to see why scientists should not pursue germline genome editing to eliminate diseases such as Duchenne's muscular dystrophy, hypertrophic cardiomyopathy, sickle cell anemia, Tay-Sachs disease, and many others. For people who have these diseases, germline genome editing promises to eradicate a defect, and replace it with a good – normal human health. But the good in question is then not natural, but artificial, and judgments predicated of individuals whose genes have been edited will not be judgments of natural goodness in Thompson's sense.

In such cases, we could say that what counts as 'nature' – as natural goodness – is being artificially altered. Though the temporal aspects of germline genome editing cannot be fully known at this point, one likely scenario should be noted. Suppose that Ben suffers from Duchenne's muscular dystrophy, which was caused by the genes he inherited from his parents. Without genome editing, he will not live to reproduce. With it, he will live to reproduce, but his children will not possess the same genetic inheritance that caused his disease. The good that he obtains through genome editing – freedom from Duchenne's muscular dystrophy – is not natural, but is artificial, and is passed on to his children through gene sequences that do not result in Duchenne's muscular dystrophy. The good that they receive is not a natural good, but an artificial one. The artificially altered genes possessed by Ben's children combine with other, natural (non-altered genes) to produce other traits and characteristics – in addition to freedom from Duchenne's muscular dystrophy -- that will count as goods in their lives. But these goods will not be entirely natural, having been brought about through germline genome intervention. So one might say that in this scenario, the course of nature, and what counts as natural, has been artificially altered.

Given the pain and suffering that these and other diseases cause, I am loathe to say that germline genome editing in this area should not proceed, even when the long-term effects of such editing cannot be fully known. But what about the prospect of 'designer babies,' mentioned earlier – whose genome is selected not only to eliminate natural defects, such as high risks of disease, but to produce desirable traits, such as gender or eye color (see Belluck, August 4, 2017; Regalado May/June 2015)[ix]? I take it the traits in question need not be only physical, but could eventually come to encompass morally relevant traits, such as capacities for empathy, kindness, perseverance, and so on. Extensive debates about changes in human nature and their implications for the human good can be found in the literature on the ethics of human enhancements (see, for example, Sandel 2007; Savulescu and Bostrom 2009;

Daniels 2009; Ida 2009; and Buchanan 2011). Buchanan (2011, 75-76), for example, suggests that moral enhancements by biomedical means could improve our cognitive powers, our moral emotions, and our capacities for sympathy and moral imagination. If, for example, my capacity for sympathy and moral emotion has been enhanced beyond the natural baseline, does that make me morally better than the average human? Does it make the person with average capacities morally defective by comparison with my artificially enhanced capabilities?

In my view, the potential to change the human genome, either to eliminate disease or to improve the species in other ways, raises these and other questions about what we take human goods to be, how they should be brought about, and whether we can be entitled to view the landscape of goods that is altered by genome editing as natural or must instead recognize that artificial interventions have changed the course of nature and what can count as 'natural' goods. Someone might interject that genome editing is still in early stages (see Belluck August 2, 2017; Ma, et. al. 2017 on germline gene editing; and Regalado (November/December 2016) on somatic gene editing). Changes to goods at this point do not affect the species as a whole. But before they affect the species as a whole, they will affect the lives of individuals, and this raises a host of comparative questions such as those mentioned at the end of the preceding paragraph. It is worth asking questions about how goods secured through genome alteration at the individual level could impact the lives and the virtues of their possessors and others, as well as how they could affect the species as a whole.

(4) Potential implications for virtue. The central question is this: if human goods change and virtues are partially constitutive of or contribute to the attainment of human goods, how does germline genome editing change our perspectives on virtue and how virtues are actualized in human lives?

This question can be addressed on both the theoretical and practical levels. Let us consider one example at the theoretical level. Neo-Aristotelian Daniel C. Russell (2009) argues for a finite list of virtues. His argument rests in part on the idea that the existence of infinitely many virtues is inconsistent with ethical naturalism because human psychology is finite; thus, our characters cannot have infinitely many traits (Russell 2009, 172). But germline genome editing presents the possibility that human psychology is not finite, but indefinite, for it is amenable to being genetically altered in ways we cannot yet foresee. We should note that a similar argument for the indefiniteness of human psychology can be made on the basis of epigenetics, for it is impossible to foresee the diversity of new heritable traits that might be introduced through cultural variables that shape gene expression. Germline genome editing increases the potential malleability of human psychology even further than epigenetics, however, through its capacity to change what has hitherto been the stable natural anchor of DNA sequencing. On this picture, what can count as human goods and virtues seems capable of indefinite expansion. But if such changes are possible, Russell can no longer rely on the finitude of human psychology to support claims about a finite number of virtues.

Changes wrought by germline genome editing have implications at the practical level also. We noted earlier that such changes could affect individual members of the human species before it has species-wide effects. In the example of Ben and his children, the good of health is no longer a purely natural good, but something capable of being genomically altered at the level of the germline. Such alterations in individuals might also affect the traits that contribute to, and in some cases, partly constitute, the possession of the good of health. For example, if, through alteration of their genome, some people no

longer have to worry about diet and exercise to stay healthy, their capacities for temperance, perseverance, and self-regulation could lapse, as these would no longer be necessary to maintain fitness. If some people find themselves immune to disease or illness, would their capacity for compassion for the suffering of others diminish? Would they lose the ability to empathize with those who have not received or do not wish to have genome alterations? If genome editing is costly and not widely available, would this foster attitudes of snobbery on the part of the recipients of health-enhancing or life-saving editing, and envy, resentment, and the feeling of having been unjustly denied a crucial good on the part of those unable to afford it?

Similar questions are presented by enhancements. The basic question here is whether genetically engineered enhancements are truly goods that would foster virtues, or only apparent goods that would instead foment vice. Would parental love change if parents knew they could have a 'designer' baby – one with perfect looks, health, a wonderful temperament, and desirable qualities – yet had to "settle" for an ordinary, natural baby without genetic enhancements?[x] Would parents with natural babies look with envy on the parents of designer babies, and be disappointed with their own, 'unenhanced' baby, or would they love her all the same or even more? As was mentioned earlier, if someone were genetically modified to have a greater capacity for sympathy, would that person be considered morally better, other things being equal, than someone whose capacity for sympathy was not genetically enhanced? How would the genetic modification of one morally relevant capacity or trait affect the possession of other, purely natural capacities and traits within a single individual's moral psychology? Could it have a detrimental effect on her usage of unenhanced capacities and traits, since, by comparison with her enhancement, the unenhanced would now seem defective? How would the presence of genetically enhanced people affect the rest of the population? Would others view them as more superior than purely natural people, or as anomalies? Would the genetically enhanced view themselves as morally superior or morally inferior to the 'unenhanced'?

***Conclusion***

Genome editing is so new that it raises more questions than answers. But germline genome editing, in particular, poses novel challenges for neo-Aristotelian ethical naturalism. By presenting the prospect of changes in that which has always been the anchor in the face of cultural variations, namely, stable DNA sequences, germline genome editing upsets the boundary between the natural and the artificial, with implications for conceptions of nature, naturalistically based judgments of goodness and badness, and the nature of species-wide and individually possessed human goods and virtues. Debates on these issues are just beginning.

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[1] Most of this section is taken from Snow (2018).

[2] See Foot, (2002b, 159-174); and (2002a, 189-208). References to Geach and Anscombe can be found in both papers; see Geach (1956, 33-42), cited at Foot (2002a, 162), and Anscombe (1981) cited at Foot (2002a, 168), and Anscombe, (1981, 15, 18-19, 100-101, and 139, quoted and cited at Foot (2002b), 198-199. See also Geach (1977, 17) quoted in Foot (2001), 35 and cited at p. 44.

[iii] Epigenetics is controversial. See, for example, Hawks (2018, C8), and Heard and Martienssen (2014).
[iv] This section draws on unpublished material from Snow (2017), my inaugural lecture for the research series of the Margaret Beaufort Institute at Cambridge University, Cambridge, UK, "Proliferating Virtues: A Clear and Present Danger?," presented October 27, 2017.

[v] The Broad Institute's affiliations and mission statement can be found at: https://www.broadinstitute.org/about-us. Accessed 14 September 2017.
[vi] This scenario is not as far-fetched as one might think. See Regalado (November/December 2016) on prospects for gene-editing experiments using CRISPR to treat people with Duchenne's muscular dystrophy. See also Marcus (2018c, A3).
[vii] As Rana (2018, A9) notes: "Using it [gene editing] to edit so-called germ cells – the genes of sperm, eggs, and embryos – is far more controversial than applying it on terminally ill adults because any changes would pass on to future generations."
[viii] Though I focus on Thompson, my discussion also has implications for Foot's view, which relies on Thompson.
[ix] Marcus (2018d, A11) discusses fertility clinics and services that use DNA testing to predict which embryos are at higher risks of certain diseases, such as diabetes or cardiovascular disease, to predict the gender of the embryo, and even to predict eye color.
[x] See Marcus (2018d, A11) for discussion of a related issue.

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