The CRISPR Apple on the Tree of Knowledge

with Arvin M. Gouw, "The CRISPR Apple on the Tree of Knowledge Conference Highlights: CRISPR in Science, Ethics, and Religion"; Arvin M. Gouw, "Introducing the Brave New CRISPR World"; Roger R. Adams, "Moral Decisions about Human Germ-line Modification"; Constance M. Bertka, "Navigating the Future in a Sea of CRISPR Uncertainty"; and Linda Groff, "CRISPR, CRISPR on My Mind."

MORAL DECISIONS ABOUT HUMAN GERM-LINE MODIFICATION

by Roger R. Adams (iD)

Abstract.   Technologies for human germ-line modification may soon enable humanity to create new types of human beings. Decisions about use of this power entail an unprecedented combination of difficulties: the stakes are immense, the unknowns are daunting, and moral principles are called into question. Evolved morality is not a sure basis for these decisions, both because of its inherent imperfections and because genetic engineering could eventually change humans' innate cognitive mechanisms. Nevertheless, consensus is needed on moral values relevant to germ-line modification. These values could be based on characteristics of human beings that would remain constant regardless of revised genomes.

Keywords: CRISPR; evolution; genetics; morality; religion and science

CRISPR and other technologies for human germ-line modification (HGLM) may soon give humanity the ability to create new types of human beings. Already, methods using CRISPR-Cas9 (acronyms for "clustered regularly interspaced short palindromic repeats" and "CRISPR-associated 9") allow bioengineers to insert and replace DNA in human reproductive cells, resulting in a genetically modified child (Gallo et al. 2018; Stein 2018). Decisions about whether and how to use this power entail an unprecedented combination of difficulties: the stakes are immense, the unknowns are daunting, and moral principles are called into question. Yet decisions will be made, and the acceptability of these decisions will require a widespread consensus on moral values relevant to uses of HGLM.

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STAKES

Potential benefits from HGLM are enormous: imagine people genetically engineered to be stronger than today's best athletes, smarter than Einstein, and so healthy that they routinely live 200 years. But disastrous consequences of germ-line modifications can also be imagined, such as the development of master and slave races, as "genetically superior" people forbade genetic enhancements to "inferiors." If this scenario seems far-fetched, one need only recall the genocidal results of eugenics concepts incorporated into Nazi ideology.

Whether heavenly or hellish, the consequences of germ-line modifications would ripple out indefinitely. Suppose a couple decided to have their sperm and/or eggs genetically edited and thus became parents of a modified child. The couple's decision would affect not only that child, but also the child's descendants over generations. If the germ-line modification significantly altered the child's and descendants' abilities or behavior, then the ripples would extend much further, as the enhancements would affect social interactions, particularly with nonmodified people. If the modified persons had received significantly enhanced abilities, then the nonenhanced individuals would be at a disadvantage, so the effects on them would likely be more harmful than helpful. Furthermore, the social interactions would also have a second-hand impact on others in the community. Eventually, the consequences of the original decision could spread to much of the world's population.

UNKNOWNS

In making a decision to use germ-line technology, one would of course want the benefits to significantly outweigh the risks, but the complexity of the systems involved would make predicting the positive and negative, direct and indirect consequences extremely difficult. Germ-line modifications could alter all of the following:

- The modified genes' interactions with other genes, noncoding DNA, and the rest of the intracellular environment;
- The functioning of modified cells in all body organs;
- Interactions of gene-modified cells with the individual's gut microbiome;
- The physical status of the body—strength, vitality, resistance to infections, so on—as a result of all the above;
- The person's cognitive processes—as a result of all the above;
- Interactions of cognitive effects with the individual's personality traits and store of experiences;

- The individual's social behavior—as a result of all the above;
- The effects on other people from interactions with the modified person;
- The indirect effects of those social interactions on wider circles of people.

At each level, knowledge would be incomplete, so with each higher level, uncertainties would be compounded and predictions would become less reliable. Psychological and social effects would be especially difficult to predict, yet they would be critical to the moral acceptability of genetic modifications. And to top it off, in view of the great complexity, one should expect the unexpected; one should expect that effects will occur that had not been anticipated.

MORAL PRINCIPLES IN QUESTION

Even if one had confidence in the predictions of outcomes, moral issues would remain. The three central concerns would be weighting of benefits and risks, consent, and distribution of benefits and risks.

Note that the list of concerns does not include the question of the acceptability of any form of human manipulation of genes. People whose religious beliefs would condemn any intervention in the natural course of procreation would likely regard this article's analysis as mostly irrelevant to their position, but there is not enough space here to address their theologies.

Nor does the list include a distinction between correction and enhancement. In some discussions, correction of mutant genes (to cure or prevent illness) has been given an aura of moral respectability, while a cloud of moral doubt has shadowed altering genomes to enhance human abilities. However, the issue is moot, as there is no clear boundary between the two. There is no difference in intention; in both uses of HGLM the goal would be betterment of lives. Also, though the conceptual distinction may be straightforward—correction is removing an abnormality, while enhancement makes an otherwise normal person abnormal (in a beneficial way)—to distinguish normal from abnormal in practice is difficult. The enormous range and variety of human behaviors, abilities, and traits defy precise, objective division between the normality and abnormality.

To return to the list of concerns, the weights given to various predicted outcomes determine whether the balance of benefits and risks favors proceeding with a proposed use of HGLM, but assigning those relative magnitudes entails problematic moral judgments. After one has identified all of the potential consequences of a proposed gene modification and has predicted the number of persons who will incur the various boons and ills, one must assess the degree of good or bad in various outcomes. Suppose, as occurred with modification of two human embryos in China in 2015 (Stein 2018), that gene editing could ensure that an HIV-infected mother would

not transmit the infection to her child, but the modification would likely reduce the child's lifespan. Would the trade-off be good? If the gene-editing were *not* done, the child would (very likely) be born with HIV infection, and several sorts of harm could be expected (either from the infection itself or from treatments). On the other hand, *with* gene-editing, other risks would ensue: fewer years of life for the child, but also possible social reactions against gene-modified people. Regardless of how precise predictions of effects might eventually become, facts alone could not determine which course was morally better, because the various types of outcomes would still be incommensurable. Pain, social rejection, disabilities, and days of life (for example) have no common unit of measurement, so the balance of benefits and risks could not be objectively calculated. Rather, one must allot degrees of moral value to various outcomes, so that in effect moral value becomes the common measure. Unfortunately, judgments of moral value are problematic, because of the nature of humans' moral processes.

Morality is a gift of evolution. The gift was a set of mental mechanisms that helped our ancestors to manage the challenges and reap the benefits of living in groups. Among these mechanisms were the models of social relations used in all cultures to understand the roles, behavioral expectations, and modes of exchange that are implied in various types of relationships. According to Alan Fiske (1991), who developed the theory, four models, singly or in combination, structure all types of social interactions:

(1) Communal Sharing, in which members of a family or other group hold resources in common, with contributions and distributions taking place without regard to what individual members have given or used;

(2) Authority Ranking, in which participants have higher or lower status, with the lower-status role requiring deference and obedience, while the higher-status role has not only privileges, such as control over resources, but also the obligation to take care of subordinates in various ways;

(3) Equality Matching, in which roles and actions are expected to be exactly equal, with all participants contributing the same things and amounts, all having identical power, and all receiving the same benefits;

(4) Market Pricing, in which relations are transactional, focusing on exchanges calculated according to relative, proportional worth determined by free negotiation among the participants.

Closely related to these models are the evolved cognitive mechanisms by which we intuitively recognize violations of role-expectations and react with moral emotions: most often anger at norm-violators, plus shame and/or

guilt felt by the violators themselves. Building on the research of Fiske, Richard Shweder, Frans de Waal, and other scientists, Jonathan Haidt and Craig Joseph and their associates identified five, now tentatively six, focal concerns that engage these moral mechanisms (Haidt and Joseph 2007; Haidt 2012). These domains of morality include:

(1)   Harm versus care (Do not injure another),
(2)   Fairness and reciprocity (Do not cheat),
(3)   In-group and loyalty (Defend your tribe),
(4)   Authority and respect (Be obedient),
(5)   Purity and sanctity (Do not defile),
(6)   Liberty versus oppression (Do not coerce others).

For example, if a father raped his eight-year-old daughter, we would be outraged, and perhaps also horrified or disgusted. His crime would have triggered at least three moral domains: he violated his duty to care for and not harm his family (a violation of a Communal Sharing relationship), he betrayed his responsibility as an authority figure to protect those over whom he had power, and he defiled the purity and innocence of a child.

In general, intuitive moral judgments and emotions serve to deter behaviors that would damage relationships and disrupt communities. While the domains of innate morality are apparently the same for all human beings, clearly there is great diversity among cultures' norms—the mostly unwritten behavioral rules that delineate actions that are required, encouraged, permitted, discouraged, or forbidden for people in various roles in various circumstances.

The moral judgments and moral emotions elicited by norm violations are intuitive, not reasoned. Moral reasoning is literally an afterthought, an explanation that justifies one's automatic, pre-thinking reactions (Haidt 2001) and thus serves to strengthen one's reputation (and self-perception) as a morally upstanding member of one's community. Moral reasoning begins inductively, as general principles are distilled from the data of people's moral reactions to various situations, and this distillation of abstract principles allows formulation of ethical systems. Reasoning cannot entirely overturn an individual's instinctive reactions, but it can influence a culture's norms.

HGLM renders moral instincts unreliable, because it raises the possibility that innate moral mechanisms could be altered. If such alterations became technologically possible, people would be in the position of choosing which moral concerns and reactions, if any, their descendants should have. The situation might seem illogically circular: explicit choice of future moral domains would entail assessing the moral rightness of the innate mechanisms that give us the idea of rightness in the first place.

However, abstraction of moral principles releases us from that circularity. With abstract principles in hand, one can assess whether our moral instincts (or which of our instincts) conform to those principles. We can ask whether our evolved morality is moral enough.

Perhaps surprisingly, the answer is no. That is, the *is* of our evolved mechanisms of morality cannot yield an incontrovertible *ought*. Indeed, our moral mechanisms cannot provide an absolutely solid foundation for rightness precisely *because* they are products of evolution. First, the hallmarks of evolutionary origin—intuitiveness, innateness, and universality—do not belong exclusively to the judgments, emotional reactions, and behavioral impulses that we label "moral." The same hallmarks also characterize other emotions—fear, grief, pride, awe, so on—and other motivations—including lust, the desire to dominate, and the urge to fight, lie, cheat, and even kill in order to gain what one wants. These, too, were "right" in that they evolved because they were adaptive for early humans, but the fact that a trait is innate or universal does not mean it is good.

Second, what was adaptive originally is not necessarily adaptive now. Moral intuitions and emotions that helped tribes of hunter-gatherers thrive on the African savannah 100,000 or 1,000,000 years ago may not be useful for meeting the challenges of social living in an era of instant global communication, nuclear weapons, and devastating climate change.

Third, *adaptive* does not imply *best*. Evolution works by *relative* adaptive success, not by ideals, so the results are relatively better than competing alternatives, but not necessarily the best possible results. Evolution does not produce perfect organisms, only a-little-more-successful ones. Our evolved moral mechanisms do not necessarily represent the best of all possible moral systems, merely one that was at least a little more useful for the species (at the time) than others that might otherwise have evolved.

Fourth, relative adaptive success is itself a troublesome basis for morality. In natural selection, some variants of a species adapt better to their environment than do other variants; that is, they survive longer and mate more frequently and thus are able to produce greater numbers of viable, reproducing offspring. Hence, the lucky variants are selected; they increase as a proportion of the population, and the genes that contributed to the reproductive success become more prevalent in the gene pool. The essence is production of greater numbers of offspring who in turn are able to produce more offspring. To put it oversimply, our morality is based on fertility. However, as the ultimate source of moral principles, reproductive success is highly problematic. Our species' ability to live in almost any environment and raise most children to sexual maturity has led to overpopulation of the planet, destruction of many ecosystems, and destabilization of the global climate. We cannot rely on reproductive-success-based morality when the evolutionary imperative to breed has brought such peril.

Fifth, we can no longer take our evolved moral mechanisms to be permanent. We can no longer assume that changes in innate human psychological mechanisms could occur only in negligible increments at evolution's glacial pace. Germ-line modification has begun taking over for natural selection. If technology became able to modify moral mechanisms and other features of human cognition, on what basis could we decide which modifications, if any, were morally acceptable?

GLOBAL MORAL CONSENSUS

The weaknesses of evolved morality leave us in a quandary regarding use of human germ-line editing. Nevertheless, decisions about research and clinical applications of HGLM will continue to be made, and the decisions must be morally acceptable to people around the world. Here, we take up the second item on the list of moral issues: consent. HGLM could alter the future of our species in profound ways, so consent for its use should be given by the whole species.

Obviously, requiring the agreement of a majority of all adults worldwide for every proposed use of HGLM would be a practical impossibility, but the principle of whole-species consent remains valid even so. A decision process is needed that would embody the spirit of that principle. At a minimum, the process should be trusted and the resulting decisions should be accepted by a large majority of people and constituencies in every part of the world. Decision makers would be acting as if by proxy on behalf of all human beings, and the legitimacy of their decisions would depend on maintaining global trust and acceptance.

Trust and acceptance, in turn, would depend on decisions being consistent with moral values that diverse people and constituencies could endorse. Yet the problems with evolved morality identified earlier would seem to make it unsuitable as a basis for a consensus on values. A new basis is needed, one that, could support a values consensus both now and into the future.

One approach to developing a consensus has been to seek areas of moral agreement among a wide array of religions. A prominent example of this endeavor is "Towards a Global Ethic – An Initial Declaration," formulated under the auspices of the Parliament of the World's Religions (1993) and endorsed by hundreds of people from scores of religious groups. The Initial Declaration asserts that there exists already enough agreement to support a global ethic based on the oneness of humankind and the fundamental principle that "every human being must be treated humanely." However, to be truly global, an ethic would also have to garner the support of non-religious persons (as the Initial Declaration recognized), so a consensus on moral values would need additional grounding besides divine instructions.

In the past, ethical systems could rely on human nature, the set of characteristics that all human beings share, to serve as that foundation. Human flourishing or well-being has often been assumed to be the measure of moral good, with flourishing being equated with the fulfillment of universal human needs and desires. Even philosophical systems that have deduced moral guidelines from *a priori* principles have needed to connect to human universals. For example, Immanuel Kant's Categorical Imperative depended on the idea of a desirable society (the sort of society in which a person would want to live) for judging moral maxims (Kant 1785, Sect. 2), and a desirable-society criterion is implicit in John Rawls's (1999) veil-of-ignorance choosing of societal principles. Desirable-society approaches rest on an assumption that people in general have similar views about what would make a society good for them, views arising from the needs and desires that all people have.

Unfortunately, human universals, as we saw in the case of evolved moral mechanisms, are products of inherently imperfect evolution and, with HGLM, may soon no longer be universal. Nevertheless, these liabilities can be removed (and a surer basis for consensus can be provided) by employing a revised set of universals, namely, characteristics that would remain true of future human beings, even genetically modified ones.

First, one can assume that future humans will still be conscious; they will be aware of themselves as entities with a history, present identity, and a future, and they will see others as being likewise self-aware. One may then apply Kant's axiom: all persons, by virtue of being conscious of themselves and others and being morally sovereign, have inherent, equal worth and therefore should be treated as ends in themselves, not as means to other's ends (1785). That axiom is in fact the starting point for the Universal Declaration of Human Rights. It is reflected in the first sentence of the Preamble, and in rephrased form it comprises Article 1: "All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience and should act towards one another in a spirit of brotherhood" (United Nations 1948). In a sense, the equal-worth principle is already part of a global consensus, as the 193 countries that are members of the United Nations (United Nations n.d. a) have all ratified at least one of the core human rights treaties built upon the Universal Declaration (United Nations n.d. b).

Whether or not one agrees with Kant that the equal-worth principle is truly self-evident, it is at least intuitively compelling, and probably most people would agree with it (in theory, even if not in behavior). There is no objective basis for denying equal worth: if all people have free will and thus are morally sovereign, then from the point of view of a disinterested observer, your sovereign moral judgment that I am of less worth than you has no more validity than my sovereign judgment that I am more worthy. From another angle, Rawls (1999) argued that people

would choose equality (of freedom and opportunity) as a principle for their society if they were making the choice under a "veil of ignorance," that is, if they did not know what their circumstances in life would be. Moreover, since the goal is a consensus on moral values that will enable a global community to address HGLM and other global issues, a principle of equal worth is necessary. Without that principle, there would be no consensus. People would have little reason to subscribe to moral principles under which they might be deemed less worthy than others.

One can also infer that, in general, self-aware beings would want to continue living, so they would desire sustenance and shelter to ensure biological survival, along with safety from threats from other people. Accordingly, ideals of peace, nonviolence, and secure access to biological necessities could be parts of a global values consensus.

Furthermore, future humans, being self-aware and therefore having a sense of agency and free will, would, like people today, desire many different sorts of additional goods. This diversity of desires would mean that all people would value freedom and the chance to pursue their chosen goals (Rawls 1999). So liberty and fairness of opportunity could be added to the values consensus. (The equal-worth principle would likewise imply an ideal of equality of opportunity.)

A second reasonable assumption would be that future human beings would remain social creatures; they would continue to live in relationships with others and have bonds of commitment to communities. Thus future human beings would still, like people today, want the freedom to form and join communities of their choice and would want their communities to thrive (irrespective of possible benefits for themselves as individuals). This social-creature perspective adds a dimension to the consensus values identified above, including the equal-worth principle. Communities have inherent worth, derived in part from the worth of individual members and the role a community plays in the welfare of its members, but also in their own right: communities contribute to the well-being of other communities (including nations), and communities play a crucial role as transmitters of cultures and thus as carriers of civilization. In the future, communities would continue to have inherent worth, though not necessarily equal worth. Communities would vary, as they do today, both in the levels of importance that participants attach to them and in the types of benefits they contribute to society. Yet communities overall would be regarded as necessary and good. Also, peaceful relations among communities would be important for the welfare of communities, so noncoercive coexistence could be added to the values consensus. Likewise, freedom and fair opportunity would be values for communities (as for individuals). Communities would want to be free to develop their cultures as they see fit and would want fair opportunity to recruit members, attract contributions, and pursue their goals.

A third assumption can also be made about future humans: they would understand (probably more fully than people today) that they are fellow participants with other species in complex ecosystems and thus are interdependent with all other forms of life. Accordingly, a global values consensus could include the principle that all living things have worth and should be respected, and therefore humans should attend to the impact of their actions on the welfare of other life.

In summary, widespread agreement among people, both now and in the future, is achievable regarding a number of values-statements:

(1) All persons have inherent, equal worth.

(2) All people should live in peace and reject the use of coercion.

(3) All people should be secure in their access to basic necessities of life.

(4) All people should be free to pursue their chosen goals.

(5) All people should have fair access to educational, economic, political, social, and other types of opportunities.

(6) Communities have value, and the ideals of peace, security, freedom, and opportunity apply to communities as well as individuals.

(7) All forms of life have worth, and humans should respect all living things as fellow interdependent constituents of ecosystems.

These values would be able to guide the weighing of risks and benefits, and adherence to the values in decision making about uses of HGLM would be critical for extensive acceptance of the decisions, which substitutes for literal humanity-wide consent. The consensus values would also guide deliberations regarding the last of the central moral concerns, the distribution of benefits and risks. Consider a hypothetical use of germ-line editing to prevent a monogenic disease. Of the, say, worldwide total of 5,000 carriers of the pathogenic gene, whose gametes should be corrected? The equal-worth principle would seem to require an egalitarian distribution, that is, equal access to the benefits of HGLM, which in this case would mean that all the carriers would be offered the gene-editing procedure, and if all could not be accommodated, then a lottery or other equal-chance system would be used to determine who would be served and in what order.

Alternatively, one could argue that the equal worth of persons would be honored more fully by following the spirit of the difference principle, that is, by reducing socioeconomic inequalities through raising the floor of advantages so that the least fortunate people became better off. From this point of view, the benefits of HGLM should go preferentially to the least well off. Since the beneficiaries would be children not yet born, this approach would assume that children would "inherit" their parents' status, that is, that children would be approximately as advantaged or disadvantaged as their parents, so that the preferential benefit, disease prevention,

would in fact reduce inequalities in the offspring's generation. This assumption seems reasonable; in today's societies, socioeconomic advantages and disadvantages very often do get passed on from one generation to the next.

Another approach to distribution might be utilitarian: the benefits of HGLM should be distributed so as to produce the greatest overall increase in human welfare. In view of the enormous practical and theoretical problems—difficulties in quantitatively defining and then actually measuring change in well-being—one would need simplifying assumptions. One might assume that benefits of HGLM would affect all people in similar ways with roughly equal consequences for their well-being, so that, for example, prevention of a monogenic disease would give an equal boost to a person's welfare regardless of which particular individual received the corrected genome. It would then follow that distribution ought to be arranged to provide the corrective HGLM procedure to the maximum number of carriers of the pathogenic gene, and as quickly as possible. But the likely result would be that people who had easier access to technologically advanced medical treatment—through wealth, insurance coverage, or geographic proximity—would receive the procedure first, while poorer, uninsured, and remotely located people would receive it later (or perhaps never). Thus an effect of the "most people, fastest" distribution would be to increase disparities between haves and have-nots—to the detriment of overall human welfare. So the utilitarian would likely conclude that "most people, fastest" would produce less utility than a strictly egalitarian distribution.

Or the utilitarian might begin with a different simplifying assumption, namely, that disease prevention and other benefits of HGLM would yield greater per-person marginal increases in lifetime welfare if they were received by children born into less-fortunate circumstances than if the benefits were received by children of families already high in well-being. With this assumption, utility would be maximized by a distribution scheme that gave priority to the least well off.

Among theories of distributive justice, one that would be very difficult to square with the consensus moral values would be libertarianism. There are many varieties of libertarianism, but in general the most prominent versions (at least in the United States) deem freedom to be the highest good for people, with other values being secondary, if they register at all. Furthermore, these versions generally emphasize property rights as being essential to freedom. These libertarians argue along the following lines: having free will and being morally sovereign, people own themselves and by extension have a right to the fruit of their labor and have ownership rights over property they acquire. Without such rights, people's freedom to pursue their aims would be constantly at risk. And, libertarians generally argue, free markets are the purest expression and most efficient realization of the ideals of fair reward for labor, just acquisition of property, and use of money and property to pursue individual aims.

However, if applied to decisions about uses of HGLM, these views would be destructive. Making individual freedom the preeminent value would distort decisions about HGLM, because consequences for relationships and communities would be discounted. According to psychological science, freedom is not in fact the most important factor in human well-being; security and relationships are of equal, if not, greater importance. Survival obviously is a prerequisite for freedom, and relationships are also essential for normal human beings. Relationships entail mutual obligations and thus relinquishment of some freedom, and this is true for social bonds at all levels, from individual friendships and families up to national societies. Overemphasis on individual freedom weakens these bonds.

In addition, treating HGLM as a commodity—as by granting patents on techniques of genetic editing and perhaps even on specific genes and enzymes or by limiting access to the benefits of HGLM to those who can pay the market price—would also be socially destructive. The libertarian justification for a free-market approach invokes two principles—exclusive claim on the fruits of one's labor and rightful exclusive ownership—but neither principle is defensible. Libertarians' chain of reasoning from ownership of oneself to exclusive ownership of one's labor and then to exclusive claim on the fruits of one's labor is flawed, because the fruits that result from one's labor depend on many factors besides one's effort. Not even considering dependence on the body of knowledge, developed by predecessors, that has made current genetic technologies possible, a scientist (or physician or entrepreneur or any other person) relies on social institutions, such as systems of laws, markets, and transportation, to turn work into reward. Societies and their institutions are so necessary for life and civilization that they have legitimate claims on their members, including claims on members' labor and property. The laborer's claim to the fruits of labor is not exclusive.

Nor can rightful ownership be established. Property is rightfully owned, according to libertarians, if the original owner acquired the property justly and subsequent owners acquired it through fair, just transfers. This assumes that everything began in an unowned state and that anyone has a right to claim any unowned property (perhaps with the restriction that the acquisition not harm anyone else and/or that the acquirer make productive use of the property). However, original ownership cannot possibly be determined. One cannot identify the point in our evolutionary past when behaviors such as defense of a territory or caching of food became conceptualized as ownership rights. Nor can one identify the first human to enter a previously uninhabited land (whether the human was *Homo erectus*, *Homo neanderthalensis*, *Homo sapiens*, or other), let alone whether that human actually made a specific claim to that land. Furthermore, it is also impossible to trace the tangled history of just and unjust transfers of money and other possessions in order to judge whether current ownership is rightful.

Furthermore, along with these issues is the question of what can be possessed. Different cultures, past and present, have conceived owner-ship differently, varying in the categories of things that may be owned, the rights that may be exercised regarding possessions, and what counts as unowned and therefore claimable. I would argue that HGLM and other scientific discoveries are not things that may be owned. The uni-verse exists and operates as it does, and anyone (who has the desire and resources) can see what it is and how it works. Knowledge is not a one-of-a kind entity that only one person at a time can possess. Discovery of some aspect of the how the universe works does not confer ownership, as if one had caught a fish in the open ocean. Nature's laws cannot be owned.

One additional consideration: though HGLM has the potential to al-leviate suffering, increase health, and enhance abilities, if access to those benefits were determined by markets, today's disparities in wealth and other advantages would grow. If parents' accumulations were the ticket to HGLM's benefits, offspring would be gifted with much more than money. People born without enhanced physical, intellectual, or creative abilities could hardly compete, so social mobility would decline, and the gulf be-tween advantaged and disadvantaged would widen. Libertarians might argue that such an outcome would be fair, because people should be free to do whatever they want with their money, including buy advantages for their children. But that position would ignore limitations on ownership rights, both a society's legitimate claim on one's money for maintenance of the society and the moral limitation that the rightfulness of current own-ership cannot be established. Though most people would judge it fair that one's labor should be rewarded, that general principle is not a sufficient basis for libertarian theory and in particular does not justify unfettered transfer of advantages to offspring. After all, the children would not have "earned" the benefits through their own productivity; they merely had the luck to be born to rich parents.

In summary, the prospect that HGLM may enable human beings to change basic human characteristics underscores the necessity that decisions regarding use of genetic technology must be morally acceptable to the widest range of people and communities. Yet the possibility that cognitive mechanisms underlying social relations and morality could be altered makes current moral systems questionable. Needed is a global consensus on values sufficient to guide weighting of outcomes, serve as an equivalent for species-wide consent, and direct the fair distribution of benefits and risks. Such a consensus could be based on a combination of the equal-worth principle and features of human beings that would remain constant regardless of revised genomes.

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