The Committee on Jewish Law and Standards of the Rabbinical Assembly provides guidance in matters of halakhah for the Conservative movement. The individual rabbi, however, is the authority for the interpretation and application of all matters of halakhah.

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CJLS YD 297

Halakhic Perspectives on Genetically Modified Organisms

Approved by the CJLS on November 10, 2015, by a vote of 21-0. Voting in favor: Rabbis Aaron Alexander, Pamela Barmash, Miriam Berkowitz, Noah Bickart, David Booth, Elliot Dorff, Baruch Frydman-Kohl, Susan Grossman, Reuven Hammer, Josh Heller, David Hoffman, Jeremy Kalmanofsky, Adam Kligfeld, Gail Labovitz, Amy Levin, Jonathan Lubliner, Daniel Nevins, Micah Peltz, Paul Plotkin, Avram Reisner, Jay Stein.

Questions:

What halakhic values and norms should be applied to the genetic modification of organisms, whether plant or animal, particularly through the use of recombinant DNA? May Jewish consumers receive medical, nutritional and commercial benefit from genetically modified products? Must modifications to the human genome be limited in scope?

Response:

מָה־אֱנוֹשׁ כִּי־תִזְכְּרֶנּוּ וּבֶן־אָדָם כִּי תִפְקְדֶנּוּ: וַתְּחַסְּרֵהוּ מְּעַט מֵאֱלֹהִים וְכָבוֹד וְהָדָר תְּעַטְּרֵהוּ: תַּמְשִׁילֵהוּ בְּמַעֲשֵׂי יָדֶיךָ כֹּל שַׁתָּה תַּחַת־רַגְלָיו: צֹנָה וַאֲלָפִים כֻּלָּם וְגַם בַּהֲמוֹת שָׂדָי: צִפּוֹר שָׁמַיִם וּדְגֵי הַיָּם עֹבֵר אָרְחוֹת יַמִּים: יְקֹוָק אֲדֹנֵינוּ מָה־אַדִּיר שִׁמְךָ בְּכָל־הָאָרֶץ: (תהלים פרק ח, ה-י)

What are humans, that You have been mindful of them, mortals, that You have taken note of them, that You have made them little less than divine, and adorned them with glory and majesty; You have made them master over Your handiwork, laying the world at their feet, sheep and oxen, all of them, and wild beasts too; the birds of the heavens, the fish of the sea, whatever travels the paths of the seas. O LORD, our Lord, how majestic is Your name throughout the earth! (Psalm 8: 5-10)[1]

ותחסרהו מעט מאלהים (תהלים שם ו') זה יעקב שנאמר ויחמו הצאן אל המקלות. א"ר הושעיא היה צר צורה וכשם שהיה צר נעשו המים זרע בתוך מעיהם וכך היו יולדות, מלמד שלא היה חסר אלא לתת בהם נפשות. (בראשית רבתי פרשת ויצא עמוד 129)

That you have made them little less than divine—This refers to Jacob, for it says (in Genesis 30:39), *and since the goats mated by the rods*…. Rabbi Hoshaya explains, "He would draw an image, and just as he drew, so the seed formed in the water of their wombs, and so did they give birth. This teaches that [Jacob] lacked only the ability to give them a soul."
(Midrash *Bereshit Rabbati, VaYetze*, p.129)

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[1] I have adapted this translation from the *JPS Tanakh* (1985), shifting from the singular "man" to the plural and gender-neutral "humans," etc. since that is clearly the verse's intention. In general, I employ gender-neutral language in my own writing, but maintain the gendered language found in direct quotations.

I. Introduction

Humans have influenced the evolution of plants and animals since our prehistory, often without intention or awareness. For example, the evolution of fearsome wolves into friendly dogs may have originated from the advantage conferred on canines with smaller jaws to access food from human encampments.[2] People are frequently unaware of the impact of their activities on the adaptation of other species. There is evidence of recent evolution of fish to favor thinner bodies, the better to evade the nets of fishermen, and of elk to favor smaller racks of antlers, which are less valued by human hunters.[3] By catching and killing specimens with particular traits, humans may paradoxically exert evolutionary pressure that causes the diminution of those very desirable qualities.

Of course farmers, herders and—since the work of mid-19th century monk-biologist Gregor Mendel was rediscovered—scientists, have also successfully bred plants and animals to favor certain qualities and avoid others. The domestication of eight plant species and four animal species in the Neolithic era was essential for the expansion of civilization in the Fertile Crescent and other regions.[4] Charles Darwin opened his great work, *On the Origin of Species* with a discussion of the impact of human selection (in contrast to natural selection) in a first chapter entitled, "Variation under Domestication." Yet for all of his remarkable prescience, Darwin did not have knowledge of genetic theory, and he could not foresee the direct modifications recently made possible by genetic engineering. He wrote, "Man…can neither originate varieties, nor prevent their occurrence; he can preserve and accumulate such as do occur."[5]

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[2] Adam Miklosi, *Dog Behavior, Evolution and Cognition* (Oxford: Oxford UP, 2007). Cited in Emily Anthes, *Frankenstein's Cat: Cuddling Up to Biotech's Brave New Beasts* (NY: Scientific American/Farrar, Straus and Giroux, 2013) 184. Raymond Coppinger has also proposed that "flight distance," the tolerance animals have for interaction with humans, would have played a role, with advantage conferred upon those wolves that exhibited greater tolerance for human contact.

[3] Anthes, 176, citing Chris T. Darimont, et al, "Human Predators Outpace Other Agents of Trait Change in the Wild," *PNAS* 106, no. 3 (2009), and Stephen Palumbi, "Humans as the World's Greatest Evolutionary Force," *Science* 293 (Sept. 7, 2001): 1786-90. Most unfortunately, we also are causing the evolution of bacteria that are adapted to resist antibiotics, especially through the use of antibiotics to accelerate muscle growth in animals raised for their meat. See Pamela Barmash's responsum, "Veal Calves," (approved by CJLS on Dec. 12, 2007, by a vote of 9-5-7), esp. note 68.

[4] Daniel Zohary and Maria Hopf, *Domestication of Plants in the Old World*, third edition (Oxford: University Press, 2000).

[5] Charles Darwin, *The Origin of Species* (NY: Signet Classics, 2003), p. 76. On the failure of Darwin to discover the genetic mechanism of inheritance, see Brian Charlesworth and Deborah Charlesworth, "Darwin and Genetics," in *Genetics* (Nov. 2009, vol. 183, no.3, 757-766).

Darwin considered his work to be compatible with religious faith, yet it was and remains challenging to a traditional world-view that asserts not only the special creation of each species of plant and animal, but also the stability of these species across time. These two foundations of early monotheistic faith are grounded in the first two portions of the Torah, *Bereshit* and *Noah*, and are implicit in the writings of great sages such as Ramban, when he writes in his commentary to Leviticus 19:19:

> והמרכיב שני מינין, משנה ומכחיש במעשה בראשית, כאילו יחשוב שלא השלים הקדוש ברוך הוא בעולמו כל הצורך, ויחפוץ הוא לעזור בבריאתו של עולם להוסיף בו בריות.
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> *One who grafts together two species alters and undermines the work of creation. It is as if he thinks that the Holy Blessed One did not complete the needs of His world, and he desires to assist in His creation of the world by adding more creatures to it.*

Ramban developed a doctrine of species preservation, קיום המין, which was expanded in *Sefer HaHinukh*,[6] and has religious significance to this day. The divine origin of life on earth remains an important if mysterious belief for many religious people, but faith in the immutable permanence of species does not. Indeed, the Torah itself mentions Jacob's breeding technique for producing hardy dark sheep and speckled goats in Genesis (30: 37-39).[7] Isaiah's messianic prediction of an end to carnivorous animal diets assumes dramatic changes in nature.[8] On a practical level, the sages of Israel were familiar with techniques for grafting plants and interbreeding animals in order to form hybrids, which though forbidden to Jews under the rubric of *kilayim,* were nevertheless common in antiquity.

Belief in an unchanging natural world was problematic already in antiquity, and has become

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[6] ספר החינוך מצוה תקמה. משרשי המצוה לתת אל לבנו שהשגחת האל ברוך הוא על בריותיו במין האדם בפרט, כמו שכתוב כי עיניו על כל דרכי איש וגו', ובשאר מיני בעלי חיים במינין דרך כלל, כלומר שחפצו ברוך הוא בקיום המין, ועל כן לא יכלה לעולם מין מכל מיני הנבראים, כי בהשגחת החי וקיים לעד ברוך הוא על הדבר ימצא בו הקיום, ובהניח האדם דעתו על זה יבין דרכי ה' ויראה כי המשכת קיום המינין בעולם שלא כלה ואבד אחד מכולם מביצי כנים ועד קרני ראם מיום שנבראו הכל במאמרו וחפצו על זה. וכו'

[7] While this episode is generally read as a miracle narrative, some modern commentators have sought an epigenetic explanation in which the amino acids in the fungi of the exposed bark could theoretically have caused the development of brown coats in the sheep. See "Jacob and the Spotted Sheep: The Role of Prenatal Nutrition on Epigenetics of Fur Color," by Joshua Backon, a cardiologist and faculty member at the Hebrew University Medical School, in *The Jewish Bible Quarterly*, Vol. 36, no. 4, 2008, pp.263-5. http://jbq.jewishbible.org/assets/uploads/364/364_sheep.pdf, as well as Nahum M. Sarna's comments in *JPS Torah Commentary: Genesis* (1989), p.212. The late Midrash cited in our frontispiece claims that Jacob was engaged in something akin to genetic engineering, intentionally modifying the qualities of his herd.

[8] Isaiah 11:6-9 and 65:25 (cf. Hosea 2:20). Rabbi David Kimhi (France, 1160-1235) comments on Isa. 11:7 that in the messianic era carnivorous species will "return" to the vegetarian ways that had purportedly been their original practice on the ark, before they devolved into wild creatures.

untenable in the past two centuries.[9] While there remain religious practitioners of various faiths who insist that the world and all of its current species were literally created according to the timeline laid out in Genesis, Jews from across the spectrum have long since integrated the concept of natural history into their religious world view.[10] As we consider the halakhic implications of the reengineering of plant and animal life, it will not be the preservation of a mythic stasis of all creation that guides our inquiry. Rather, Jewish norms that mandate a ban on artificial hybridization (כלאים), the protection of human life (פקוח נפש), and the prevention of animal suffering (צער בעלי חיים), will form the fertile ground for our study of genetic engineering.

Darwin devoted an entire chapter of *On the Origin of Species* to hybridism, and in the past twenty years biologists have increasingly seen natural hybridization as an important factor in speciation.[11] Intentional hybridization by farmers and agricultural scientists is an essential practice for the cultivation of fruits such as apples and grapes. Since the 1950s researchers have used hybridization and backcrossing to create lines of wheat and other grains that have greater disease resistance, thereby feeding the rapidly growing populations of developing countries.[12] In a sense, they were merely continuing the process of improving crop yields that began in the Neolithic era. Still, until recently it was not possible for humans directly to manipulate the genome. New methods are yielding radically new results and eliciting urgent new questions.

Recent Developments in Genetic Engineering

Genetic engineering, which involves the direct modification of DNA, was first demonstrated in 1973 by Herbert Boyer, Paul Berg and Stanley Cohen (who coaxed bacteria to develop foreign

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[9] Darwin's theory of evolution was dependent, as he explicitly acknowledged (p.499), on the prior work of geologists such as Charles Lyell in establishing the great antiquity of earth. Without this insight, there would not have been sufficient time for the small mutations described by Darwin to yield the enormous diversity of plant and animal life on earth. However, contemporary biologists have observed a much more rapid pace of evolution, as discussed below.

[10] For an Orthodox approach, see Natan Slifkin, *The Challenge of Creation: Judaism's Encounter with Science, Cosmology and Evolution* (New York: Yashar Books, 2006). Arthur Green discusses the "sacred dimensions" of evolution in the first chapter of *Radical Judaism: Rethinking God and Creation* (New Haven: Yale UP, 2010). The most recent entry is by Alan L. Mittleman, *Human Nature & Jewish Thought: Judaism's Case for Why Persons Matter* (Library of Jewish Ideas, Princeton UP, 2015).

[11] Peter R. Grant and B. Rosemary Grant, *Forty Years of Evolution: Darwin's Finches on Daphne Major Island* (Princeton: Princeton UP, 2014), p. 245.

[12] I thank Pamela Barmash for directing my attention to the remarkable work of Nobel-prize winning researcher Norman Borlaug and for sharing her general expertise in biblical, rabbinic and horticultural matters. Borlaug is known as "the man who saved a billion lives." See his entry in Wikipedia for biographical information as well as a description of his work.

proteins), and the field has grown rapidly since then from manipulating the DNA of yeast and bacteria to that of plants, fish, birds and mammals. By the 1980s researchers were capable of inserting DNA from one species into the fertilized egg of a different species, producing new specimens with hybrid characteristics, which are referred to as transgenic. Zebra fish have received the DNA of coral and sea anemones to make them glow; salmon have been artificially endowed with the DNA of deep sea eels (ocean pout) to make them grow year-round; and goats have had snippets of human DNA inserted into their fertilized ova to cause them to produce enzymes such as antithrombin and lysozyme for human benefit.[13] The resulting recombinant DNA includes sequences from both of the original organisms, even though they are of different species that could not naturally reproduce together. The use of transgenic mice has become commonplace in contemporary laboratories, with companies such as The Jackson Laboratory's JAX Mice making hundreds of variants—with targeted genes "knocked out," activated, or added—easily available to researchers.[14]

Methods for blending the DNA of different species have become ever more sophisticated, from the initial insertion of foreign DNA into a fertilized egg using a micro-syringe, to more recent efforts that employ a "gene gun," agrobacteria, or modified viruses to transfer DNA from one organism to another. Hybrids have been created in laboratories between species (e.g. lions and tigers) and even between genera (e.g. sheep and goats).[15] An international industry known as "pharming" has arisen to develop genetically modified organisms to grow medications and other substances such as biofuels that are useful to humans.

Genetic engineering is a field of great promise in combating hunger and disease.[16] Genetically

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[13] Antithrombin is an anticoagulant made by the human liver that prevents blood clots from forming; lysozyme is an enzyme found abundantly in human breast milk that destroys harmful bacteria such as E. coli, protecting the child from dysentery, and allowing the development of a stronger immune system. Both products might be "pharmed" to produce medication for humans who have a deficiency of the requisite enzyme. These experiments are discussed by Anthes in *Frankenstein's Cat*.

[14] I thank Mark Berger for alerting me to this company and the implications of its products.

[15] See Wikipedia entries on Genetic Engineering, Horizontal Gene Transfer, Agrobacterium, and Hybrids.

[16] Genetically modified rice has, it is claimed, the potential to alleviate global hunger, malnutrition and poverty. See Dermont, M. and Stein, A.J., "Global Value of GM Rice: A Review of Expected Agronomic and Consumer Benefits" in *New Biotechnology* (2013). Still, there are unresolved controversies about the safety and also the ethics of GM crops, since the GM products of agribusiness giants such as Monsanto are displacing the unmodified crops of subsistence farmers, requiring them to purchase new seed annually rather than simply reserving some of their traditionally grown crops for replanting. Organic farmers have likewise taken legal action out of concern that their crops would become contaminated by GM pollen, leading patent owners to sue farmers for unintentional copyright violation.

modified crops, first introduced in 1994 with the FlavrSavr Tomato (approved, but then removed from market), had by 2013 been planted on 420 million acres, including half the world's soybeans and a third of its corn.[17] Many scientists believe that it will be impossible to feed the world's rapidly growing human population without genetically modified crops.[18] Not only may such crops reduce the need for herbicides, but some seeds such as Golden Rice are engineered to include Vitamin A and thus to combat vitamin deficiencies that cause blindness in a half million children each year. J.R. Simplot's USDA-approved modified potato has been designed to produce less acrylamide, a possible carcinogen, when fried.[19] Some crops would be wiped out by fungus or infestations without their genetic modification. However, concerns about the safety of some of these products persist; for example, genetically modified corn may be grown using neonicotinoids, a class of neurotoxic insecticides that activists have claimed to have played a role in the recent collapse of honeybee populations, and may even disrupt nerve-cell activity in mammals.[20] Scientific reviews have not, however, confirmed these claims.[21] GM cotton crops often integrate the insecticide Bt in every cell, which may be causing the selection for resistance in "superbugs," leading farmers to increase the use of pesticides. Attacks and defenses of GMOs on health grounds are contentious and complex, defying simple conclusions. Regulations to alert consumers to the use of genetically modified products (such as those already in place in Europe),

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[17] See the following USDA web site for data on the adoption of genetically engineered crops by American farmers: http://www.ers.usda.gov/data-products/adoption-of-genetically-engineered-crops-in-the-us.aspx

[18] I realize of course that many causes of hunger are of a political, economic and even cultural nature. If crops cultivated to feed animals for meat production were replaced with vegetables intended for human consumption, the farms of America alone could feed the world on a vegetarian diet. Still we cannot assume that human appetites for meat, and also for financial profit, will be eliminated. Perhaps the development of cultured (lab-grown) meat will address human appetites in a way that is more efficient, ethical and less polluting in the future. This is the subject of my next halakhic study.

[19] Andrew Pollack, "U.S.D.A. Approves Modified Potato," *New York Times*, Nov. 7, 2014.

[20] An article defending GMOs is found in Michael Specter, "Seeds of Doubt: An Activist's Controversial Crusade against Genetically Modified Crops," in *The New Yorker* (August 28, 2014). For a critical response, see "Rooted in Science," letter to the editor by Eric Chivian published in response to "Seeds of Doubt," *The New Yorker* (September 15, 2014), and Ramon J. Seidler's essay, "Pesticide Use on Genetically Engineered Plants," in EWG *AgMag* (September 2014).

[21] See "Risks of Neonicotinoid Insecticides to Honeybees," by Anne Fairbrother, John Purdy, Troy Anderson and Richard Fell in *Environmental Toxicology and Chemistry,* (Volume 33, Issue 4), pages 719–731, April 2014. They conclude, "However, under field conditions and exposure levels, similar effects on honeybee colonies have not been documented. It is not reasonable, therefore, to conclude that crop-applied pesticides in general, or neonicotinoids in particular, are a major risk factor for honeybee colonies, given the current approved uses and beekeeping practices."

and continued study of their ramifications for animal and human health are certainly warranted.[22]

Aside from the development of new foods, genetic engineering has become increasingly significant in medical research and therapy. Long-term safety trials have already been completed for certain genetically modified medications, some of which are indispensable to the contemporary pharmacy. In 1978 the first synthetic human insulin was bioengineered using E. coli, and in 1982, Eli Lilly and Company marketed the first commercial product of bioengineered insulin under the brand name Humulin. In 2007 the company SemBioSys announced plans to bioengineer insulin by introducing the human gene for insulin production into safflower plants, thereby reducing the costs of creating this vital medication. The company went bankrupt in 2012,[23] but the majority of insulin produced today is made from biosynthetic processes using bacteria and yeast to grow this important medical product.[24]

Cancer researchers have capitalized on the human immune system's intolerance for certain foreign DNA to stimulate auto-antibodies to inhibit the growth of cancer cells. For example, NewLink Genetics has a product called HyperAcute that, according to its web site is,

> …composed of human, tumor-specific cancer cell lines. These cells have been modified to express alpha-gal, a carbohydrate to which humans have preexisting immunity. These alpha-gal-modified cancer cells stimulate a rapid and powerful immune response that trains the body's natural defenses to seek out and destroy similar cancer cells in the patient. The objective of HyperAcute™ immunotherapies is to elicit an antitumor response by 'educating' the immune system to attack a patient's own cancer cells.[25]

Another anti-cancer gene therapy involves, "A plasmid DNA vaccine encoding the extracellular domain of porcine endoglin [that] induces anti-tumor immune response against self-endoglin-related angiogenesis in two liver cancer models."[26] This is a method that modifies DNA from a pig and introduces it to a tumor site within a human in order to induce an auto-immune response from the host to attack the tumor.

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[22] A FAQ document by the World Health Organization includes links to detailed documents such as Principles for the risk analysis of foods derived from modern biotechnology.

[23] See "SemBioSys Bankruptcy," blog posted on May 24, 2012 by Paul Christensen.

[24] See this page from Iowa Public Television for a graphic illustration of the process, and this YouTube instructional video.

[25] See http://newlinkgenetics.com/. I thank Michael B. Weiss for informing me about this new technology and generally about the state of the field.

[26] Article by Jiao JG, Li YN, Wang H, Liu Q, Cao JX, Bai RZ, Huang FY, in Dig Liver Dis. 2006 Aug; 38(8):578-87. Epub 2006 Jun 13, accessed via PubMed on July 16, 2014.

Yet another promising field is immunoprophylaxis by gene transfer (IGT), a form of genetic engineering that seeks to re-engineer human DNA for permanent resistance to a broad spectrum of viruses.[27] A detailed analysis of the science involved in these projects is well beyond the scope of this paper (and this rabbi's understanding), but the significance of genetic engineering is manifest, as is the need to consider the ethical and religious implications of this rapidly growing field.

Our focus in this responsum is primarily on the field of transgenics, which impinges on established halakhic concerns. We note, however, that genetic engineering has begun to focus on "cisgenic" products, which artificially blend materials from different members of the same species, and thereby evade government regulation,[28] and to our concerns, the Jewish prohibition on blending species (*kilayim*). We will not focus on the fascinating field of synthetic biology, which involves engineering organisms from synthetic sources (even creating DNA from nucleotides other than the four found in nature). These forms of genetic engineering raise issues of human safety and animal welfare, and perhaps other halakhic issues as well, but they do not trigger the same religious concerns with the blending of species that are found in transgenic organisms, and will need to be considered separately.[29]

While the methods employed by contemporary biotech researchers are stunning to consider, in many ways they are employing mechanisms already evident in nature. Horizontal Gene Transfer (HGT) has been studied since the 1950s. Recent research indicates that HGT occurs naturally not only among bacteria and viruses, but has also played an important role in the development of animals, including primates. Alastair Crisp and Chiara Boschetti and their collaborators recently demonstrated that as many as 145 genes (from among 20,000 in the human genome) have been picked up from other species.[30]

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[27] See "Protection without a Vaccine" by Carl Zimmer, published in *The New York Times*, March 9, 2015. Also, "Vector-Mediated Antibody Gene Transfer for Infectious Diseases" by Bruce C. Schnepp and Philip R. Johnson in *Gene Therapy for HIV and Chronic Infections*, Volume 848 of the series *Advances in Experimental Medicine and Biology*, pp 149-167, published Feb 12, 2015).

[28] "Genetically Engineered Crops that Fly Under the US Regulatory Radar," by Alex Camecho, Allen Van Deynze, Cecilia Chi-Ham, and Alan B. Bennett in *Nature Biotechnology* (Nov. 2014) Vol. 32, No. 11, pp.1087-1091. See also Andrew Pollack, "By 'Editing' Plant Genes, Companies Avoid Regulation" *New York Times*, January 1, 2015.

[29] But see *Regenesis: How Synthetic Biology will Reinvent Nature and Ourselves*, by George Church and Ed Regis (New York: Basic Books, 2014). Among their more radical notions is the development of a "posthuman" species, dubbed *Homo evolutis:* "It seems likely that legal, moral and ethical concerns will loom larger and sooner due more to selection than to speciation—and due more to mixing of species than to isolating one species from another." p.248.

[30] See "Expression of multiple horizontally acquired genes is a hallmark of both vertebrate and invertebrate

Blending the DNA of different organisms can produce scientific, medical and financial benefits to academic researchers and for-profit businesses, which increasingly work in concert.[31] Humans are profiting (in both senses) from many of these new products, and genetic engineering is already being used to combat cancer and other diseases. Yet as the "code of life" gets reprogrammed, and the genomes of different organisms are artificially combined, difficult issues arise regarding intellectual property, ethical limits of experimentation, and the long-term consequences of these scientific interventions. Independent organizations such as the Union of Concerned Scientists have expressed caution about harmful side effects of genetically modified crops, such as the evolution of "super-weeds" that incorporate the herbicide resistance intended for GM rice or corn.[32] In the United States, the National Institutes of Health established a National Human Genome Research Institute in 1990 with a program called ELSI (Ethical, Legal, and Social Implications), "to foster basic and applied research on the ethical, legal and social implications of genetic and genomic research for individuals, families and communities."[33] What is missing is a systematic and sustained discourse among religious people regarding genetic engineering.

Overview of Halakhic Concerns

Even as scientists and businesses around the world rapidly transform the genetic structures of plants and animals, religious thinkers have been relatively slow to engage in these profound matters, whether in support, in criticism, or simply from curiosity about the implications for established theological and moral principles. However, we are not at the starting position. In recent decades several of our scholars from the Committee on Jewish Law and Standards (CJLS), together with rabbis from other circles, have initiated inquiry into the halakhic ramifications of genetic engineering. In 1980 Rabbi Seymour Siegel z"l, who was then chair of the CJLS, published an article entitled, "Science and Ethics: A Creative Partnership."[34] He called for a, "creative

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genomes," by Alastair Crisp, Chiara Boschetti, Malcolm Perry, Alan Tunnacliffe and Gos Micklem, published in *Genome Biology* 2015, 16:50, available at: http://genomebiology.com/2015/16/1/50, and also a popular review, "Genetically modified people," in *The Economist*, published Mar. 14, 2015, and available at http://www.economist.com/node/21646197/print. I thank CJLS secretary and JTS rabbinical student Philip Gibbs for directing me to this material.

[31] See *Genes, Cells and Brains: The Promethean Promise of the New Biology* by Hilary Rose and Steven Rose (Verso, 2014), esp. Ch.1, "From Little Genetics to Big Genomics."

[32] See http://www.ucsusa.org/food_and_agriculture/our-failing-food-system/genetic-engineering/

[33] http://www.genome.gov/elsi/. In its 2011 strategic plan, published in *Nature* (Vol. 470, 10 Feb. 2011), p.210, box 5, NHGRI identified "broader social implications" as including "the implications of increasing genomic knowledge for conceptualizing health and disease; for understanding identity at the individual and group levels, including race and ethnicity; for gaining insights about human origins; and for considering genetic determinism, free will and individual responsibility."

[34] Seymour Siegel, "Science and Ethics: A Creative Partnership," in *Conservative Judaism* 33:4 (1980) 56-60.

partnership between the scientific community and those who express the values of our society," and expressed confidence that even revolutionary advances in DNA research could be compatible with monotheistic ethics since nature itself is not deemed divine, and, "illness, disability and disease are, in a sense, challenges which God puts to man."

The CJLS subsequently approved two responsa that considered the kashrut implications of genetically modified organisms. In 1994 Rabbi Kassel Abelson (who was then the CJLS chair) found that microbial enzymes that were isolated from an animal source, or genetically engineered, should be considered kosher.[35] Rabbi Avram Reisner followed this in 1997 with an extensive study of kashrut and other halakhic issues raised by genetic engineering, concluding that, "the kashrut laws of prohibited admixtures do not apply to the microscopic manipulation of genetic materials." Although there have been significant biotechnology developments in the subsequent years, and his focus was primarily on matters of kashrut, Rabbi Reisner also discussed broader questions that will be integral to our investigation.[36]

In addition to questions of kashrut, what are the relevant halakhic concerns? The following list is not exhaustive or conclusive; we shall return to the most salient halakhic concerns below. A formidable amount of animal suffering is engendered by these experiments, and many sterile and severely deformed animals are being created for uncertain human benefit. Judaism prohibits the infliction of needless animal suffering, צער בעלי חיים.[37] The introduction of genetically modified

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[35] Kassel Abelson, "The Kashrut of Microbial Enzymes," approved by the CJLS on Dec. 14, 1994 (16-0-3). Below we will also mention the work of Isaac Klein on the kashrut of rennet and of gelatin that are derived from animal sources, and then chemically transformed.

[36] Avram Israel Reisner, "Curiouser and Curiouser: The Kashrut of Genetically Engineered Foodstuffs," approved by the CJLS on Dec. 10, 1997 (16-0-0). See discussion in Section IV below.

[37] See esp. MT *Shabbat* 21:9, *Rozeah* 13:13; Tur OH 305, and HM 272; SA HM 272:9. The question of what amount of expected human benefit may justify what extent of animal suffering resists any formulaic response. Some animal rights advocates, following in the footsteps of Peter Singer's *Animal Liberation* (New York Review of Books, 1975), claim that no amount of human benefit may justify any imposition of animal suffering. At the other extreme are those who hold that any human benefit, even in the development of cosmetics, can justify any level of animal suffering, based on dominion theology. The halakhic principle of צער בעלי חיים indicates a middle ground; humans are entitled to use the labor and the bodies of animals, but must avoid causing them needless suffering. Many rules of the Torah reinforce the importance of compassionate behavior toward other animals. See the CJLS responsum of Elliot Dorff and Joel Roth, "Shackling and Hoisting," (approved by CJLS on Sept. 20, 2000, by a vote of 21-0-0); the previously cited responsum, "Veal Calves" by Pamela Barmash; Zvi Kaplan's article, "Animals, Cruelty to" in the *Encyclopedia Judaica*, 2nd edition (Macmillan, 2006), Vol. 2, 165-166; and Joshua Cahan's, "*Tza'ar Ba'alei Hayim* in the Marketplace of Values," in *Conservative Judaism* 65:4 (Summer 2014) pp. 30-48.

species could undermine the survival of extant species,[38] although minor modifications could also allow current species to survive in changing environmental conditions. As we have seen, scholars such as Ramban hold humans responsible for קיום המין, species preservation. While early fears about the creation of transgenic diseases that could cause human pandemics have not been realized, there remains the possibility that new transgenic viruses or antibiotic-resistant bacteria could be created through these processes, with dire consequences. The Torah commands Israel, "be very watchful of yourselves," ונשמרתם מאד לנפשתיכם, and this verse has been interpreted to convey special responsibility for preserving one's life from danger.[39]

The genetic modification of organisms raises thorny issues of identity. When the human genome is blended with the DNA of other species, what are the religious implications? The concept of נברא בצלם, humanity's creation in the divine image, is a cornerstone of Jewish belief; a doctrine of human exceptionalism is inherent in the ban on murder and the special responsibility to protect human life (though even the ancient sages were familiar with other species that resembled humans in one way or another).[40] Over the entire enterprise hangs the specter of eugenics, the quest to fashion an ever more perfect human species and to eliminate undesirable specimens, which was used to justify enormous evil in the past century.

While the new "consumer eugenics" is voluntary and does not involve killing people, there is a growing ability to screen fertilized eggs prior to implantation for various qualities, and also to "enhance" human abilities, both physical and intellectual. These issues were studied in Rabbi Mark Popovsky's 2008 responsum on preimplantation genetic diagnosis.[41] Rabbi David Golinkin addressed several of these concerns in a brief responsum, concluding that, "Jewish law supports

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[38] See, for example, "Gene Flow from Genetically Modified Rice to its Wild Relatives: Assessing Potential Ecological Consequences," by Bao-Rong Lu and Chao Yang in *Biotechnology Advances* (Nov.-Dec 2009) Vol. 27(6) 1083-1091. As the authors write, "Pollen-mediated gene flow is the major pathway for transgene escape from GM rice to its wild relatives." Other studies report that insect-mediated gene transfer may be an even larger vector for contamination of non-GM crops. These authors raise many questions, including, "fitness changes brought to wild relatives by the transgenes." It would seem that similar questions are relevant to the modification of animal DNA, as for example, in the case of the Aquabounty transgenic salmon. See http://aquabounty.com/.

[39] בבלי ברכות לב ע"ב.

[40] See discussion of the "siren" below. Mishnah Kilayim 8:5 mentions אדני השדה, "men of the field," human-like primates mentioned in M. Kilayim 8:5 (according to the comments of Hanokh Albeck there, אדם=אדן), that Rabbi Yosi considered to be human enough to convey ritual impurity. In his Mishnah commentary, Rambam derides this as a creation of fable-tellers. I thank Joshua Heller for drawing this text to my attention.

[41] Mark Popovsky, "Choosing our Children's Genes: The Use of Preimplantation Genetic Diagnosis," approved by CJLS in 2008 (10-2-4).

gene therapy that seeks to eliminate serious or fatal genetic diseases," but arguing that gene therapies employed for enhancement or eugenic purposes should be banned for ethical and theological reasons.[42] A new volume, *Jews and Genes: The Genetic Future in Contemporary Jewish Thought*, edited by Rabbi Elliot Dorff and Laurie Zoloth (JPS, 2015) includes 22 chapters by leading scholars, with an entire section dedicated to genetic engineering. We will refer to several of these essays below.

Genetic engineering raises questions about what is meant by terms such as illness and health, and what forms of intervention may be justified as medically necessary.[43] Positive halakhic values are also at play in this discourse, since genetic engineering holds the promise of improving human nutrition and general health, and we are obligated to feed the hungry,[44] heal the ill,[45] and to preserve human health.[46] Before we can turn to such broad mandates, we begin with the most direct halakhic concern, which is the Torah's prohibition on כלאים, the breeding of different species of plants and animals together.

II. *Kilayim*: The Ban on Interspecies Breeding

Biblical Texts

Chapter 19 of Leviticus begins with the statement that all of Israel should become holy, "for I the

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[42] Rabbi David Golinkin, *Responsa in a Moment*, *Even HaEzer 2:7*, "Does Jewish law permit genetic engineering on human beings?" This collection was published on 13 Sivan 5760 (June 16, 2000). It is noteworthy that Golinkin treats ethical and theological concerns as separate from "Jewish law," which he feels may nevertheless respond with a ban based on these external concerns.

[43] An outstanding essay on this subject was written by Ronald M. Green, "Curing Disease and Enhancing Traits: A Philosophical (and Jewish) Perspective," in *Jews and Genes: The Genetic Future in Contemporary Jewish Thought, ed.* Elliot N. Dorff and Laurie Zoloth (U of Nebraska Press/ JPS, 2015), pp.257-273. On his first page he provides Charles M. Culver's precise definition of what is meant by "disease," (though they prefer the somewhat archaic term "malady"): *A person has a malady if and only if he has a condition, other than his rational beliefs and desires, such that he is suffering, or is at increased risk of suffering, a harm or an evil—namely death, pain (physical or psychological), disability, loss of freedom or loss of pleasure—and there is no sustaining cause that is distinct from the person.* Green provides an extended analysis of this definition and its utility in determining whether a proposed gene therapy should be considered to be for purposes of medicine or enhancement.

[44] שולחן ערוך יורה דעה הלכות צדקה סימן רנ. כמה נותנין לעני, די מחסורו אשר יחסר לו. כיצד, אם היה רעב, יאכילוהו.

[45] טור יורה דעה הלכות ביקור חולים ורפואה ונוטה למות וגוסס סימן שלו. ע"כ בא ללמדנו שנתנה לו רשות לרפאות ומצוה היא ובכלל פיקוח נפש הוא והזריז ה"ז משובח ואם מונע עצמו ה"ז שופך דמים.

[46] רמב"ם הלכות דעות פרק ג. המנהיג עצמו על פי הרפואה, אם שם על לבו שיהיה כל גופו ואבריו שלמים בלבד ושיהיו לו בנים עושין מלאכתו ועמלין לצורכו אין זו דרך טובה, אלא ישים על לבו שיהא גופו שלם וחזק כדי שתהיה נפשו ישרה לדעת את ה', שאי אפשר שיבין וישתכל בחכמות והוא רעב וחולה או אחד מאיבריו כואב.

Lord your God am Holy."[47] Following the chapter's climactic verse 18, "love your neighbor as yourself," the foundation of Jewish interpersonal ethics, the Torah turns in v.19 to an apparently different concern, the mingling of species:[48]

> אֶת-חֻקֹּתַי תִּשְׁמֹרוּ בְּהֶמְתְּךָ לֹא-תַרְבִּיעַ כִּלְאַיִם שָׂדְךָ לֹא-תִזְרַע כִּלְאָיִם וּבֶגֶד כִּלְאַיִם שַׁעַטְנֵז לֹא יַעֲלֶה עָלֶיךָ׃
> *You shall heed my statutes: you shall not let your cattle mate with a different kind; you shall not sow your field with two kinds of seed; and clothing made of two kinds of yarn you shall not put on yourself.*[49]

These laws banning the interbreeding of different species of animals and plants, and even of wearing mingled garments, are perplexing, as is their dramatic location in Leviticus 19 under the headline, "you shall keep my statutes." The laws are restated in Chapter 22 of Deuteronomy, vs.9-11:

> (ט) לֹא-תִזְרַע כַּרְמְךָ כִּלְאָיִם פֶּן-תִּקְדַּשׁ הַמְלֵאָה הַזֶּרַע אֲשֶׁר תִּזְרָע וּתְבוּאַת הַכָּרֶם׃ (י) לֹא-תַחֲרֹשׁ בְּשׁוֹר-וּבַחֲמֹר יַחְדָּו׃ (יא) לֹא תִלְבַּשׁ שַׁעַטְנֵז צֶמֶר וּפִשְׁתִּים יַחְדָּו׃
> *9. You shall not sow your vineyard with a second kind of seed [else the fullness from the seed you have sown, and the yield of the vineyard, may not be used]. 10. You shall not plow with an ox and ass together. 11. You shall not wear cloth combining wool and linen.*

Each of the three regulations is modified by Deuteronomy. The prohibition of mixing seeds is extended (or perhaps limited) to the vineyard, and the produce of such forbidden mingling is itself forbidden; the unfamiliar term "*shatnez*" is explained as (or perhaps limited to) a blend of wool and linen; and, most surprisingly, the ban on *breeding* different species is transformed into a ban on *hitching* an ox and an ass to a single plow.

Ramban harmonizes Deuteronomy's ban on hitching the ox and ass together with Leviticus's prohibition of cross breeding by saying that farmers tend to house their plow team together in a

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[47] Israel Knoll argues in *The Sanctuary of Silence* (Fortress, 1995; Eisenbrauns, 2007), that the Holiness Source (HS or H) differs from the Priestly Source (PS or P) in extending the mandate to practice holiness beyond the realm of the priesthood and the sanctuary to extend to all of Israel. See esp. Chapter 4.

[48] While verse 19 appears to be a complete *non sequitur* from v.18, attention to the juxtaposition may clarify the meaning of כמוך, *as yourself*. Leviticus may be teaching that humans have a special responsibility towards members of their own species, and a related responsibility to preserve the distinction between other species of animals and plants.

[49] Translations of this and the following text from Deut. 22 are from Jacob Milgrom, *The Anchor Bible, Leviticus 17-22: A New Translation with Introduction and Commentary* (New Haven: Yale UP, 2000) 1657. Remaining translations are mine unless otherwise indicated.

single barn, which could lead to interspecies intercourse.[50] Modern Bible scholars, however, are not impelled to harmonize the texts. Jacob Milgrom explains the disparity between the two presentations as a conflict between the interests and contexts of the holiness source (H) and the Deuteronomist (D).[51] Perhaps, he speculates, in the interim between the composition of H and D, the use of mules had been introduced to the region, causing the modification of the law to allow for the use of these hybrids.[52] It is also possible (if far-fetched), as Michael Fishbane has surmised, that Deuteronomy's reference to "plowing" is a biblical-era euphemism for sexual intercourse, as found in the book of Judges, where Samson charges, לוּלֵא חֲרַשְׁתֶּם בְּעֶגְלָתִי לֹא מְצָאתֶם חִידָתִי, *"If you had not plowed with my heifer* [that is, his wife], *you would not have found out my riddle"* (Judges 14:18).[53] If so, then both traditional and modern scholars may find no practical difference between Leviticus and Deuteronomy, both of which prohibit interspecies breeding.[54]

Rabbinic Understandings of *Kilayim*: Grafting Plants

Leviticus instructs the Israelite not to "sow mixed seeds" in the field, but leaves uncertain what precisely is the problem. Rabbinic interpreters have argued that when different species of plants draw moisture from the same soil they may interfere with each other, and perhaps also cross-pollinate. This, of course, could happen even if different crops were planted in distinct rows or even fields. In the Mishnah, the sages dutifully prohibit blending crops in the field, but then focus on a more direct form of "mingling" known in the ancient world, המרכיב, the grafting of one plant's stem onto the rootstock of another plant, which is also known as כלאי האילן.

Grafting is prevalent in contemporary gardening and agriculture, and it also occurs naturally when the branches of two trees grow together. Gardening author Ken Druse explains the process:

> The branches squeeze tighter as they grow, until the cambium layers of both are exposed at the contact point. If the branches remain in place, the cells will knit together and may merge into a single limb. The horticultural process starts with a section of stem, called a scion that is surgically attached to a growing plant, called

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[50] רמב"ן ויקרא פרק יט (יט) ...ואסור לחרוש בשור ובחמור, מפני שדרך כל עובד אדמתו להביא צמדו ברפת אחת ויבאו לידי הרכבה:

[51] Milgrom, *Leviticus 17-22*, p.1658.

[52] Midrash Sifra prohibits the cross-breeding not only of "pure" species but also of "impure" species such as the horse and the donkey. This, Milgrom notes, is in contrast to the Qumran sect, which in a reconstructed text of MMT (מקצת מעשי תורה) B 75-82, limits the prohibition to "pure" species.

[53] Michael Fishbane, *Biblical Interpretation in Ancient Israel* (Clarendon Press, 1985) 59, n.38, cited in Milgrom, *Leviticus 17-22*, p. 1658f.

[54] Nevertheless, rabbinic sources prohibit the hitching of different animal types to one yoke (See M. Kilayim 8:2-6).

the understock or the rootstalk.[55]

Druse adds that grafting conveys many advantages, from speeding the process of producing salable fruits to the imparting of disease resistance or winter hardiness from the understock to the scion. Nearly every apple eaten today comes from a grafted tree and, as he explains, it is even possible to graft a different variety of apple onto each branch of a single tree. Likewise, nearly all grapes produced for winemaking are the result of cuttings, grafting or layering.[56]

Ancient grafting techniques were presumably distinct from some of today's methods, but the basic principles were similar. Tractate Kilayim discusses (and prohibits) grafting in chapter one, Mishnah 7 and 8 (Soncino translation):

> משנה ז. אין מביאין אילן באילן ירק בירק ולא אילן בירק ולא ירק באילן ר' יהודה מתיר ירק באילן :
>
> *7. It is not permitted to graft from one tree to another, or from one herb to another, or from a tree to a herb, or from a herb to a tree. R. Judah permits it from an herb to a tree.*

> משנה ח. אין נוטעין ירקות בתוך סדן של שקמה אין מרכיבין פיגם על גבי קדה לבנה מפני שהוא ירק באילן אין נוטעין יחור של תאנה לתוך החצוב שיהא מקירו אין תוחבין זמורה של גפן לתוך האבטיח שתהא זורקת מימיה לתוכו מפני שהוא אילן בירק אין נותנין זרע דלעת לתוך החלמית שתהא משמרתו מפני שהוא ירק בירק:
>
> *8. It is not permitted to plant herbs in a trunk of a sycamore. It is not permitted to graft rue on white cassia, since that is [grafting] an herb on a tree. It is forbidden to plant a young fig-shoot in a cistus shrub for the purpose of providing shade for the latter, or to insert a vine-shoot into a melon in order that the latter might contribute its moisture to the former, since that is [grafting] a tree on an herb. It is prohibited to place gourd seed into the juice of a mallow for the purpose of preserving the former, since that constitutes [grafting] an herb on a [heterogeneous] herb.*

There is no Babylonian Talmud to Tractate Kilayim (though as we will see, this subject is discussed in B. Kiddushin 39a). The Yerushalmi discusses grafting as follows:

> מניין שאין מרכיבין עץ סרק על גבי עץ מאכל ולא עץ מאכל על גבי עץ מאכל מין בשאינו מינו מניין תלמוד לו' את חקותי תשמורו ר' יונה ר' לעז' בשם כהנא דר' לעזר היא משום חוקים שחקקתי בעולמי

[55] Ken Druse, *Making More Plants: The Science, Art and Joy of Propagation* (New York: Clarkson Potter Publishers, 2000) 173.

[56] See http://en.wikipedia.org/wiki/Propagation_of_grapevines.

מעתה אסור לאדם הראשון ר' יוסי בשם רבי הילא דברי הכל היא משום חוקים שחקקתי בעולמי מעתה אסור להרכיב תאינה שחורה על גבי תאינה לבנה.[57]

How do we know that one may not graft a barren tree onto a fruit tree, nor a fruit tree onto a fruit tree of a different species? Because it [the Torah] states: Guard my statues. R' Yonah [quotes] R' 'Lazar in the name of Kahana: It is in accord with R. 'Lazar's saying—"the statutes—are those that I have established in My world." Henceforth it is forbidden [to blend species] since Adam the First. R' Yosi in the name of Rabbi Hila [says], all agree that [the prohibition derives from the word] "statutes" that I have established in my world. Henceforth it is forbidden to graft a black fig [tree] onto a white fig [tree].[58]

The Yerushalmi here is quite prohibitive, banning not only the mingling of different fruits but even the grafting of varieties of the same fruit, e.g. dark and light figs. The parallel text in Midrash Sifra, Kedoshim 2:17, does not include Rabbi Hila's extension of the ban to grafting varieties of the same fruit, but offers an unqualified ban on grafting in general:

(יז) מנין שאין מרכיבים עץ סרק על גבי עץ מאכל ולא עץ מאכל על גבי עץ סרק ולא עץ מאכל על גבי עץ מאכל תלמוד לומר את חוקותי תשמורו.

What is the source for prohibiting the grafting of a barren tree upon a fruit-bearing tree, or a fruit bearing tree upon a barren tree or a fruit bearing tree upon a fruit bearing tree? This is taught by the verse, "guard My statutes."

The sages are apparently not concerned with the grafting of a non-fruiting tree upon another non-fruiting tree, and indeed, Rambam limits the ban of כלאי זרעים, horticultural blending, to edible fruits and vegetables, explicitly permitting such mixed-sowing for medicinal purposes:

אין אסור משום כלאי זרעים אלא הזרעים הראויין למאכל אדם, אבל עשבים המרים וכיוצא בהן מן העיקרין שאינן ראויין אלא לרפואה וכיוצא בהן אין בהן משום כלאי זרעים.[59]

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[57] תלמוד ירושלמי (ונציה) מסכת כלאים פרק א דף כז טור א /ה"א.

[58] The line of tradition here is rather confusing, and I thank Richard Kalmin of JTS for clarifying it for me. The *amoraim* R' Yonah and R' Lazar are here citing a Babylonian *amora* named Kahana (who was not ordained), who in turn cites the *tanna*, R' Lazar. R' Yossi cites Rabbi Hila to say that this statement was shared by all of the *tannaim*. Still, the two versions of the expression diverge after מעתה אסור, making it seem that the tannaitic statement was limited to the first three words. That might explain why the Bavli cites this tradition in the name of Shmuel—he was expanding upon the three-word tannaitic statement that was "said by everyone." The opening question is also somewhat ambiguous; its three clauses could be read sequentially, or the third phrase could modify the second. I accept Jeremy Kalmanofsky's preference for the latter reading.

[59] רמב"ם הלכות כלאים פרק א, הלכה ד.

The prohibition on mixed seeds is limited to species fit for human consumption, but bitter grasses and such from roots which are not fit except for [eating, but only for] medicine, and similar [plants] are not included in the ban on mixed seeds.

Rambam's limitation of the ban to human edibles draws the objection of his commentators, starting with Rabbi Yosef Karo in Kesef Mishneh. He is "surprised" by Rambam's claim in light of the Mishnah and Yerushalmi's broader statements that would ban any mingling of crops, even for animal fodder, and in turn limits Rambam's permission to blended bitter grasses that have no nutritional value for either people or domesticated animals.[60] Nevertheless, Rabbi Karo reiterates Rambam's ruling nearly word for word in his Shulhan Arukh.[61]

While halakhic sources ban the sowing of seeds in the field and the grafting of trees, it is only *the action, not the product*, which is banned. Rambam states this clearly in Halakhah 7:

הזורע זרעים כלאים וכן המרכיב אילנות כלאים אף על פי שהוא לוקה הרי אלו מותרין באכילה ואפילו לזה שעבר וזרען שלא נאסר אלא זריעתן בלבד, ומותר ליטע ייחור מן האילן שהורכב כלאים ולזרוע מזרע הירק שנזרע כלאים.

Although a person who sows mixed seeds, and also one who grafts mixed species of trees is to be lashed, nevertheless their [fruits] are permitted for consumption, even for the very person who transgressed and sowed them, for the only prohibition is in their sowing. And it is permitted to plant a shoot [i.e. a cutting] from the grafted tree and to sow from the seed of a plant that was cross-sown.

Rabbi Karo accedes to this ruling in Beit Yosef YD 295:7, citing the Rosh and the Yerushalmi itself to permit use of the produce of grafting both for consumption and for replanting.[62] Grafting trees is considered to be biblically banned, but enjoying their produce is permitted. The one exception, based on the verse in Deuteronomy and formulated as a unique prohibition by the rabbis, is כלאי הכרם a ban on enjoying the fruit of grafted vines, even outside Israel.[63]

It is not evident why the rabbinic sages were so lenient in permitting benefit (הנאה) from the produce of forbidden hybrids. After all, the sages forbade benefit from *hametz* owned by a Jew on

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[60] כסף משנה הלכות כלאים פרק א. לכן נ"ל דלאו דוקא נקט רבינו מאכל אדם אלא כל דבר שרוצה בקיומו אסור זה בזה ואפי' אם רוצה בקיומו למאכל בהמה ולא נתכוון רבינו לשלול אלא העשבים המרים בלבד וכדדייק סיפא דלישניה ודין זה נ"ל שלמד רבינו ממה שאמרו בירושלמי בריש כלאים גבי זונין:

[61] שולחן ערוך יורה דעה הלכות כלאי זרעים וכלאי בהמה סימן רצז. אין אסור משום כלאי זרעים אלא הזרעים הראויין למאכל אדם, אבל עשבים המרים וכיוצא בהם, מן העיקרים שאינם ראויים אלא לרפואה וכיוצא בהן, אין בהן משום כלאי זרעים.

[62] בית יוסף יורה דעה סימן רצה אות ז ד"ה ואסור לקיים. ומותר ליקח ענף מן המורכב ולנטעו במקום אחר. כן כתב הרמב"ם והרא"ש (שם) והוא ירושלמי בפרק קמא דכלאים (ה"ד) תני גוי שהרכיב אגוז על גבי פרסק אף על פי שאין ישראל רשאי לעשות כן נוטל ממנו יחור והולך ונוטע במקום אחר:

[63] בית יוסף יורה דעה סימן רצה. וכתב הרא"ש (כלאים סו"ס א) נמצא דין כלאים עכשיו בחוצה לארץ נחלק לג' חלקים הרכבת אילן מדאורייתא כלאי הכרם מדרבנן כלאי זרעים מותר:

Passover (M. Pesahim 2:2), libation wine acquired from an idolater (M. AZ 5:10), meat mixed with milk (M. Hulin 8:4) and many other products of ritually forbidden activities.[64] It is possible that the Torah's phrasing of these prohibitions, which focus on the act rather than the result, is the reason, but perhaps the sages were simply being realistic. They had no certain method for identifying the provenance of produce in the market. If they were to declare all vegetables and grains that were grown in mingled plots to be forbidden, and likewise were to ban all grafted fruits, they would essentially be cutting themselves off from the food supply of their region. The sages suspected the local population of neglecting their tithes, but such doubts could always be addressed by re-tithing purchased produce. But if the fruits of *kilayim* were forbidden, there could be no remedy for them. Mishnah Shekalim 1:2 attests to the prevalence of transgressors of the rules of *kilayim*, and perhaps this explains why the sages chose to forbid the act of mingling, and to use their influence to disrupt such practices, but not to go so far as to ban the produce.

Rambam and the later codifiers go into extraordinary detail on gardening techniques for keeping different species apart, even when attempting to grow a diverse crop in a small plot. In chapter 3 of MT Kilayim, he discusses plants that look similar but are of different species, which must be kept distinct, and others that look different but are in fact related and may be mingled. He explains that the unique qualities of the plot (today known by the French term *terroir*) and cultivation techniques can produce different forms from the same species. Though they look distinct, they may be sown together.[65] Some plants are best identified by their fruit, others by their leaves and yet others by their flowers. These details indicate the intimate knowledge that our sages had of botany, yet the details are not essential for our inquiry. Their overarching concern was *to prevent the blending of different species*, whether of plants or of animals.

Despite Shmuel's statement in B. Kiddushin 39a (see below) forbidding all forms of *kilayim* in both the land of Israel and abroad, halakhic codes limited the prohibition of mixing seeds in the field and vineyard to the Land of Israel, reading the biblical words שדך and כרמך, "your field" and "your vineyard" restrictively. They may also have been influenced by the closing words of the Mishnah in Tractate Orlah (3:9), החדש אסור מן התורה בכל מקום והערלה הלכה והכלאים מדברי סופרים, *"New grain is biblically forbidden in every place, and orlah-fruits are forbidden [outside Israel] in a tradition [back to Moses], and kilayim are forbidden [outside Israel] according to the sages."* In his Mishnah commentary there, Rambam explains that because grapes produced from vines that have been grafted onto a rootstock of a different species are forbidden even for sale (בהנאה) in Israel, the

[64] עיין אנציקלופדיה תלמודית, כרך ב, אסורי הנאה [עמוד צב טור 2].

[65] רמב"ם הלכות כלאים פרק ג. יש מינין בזרעין שיהיה המין האחד נפרד לצורות הרבה מפני שינוי מקומות והעבודה שעובדין הארץ עד שיראה כשני מינין ואף על פי שאין דומין זה לזה הואיל והן מין אחד אינן כלאים זה בזה.

sages were strict in adding a ban on the grafting of grapes abroad.[66] Nevertheless, the grafting of different species of trees, and interspecies breeding of animals, neither of which is restricted by the Torah to "your field" or "your vineyard," are prohibited biblically both in Israel and abroad according to all of the codes. Thus while Shmuel's claim for the universal application of *kilayim* within and without the land was not accepted, the established halakhah maintains a broad prohibition, whether rabbinic or biblical in force, of most forms of *kilayim*, with the exception of mixing seeds in the field, which is permitted abroad.[67]

Cross-Breeding Animals

Chapter 8 of Mishnah Kilayim focuses on the mingling of animals, and itself mingles the respective concerns of Leviticus and Deuteronomy, namely breeding different species together, and also hitching different species together as beasts of burden. The Yerushalmi (Kilayim Ch. 8, Halakha 2) asks whether it should be forbidden to house males and females of different species near one another, lest they mate, but concludes that the verse forbids only actively causing them to mate. Rambam (9:1) provides an explicit image that is restated by the later codes: ואינו לוקה עד שיכניס בידו כמכחול בשפופרת, אבל אם העלם זה על זה בלבד או שעוררן בקול מכין אותו מכת מרדות, *he is not lashed unless he inserts [the male's organ] with his hand like a kohl applicator into its tube, but if he mounted them onto one another or encouraged them with his voice then he is [only] lashed for rebelliousness [against the sages, but not for violating the biblical decree].*

As with the fruit of mixed plants (other than grape vines), the progeny of mixed animal breeds are permitted for subsequent enjoyment and, in the case of "pure" species, sacrifice and consumption. When it comes to the offspring of mixed-species parents, the one prohibition is not to cross-breed them for a second generation. What then is one to do with such mixed breeds? Rambam rules (at 9:6, reflecting Mishnah Kilayim 8:5) that the identity of the mother is determinative. Thus a mule that has a donkey for its mother and a horse for its father may be bred with a donkey, but not with a horse. If one is uncertain of the pedigree of the animal, then checking its ears, tail and voice will suffice to determine if it is suitable for breeding with another animal (that shares these characteristics). These rulings are restated by Rabbi Yaakov b. Asher in Tur, Yoreh Deah 297 and by Rabbi Karo in the Shulhan Arukh.[68]

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[66] In the production of kosher wine in Israel, the ban on grafting is understood to apply only to the grafting of a grape vine onto the rootstock of a different species of tree, not to the grafting of one grape variety upon another.

[67] See Rambam (MT Kilayim 1:1 and 1:5), with Kesef Mishneh, and R' Karo (SA YD 295:1 and 296:1) with Levush and Biur HaGr"a.

[68] R' Karo needs to start a second series of paragraphs within YD 297 to accommodate the great quantity of regulations for *kilayim*. This one appears at 297:9'.

While the codifiers were intent upon reinforcing the Torah's prohibitions on cross-species breeding, as with vegetables, they were rather lenient in permitting the use of the mixed progeny. Perhaps they were convinced that such animals are generally sterile (as Ramban comments at Lev. 19:19), or believed that the total number of species has remained constant since the time of creation. Again, they may also have been realistic about how much control they could hope to exert on animal husbandry, and the great difficulties that would ensure if only "pure breed" sheep, goats and cows were permitted to their followers. Nevertheless, the rabbis understood their role to be the prevention of activities banned by the Torah to the best of their abilities. Before we extrapolate from these pre-modern prohibitions to the remarkable innovations of biotechnology it is necessary to explore the theological underpinnings of the halakhic ban on *kilayim*.

III. The Significance of Species: Theological and Scientific Perspectives

What was the Torah's objection to the cross breeding of plants and animals and also to the blending of wool and linen cloths? The text does not state its rationale, but the headline of אֶת-חֻקֹּתַי תִּשְׁמֹרוּ "Heed my statutes," and the situation of this text within the great holiness code of Leviticus 19 has led generations of interpreters to discern a cosmic concern in these regulations. The first-generation Babylonian Amora, Shmuel,[69] is cited at B. Kiddushin 39a:

> דאמר שמואל: את חקתי תשמורו חוקים שחקקתי לך כבר, בהמתך לא תרביע כלאים שדך לא תזרע - מה בהמתך בהרבעה, אף שדך בהרכבה; ומה בהמתך נוהג בין בארץ בין בח"ל, אף שדך נוהג בין בארץ בין בח"ל.
>
> *As Shmuel taught, "guard my statutes" means, the statutes that I have enacted for you already [i.e. before Sinai]: do not cross-breed your cattle, and do not [mingle species] in your field. Just as [it is forbidden] to cross-breed your cattle, so [it is forbidden] to graft species in your field. And just as [the prohibition regarding] your cattle applies whether in the Land of Israel or abroad, so too does [the prohibition] regarding your field apply whether in the Land of Israel or abroad.*[70]

That is, the Creator has determined the development of plant and animal species, and thereafter humans may not modify them, whether by cross-breeding or by grafting, whether in Israel or abroad. The idea that חֻקֹּתַי, "My statutes," alludes to a cosmic order is reinforced by a verse from Job, הֲיָדַעְתָּ חֻקּוֹת שָׁמַיִם אִם-תָּשִׂים מִשְׁטָרוֹ בָּאָרֶץ, *"Do you know the statutes of heaven? Can you establish its*

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[69] As we have seen, Shmuel's saying is repeated in B. Sanhedrin 60b, but the expression חוקים שחקקתי is stated in the name of a different chain of sages in Yerushalmi Kilayim; in his Torah commentary to Leviticus 19:19, Ramban ascribes the saying to R. Pinhas in the name of R. Hanina, who do appear on the same page of the Yerushalmi, but regarding a different subject; perhaps Ramban was working from memory and misattributed the expression, or perhaps he had a different text of the Yerushalmi.

[70] Shmuel's universal application of *kilayim* abroad is not accepted as the halakhah.

dominion on earth?"(38:33). In Midrash Bereshit Rabba Rabbi Simon claims, אין כל עשב ועשב שאין לו מזל ברקיע שמכה אותו ואומר לו גדל ה"ה הידעת חוקות שמים אם תשים משטרו בארץ, *"There is no single grass which lacks a heavenly patron that goads it and says, 'grow!' This is the meaning of the verse, 'Do you know the statutes of heaven? Can you establish its dominion on earth?'"*[71]

Even a simple reading of the Torah reveals the conviction that observing divine statues leads to blessing, whereas violation of the divine order leads to devastation. Leviticus 26:3-4 states:

> (ג) אִם-בְּחֻקֹּתַי תֵּלֵכוּ וְאֶת-מִצְוֹתַי תִּשְׁמְרוּ וַעֲשִׂיתֶם אֹתָם: (ד) וְנָתַתִּי גִשְׁמֵיכֶם בְּעִתָּם וְנָתְנָה הָאָרֶץ יְבוּלָהּ וְעֵץ הַשָּׂדֶה יִתֵּן פִּרְיוֹ:
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> 3. *If you walk in my statutes, and keep my commandments, and do them;* 4. *Then I will give you rain in due season, and the land shall yield her produce, and the trees of the field shall yield their fruit.*

Midrash Vayikra Rabba understands this verse, in light of other verses from Jeremiah and Proverbs, to mean that there is a "natural order" to creation—God creates the celestial bodies, the sea, the sand and the depths all with a specific design.[72] The combination of respecting natural law and observing the mitzvot will ensure blessing for the world and for Israel.

This theme is greatly developed in the Jewish mystical tradition, which views human conduct as playing a direct role in supporting or interrupting the flow of blessing from heaven into the world. The Zohar (*Kedoshim*, III: 86b) builds upon Rabbi Simon's statement in Bereshit Rabba, concluding:

> ועל דא כתיב את חקותי תשמרו בגין דכל חד וחד ממנא על מלה ידיעא בעלמא בההוא חק, ובגין כך אסיר למחלף זינין לאעלא זינא בזינא אחרא בגין דאעקר לכל חילא וחילא מאתרייהו ואכחיש פמליא דלעילא, ואכחיש פומבי דמלכא.
>
> *Thus it is written huqqotai, My statutes you shall keep. [Your cattle you shall not mate kilayim with a different kind; your field you shall not sow kilayim, with two kinds; two kinds of threads—shatnez--shall not come upon you] (Lev. 19:19)—because every single one is appointed over a specific object in the world by that hoq. Consequently, it is forbidden to switch species, to insert one species into another, because one thereby uproots each power from its place and negates the celestial family, falsifying the royal solemnity.*[73]

The Zohar here warns of the dire consequences of creating new species; they disrupt the harmony

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[71] בראשית רבה (תיאודור-אלבק) פרשת בראשית פרשה י ד"ה וכל צבאם אמר.

[72] ויקרא רבה (מרגליות) פרשת בחוקותי פרשה לה [ד]. ד"א אם בחוקותי תלכו, חוקים שחקקתי בהם את השמים ואת הארץ, אם לא בריתי יומם ולילה חוקות שמים וארץ לא שמתי (ירמיה לג, כה). חוקים שחקקתי בהן את השמש ואת הירח, שנ' כה אמר י"י נותן שמש לאור יומם חקות ירח וכוכבים לאור לילה (שם /ירמיהו/ לא, לד). חוקים שחקקתי בהן את הים, בשומו לים חקו (משלי ח, כט). חוקים שחקקתי בהן את החול, אשר שמתי חול גבול לים חק עולם לא יעברנהו (ירמיה ה, כב). חוקים שחקקתי בהן את התהום, בחוקו חוג על פני תהום (משלי ח, כז), חוק וחוג לגזירה שוה.

[73] Translation by Daniel Matt, *The Zohar: Pritzker Edition*, Volume 8 (Stanford UP, 2014), pp.39-40. See notes 115, 116 and 117.

of heaven and earth.

Writing in the same era, as we have seen, Ramban argues at Leviticus 19:19 that for humans to breed new species would be to imply deficiency in the divine creation and thus in the Creator.[74] Rabbeinu Bahya restates this concern (31:2). Moreover, hybrid progeny such as mules are, Ramban observes, generally incapable of reproducing themselves, and ultimately undermine the preservation of species ordained by God.[75] Rabbinic texts from the classical and medieval period thus support the idea that the mitzvah of *kilayim* is a shield for the cosmic order. The identification of this mitzvah as a statute, a חוק, is not meant to strip it of apparent reason, but rather to invest it with ultimate significance.

While Ramban's perspective is in harmony with midrashic and mystical texts, there are, as always, different currents within the stream of Torah. Midrash Bereshit Rabba encapsulates the tension between viewing the natural world bequeathed by God to be perfect, while simultaneously assigning humanity the responsibility to improve life.[76] In Parashah 12:1, the midrashic voice mocks the idea of "improving" on the human form by adding a third eye or leg, and then concludes, "*As it were, God takes pride in His world, saying, look at this creature that I have created, and this shape that I have formed,*" כביכול הקדוש ברוך הוא מתגאה בעולמו ואומר ראו בריה שבראתי וצורה שצרתי.[77] But in Parashah 11:6, a midrash defending the need for circumcision to "repair" the male body argues, "*Everything that was created in the six days of creation requires further labor—just as mustard needs sweetening, and lupine needs sweetening, and wheat needs to be ground, so too does man need to be repaired,*" כל מה שנברא בששת ימי בראשית צריכין עשייה, כגון החרדל צריך למתוק, התורמוסים צריך למתוק, החיטין צריכין להטחן, אפילו אדם צריך תיקון. Do the sages conceive of the world as perfect, and

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[74] והמרכיב שני מינין, משנה ומכחיש במעשה בראשית, כאילו יחשוב שלא השלים הקדוש ברוך הוא בעולמו כל הצורך ,ויחפוץ הוא לעזור בבריאתו של עולם להוסיף בו בריות.

[75] Ramban discusses his concern with species preservation elsewhere. See his comments to Genesis 1:11, and also to Deut. 22:6, regarding the commandment to send away the mother bird which, like the ban on sacrificing two generations of an animal family in one day, he understands to be motivated in part by species preservation (in addition to being cruel):
רמב"ן דברים פרק כב פסוק ו (ו) כי יקרא קן צפור לפניך - גם זו מצוה מבוארת מן אותו ואת בנו לא תשחטו ביום אחד (ויקרא כב כח). כי הטעם בשניהם לבלתי היות לנו לב אכזרי ולא נרחם, או שלא יתיר הכתוב לעשות השחתה לעקור המין אף על פי שהתיר השחיטה במין ההוא, והנה ההורג האם והבנים ביום אחד או לוקח אותם בהיות להם דרור לעוף כאלו יכרית המין ההוא :

[76] Midrash Bereshit Rabba, *Parashat Bereshit*, 11:6 and 12:1 in the Vilna edition. The first text also appears in a variant form in Theodore-Albeck, 11:2. I credit and thank Avram Reisner for noticing this dichotomy and its significance for our subject. See also the parallel text in Sifre Devarim, *Ha'azinu*, Piska 307.

[77] These words, cited from the Vilna ed. of 12:1, are absent in Theodore-Albeck, who surmise (Vol. 1, p. 99, note 3) that they were an addition to the printed edition, influenced by Kohelet Rabba 2:1(11):
א"ר יצחק בר מריון כתיב (בראשית א) ויצר ה' אלהים את האדם מה ת"ל אשר יצר אלא הצור הוא צייר נאה כביכול מתגאה בעולמו ואומר ראו בריה שבראתי וצורה שציירתי.

the responsibility of humanity to preserve it as is, or is God's creation just the beginning, with the role of humanity being to extend and improve life? Despite the piety of the former position, it is the second view that has become normative.

Rabbi Judah Loew, the Maharal of Prague (c.1520-1609), comments in *Be'er HaGolah* on a *beraita* found in B. *Pesahim* 54a.[78] There Rabbi Yosi claims that God conceived of two additional creations just before the first Shabbat, but did not complete them. Rather, at the end of Shabbat God gave Adam the idea to make them. The first task was to create fire from stones, and the second was the method for cross-breeding two species (i.e. a horse and a donkey) to create a mule.[79] The Maharal views these two actions as symbolic of the human role in completing God's creation, השלמת העולם. While the creation of fire is an obvious benefit to extend the sight of humans in the dark, and is indeed deserving of blessing as part of the weekly *havdalah* ritual, the creation of a mule is forbidden by the Torah. Yet the Maharal develops a nuanced idea that posits God's separate agendas for humanity and for Israel. Humanity has an *obligation* to create new species such as the mule, because it is possible, even though Israel is forbidden to do so:

> ומה שהם תמהים על הרכבת שני מינין, בודאי לפי התורה שנתן הקדוש ברוך הוא לישראל הדבר הוא אסור משום כלאים (ויקרא יט, יט). אבל אדם הראשון היה עושה דבר זה, כי הדבר הזה ראוי שיהיה בעולם, עד שיהיה נשלם העולם. ואף כי לפי התורה שנתן השם יתברך דבר זה אסור מפני שהוא כלאים, דרך התורה לבד. וכמה מינים שנברא בעולם והתורה אסרם באכילה, ועם כל זה נבראו בעולם, שבהם יושלם העולם. ואין איסור כלאים משום ערוה וזנות, שהרי אסרה התורה אף להנהיג אותם ביחד, ומזה תראה כי איסור כלאים הוא משום שאין לחבר המינים המחולקים יחד, וזה דרך התורה. וכבר אמרנו דרך התורה בלבד, והשלמת העולם לבד.
>
> As for those who are surprised by [God's instruction to Adam for] grafting of two species, certainly according to the Torah given by the Holy One to Israel this practice is forbidden as *kilayim* (Lev. 19:19). But Adam the First was to do this act, because this [new species] deserved to be in the world, so that the world would be completed. And even though the Torah that the blessed God gave forbids this [mixing] as *kilayim*, this is only according to the way of Torah. There are many species that were created in the world, and the Torah forbade [Jews] from eating them, and yet they were made in the world to complete the world. And the prohibition of *kilayim* is not a matter of sexual perversion, for the Torah also prohibited plowing with them together. This indicates that the prohibition of *kilayim* is only about [not] joining two separate species together, according to the way of Torah. And we have already explained that the way of Torah is one thing, and the completion of the world is another.

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[78] ספר באר הגולה באר השני פרק י.

[79] תלמוד בבלי מסכת פסחים דף נד עמוד א. דתניא, רבי יוסי אומר: שני דברים עלו במחשבה ליבראות בערב שבת ולא נבראו עד מוצאי שבת, ובמוצאי שבת נתן הקדוש ברוך הוא דיעה באדם הראשון מעין דוגמא של מעלה, והביא שני אבנים וטחנן זו בזו ויצא מהן אור. והביא שתי בהמות והרכיב זו בזו ויצא מהן פרד.

Maharal finds evidence here of a dual agenda for the world. Israel is prohibited from mixing seeds to form new hybrids. Yet, the Creator wants the world to be "completed" with creatures beyond the initial creation, and thus empowers humanity to play a role in the extension of life. It is perhaps not surprising that the Maharal is credited with the most dramatic Jewish legend of the extension of life, the creation of his "golem" in Prague. The Maharal establishes a counterweight to Ramban's theology of restraint; God wants humans to complete the world, which was "created for making," ברא לעשות. This also accords with the perspective of Psalm 8, cited at the beginning of this responsum, which proclaims that God has made humanity "little less than divine," with stewardship over all life, and concluding that human mastery expands the glory of God's name across the earth.

There is something rather modern about Maharal's concept, and indeed he has been cited by Rabbis Byron Sherwin, J. David Bleich, and Avram I. Reisner in arguing for a broad mandate to permit genetic engineering.[80] Yet, it remains true that the Torah bans interspecies breeding, and the halakhic codes will extend the ban to not allowing a Jew to hire a non-Jewish breeder to mingle species of animals.

As we explore the theological implications of Jewish texts regarding mingling species, a certain level of cognitive dissonance is unavoidable. All of our pre-modern sources, and even some contemporary rabbinic sources, accept the creation narrative in Genesis, in which each species of plant and animal was created (as Darwin describes this view, "separately created"[81]) "in the beginning," and they have remained more or less constant as part of the divine plan. Even Maharal's idea of a human role in expanding the animal kingdom seems to have been a "plus one" concept in order to develop the divine-human partnership. None of these sages anticipated the modern concept of evolution, in which all life forms mutate in reproduction, with species evolving throughout their generations in response to the competitive environment within which they live. The sages were not aware of the mass extinctions (other than in the story of Noah's flood, and even there they claimed a perfect survival rate) that are part of earth's natural history

[80] Byron L. Sherwin z"l, "Golems in the Biotech Century," in *Zygon: Journal of Religion and Science,* Vol. 42:1 (Mar. 2007), pp.133-144; J. David Bleich, "Genetic Engineering" in *Tradition: A Journal of Orthodox Jewish Thought*, Vol. 37:2 (Summer 2003), pp.66-87. See esp. p.70. Bleich cites Maharal at Be'er Ha'Golah 2:3, but the relevant text is found at 2:10 in the Bar Ilan collection (Version 21). We return to Bleich's understanding below. Avram Reisner (1997, n.24) cites this text by way of Michael Broyde, writing in *The Journal of Halacha and Contemporary Society* #34, p.64.

[81] See *The Origin of Species*, p. 499.

(and of humanity's recent unnatural history).[82] Why then bother with the views of our ancestors on matters of biology?

Some contemporary apologists find hints of anticipation among our ancient sages of the discoveries of modern science, but such attempts are neither credible nor necessary. We read our ancient sources for their moral and theological ideas, and we construct normative practices in continuity with their teachings, combined with contemporary insights, for the sake of constructing a richer and more nuanced religious life. Whether or not Ramban or Maharal would have accepted Darwin's theory of evolution, their ideas regarding the religious significance of humanity's stewardship of the world remain cogent. Ramban teaches us to conserve species as a way of honoring the Creator; Maharal adds a religious value to human creativity in completing God's world.

One perspective that has largely been shared by religious and scientific thinkers since antiquity has been the belief that hybrids are generally sterile, and that the mixing of breeds is problematic in part because it creates a "dead end" in life. This opinion has been remarkably durable, counter-evidence notwithstanding. As noted above, in *The Origin of Species,* Charles Darwin dedicates an entire chapter (9) to hybridism, observing that hybrid plants and animals do not seem to suffer universal sterility and, in fact, hybrids may in some instances outperform their parent species. Moreover, Darwin does not see evidence of a sharp distinction between the categories of *species* and *variety*. These observations of his were largely ignored in the early twentieth century, when speciation tended to be viewed as an essential and permanent form of differentiation (a view that coincided in some cases with racialist abhorrence of human "miscegenation").

In recent decades, however, biologists have come to view naturally occurring hybridism as a common and often beneficial response to environmental challenges, allowing species to adapt to changed circumstances within a generation, far faster than is typically the case with random mutation and natural selection.[83] Reticulate evolution is another phenomenon in which lineages

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[82] The establishment of species extinction as a fact of natural history is credited to the French naturalist Georges Cuvier (1769-1832). For an overview of historical and contemporary extinction events, see Elizabeth Kolbert, *The Sixth Extinction: An Unnatural History* (NY: Henry Holt and Co, 2014).

[83] Again, see Peter R. Grant and B. Rosemary Grant, *Forty Years of Evolution: Darwin's Finches on Daphne Major Island* (Princeton and Oxford: Princeton UP, 2014), esp. chapters 8-10. This subject is discussed by Moises Velasquez-Manoff in "Should You Fear the Pizzly Bear? *The New York Times Magazine* (August 14, 2014). He attributes the characterization of species orthodoxy as informed by racial sentiment to Michael Arnold, who in turn faulted Darwin himself for denigrating "mixed-race" humans. See Jon Cohen, *Almost Chimpanzee: Redrawing the Lines That Separate Us from Them* (NY: Macmillan, 2010) p.37.

diverge and then recombine, which involves, "the processes of natural hybridization, horizontal transfer and viral recombination…and is now well established as having affected the origin and adaptation of organisms from all of the domains of life."[84]

Moreover, one of the newest fields of biological inquiry, epigenetics, shows that DNA alone is not determinative of gene expression. The environment within which an organism develops and its experience in life play enormous roles in its physical development down to the molecular level, mostly through a process known as DNA methylation.[85] Under the banner of "evodevo" (evolution and development), researchers are continuing to examine the complex relationship between inherited genes and their expression.[86] Species are not identical to their genomes; indeed the entire concept of species as an ontological category has been undermined by both biological and philosophical inquiry.[87]

Skepticism about the inherent traits of species is expressed already in the 12th century by Maimonides. He writes in his *Guide of the Perplexed* that, "no species exists outside of the mind, but that the species and the other universals are, as you know, mental notions and that every existent outside the mind is an individual or a group of individuals."[88] That is, discussion of "species" is a heuristic device, a means to describe individuals which share common traits, not an ontological claim about their essence. He does not deny here that which he affirms so consistently in his legal writings: distinctions between species must be maintained among plants and animals for *kashrut*, *kilayim*, *lulav*, *korbanot* and many other mitzvot.

All of our sages ultimately affirm the Torah's ban of *kilayim*, the mixing of different species of

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[84] "Reticulate Evolution and Marine Organisms: The Final Frontier?" by Michael L. Arnold and Nicole D. Fogarty. *Int J Mol Sci*. 2009 Sep; 10(9): 3836–3860. Published online 2009 Sep 3. doi: 10.3390/ijms10093836.

[85] For an introduction, see the Wikipedia article: http://en.wikipedia.org/wiki/DNA_methylation, and also, "Unique epigenomic code identified during human brain development," published on July 3, 2013, at *Science Daily*: http://www.sciencedaily.com/releases/2013/07/130705102037.htm

[86] For example, see Frances A. Champagne, "Interplay Between Social Experiences and the Genome: Epigenetic Consequences for Behavior," in *Advances in Genetics 77* (2012), and also "Transgenerational Inheritance in Mammals," by Isabelle M. Mansuy, Rahia Mashoodh and Frances A. Champagne, chapter 13 in *Epigenetic Regulation in the Nervous System* (Elsevier Inc, 2013). I thank Robert Pollack of Columbia University for sharing these articles with me.

[87] See article, "Species," in the *Stanford Encyclopedia of Philosophy*. I thank Alan Mittleman of JTS for sharing this source and discussing this topic with me.

[88] Maimonides, *The Guide of the Perplexed*, trans. Shlomo Pines (Chicago: U of Chicago Press, 1963), Section III, chapter 18. I thank Jeremy Kalmanofsky for pointing me to this text and explaining its significance within Rambam's theory of individual providence.

plants and of animals. What, in their mind, was so wrong with such hybrid beasts? Little is said by the ancient sources to explain this abhorrence, but modern Bible scholars view something deeply symbolic at stake in this passage of the Torah banning the mixing of species. Jacob Milgrom notes that the cherubim were described as hybrids, with human faces and birds' wings (Exodus 25:20, 37:9), and that they guarded access to sacred zones such as the Garden of Eden (Gen. 3:24) and the Holy of Holies, where they were embroidered into the curtains (Ex. 26:1, 31), and stood guard over the Holy Ark (Ex. 25:18-22). Ezekiel describes hybrid beings with the four faces of a human, a lion, an ox and an eagle bearing the divine chariot (1:10). He also depicts the cherubim as accompanying God in the Temple and on journeys (9:3; 10:1-20; 11:22).[89] These hybrid creatures were heavenly beings that guarded the divine throne from encroachment.[90]

Milgrom argues (p.1661) that the regulation of *shatnez*, clothing that mingles linen and wool, is symbolic of the distinction between the sacred and the profane: "Israel is commanded to be holy, but is warned that it is not allowed the privilege of breeding different animals, sowing mixed seed, or wearing fabrics of mixed seeds [sic.]—for these are reserved for the sacred sphere and, in the case of clothing, to the priests." He notes that the lower cover of the tabernacle, the curtain of the holy of holies, and the costume of the high priest all included *shatnez*, as did the belt of the regular priest.[91] The Rabbis read the juxtaposition of the ban on *shatnez* in Deut. 22:11, and the command to attach tassels to one's garment in the very next verse to imply that *tzitzit* are the exception that proves the rule.[92] It is even possible that the *tzitzit*, or tassels commanded of the regular Israelite in Numbers 15:37-41, were also designed to be an intentionally blended garment,

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[89] See discussion in Benjamin Sommer, *The Bodies of God and the World of Ancient Israel* (Cambridge UP, 2009), pp. 87-88, 156-158.

[90] Many ancient cultures discussed fantastical hybrid creatures such as the Assyrian lamasu—giant statues of a beast with a bull or lion's body, eagle's wings and a human head--that guarded the entrances to cities and palaces. Homer's sirens featured a woman's upper body and voice, but had the feet of birds, and posed mortal danger to men (see *The Odyssey*, 12:52). The scene of Odysseus lashed to his ship's mast in order safely to encounter the sirens is surprisingly depicted in the famous mosaic floor of the ancient Beit Shean synagogue, as Columbia historian Seth Schwartz reminds me. Rabbinic literature refers to mermaids in several locations, such as Sifra to Shmini, Par.3 (according to Raavad's commentary), and especially in Rashi's explanation of the "*dolphinum*" on B. Bekhorot 8a, which he identifies with the siren (despite it being half fish rather than half bird): רש"י מסכת בכורות דף ח עמוד א ה"ג הדולפנין פרים ורבים מבני אדם שאם בא אדם עליהם מתעברות הימנו. בני ימא דגים יש בים שחציין צורת אדם וחציין צורת דג ובלע"ז שריינ"א.

[91] Note, however, Ezekiel 44:17, which commands that when the priests enter the inner court, they shall be clothed in linen garments, with no wool upon them. Rada"k notices the contradiction with Leviticus, and concludes that this must be an "innovation for the future" (*hidush l'atid*). Metzudat David seeks to harmonize the texts, claiming that Ezekiel is describing a non-officiating setting.

[92] דברים פרק כב, יא-יב (יא) לֹא תִלְבַּשׁ שַׁעַטְנֵז צֶמֶר וּפִשְׁתִּים יַחְדָּו: ס (יב) גְּדִלִים תַּעֲשֶׂה־לָּךְ עַל־אַרְבַּע כַּנְפוֹת כְּסוּתְךָ אֲשֶׁר תְּכַסֶּה־בָּהּ: עיין רש"י שם על סמך בבלי יבמות דף ד עמוד א.

shatnez, with three white cords of linen, and one woolen cord dyed blue.[93] If so, then these blended garments would remind all of Israel of the boundary between heaven, where life forms are blended, and earth, where distinctions must be maintained. Looking at the *tzitzit*, the Israelite is told that as in recalling all of the commandments, "you will not stray after your hearts and eyes, after which you lust." The maintenance of boundaries between species is central to the doctrine of holiness, and this may explain the placement of these regulations in chapter 19 of Leviticus (and also the interpolation of **פרשת ציצית** between the narratives of the twelve spies and of Korah's rebellion, when social order was suddenly in disarray).

Moreover, the Bible apparently considers the blurring of species distinction to be perilous to human life. Chapter 6 of Genesis relates with disapproval the mating of "divine beings" with the "daughters of men," which leads directly to God's decision to blot out life from the earth. Alan Cooper argues that the identification of Noah as **איש צדיק תמים היה בדורותיו**, literally, "a man who was innocent, perfect in his generations," (6:9) refers not to his moral strength relative to his contemporaries, but rather to his genealogy; Noah was from pure stock, not from one of the human/divine hybrids just described, and thus his line alone was worthy of salvation.[94] Rabbinic interpreters likewise believed that the great crimes that precipitated the flood included interspecies intercourse. Only those species that had maintained "their families" were deemed worthy of salvation.[95]

These texts are important for understanding the theological concerns of our ancestors regarding the mixing of species. Many of them are quite speculative, but they do yield values that are relevant to our consideration of modern biotechnology. They demonstrate awareness of the possibility and benefits of hybridized life forms but express anxiety about blurring the established boundaries of life. If this was true for ancient methods of breeding, one is tempted to say **על אחת כמה וכמה** (how much the more so!) in the contemporary laboratory. Nevertheless, we must not

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[93] See Israel Knoll's discussion of the *tztitzit* as symbolic of the expansion of holiness regulations to all of Israel in the Holiness Source (HS) in *The Sanctuary of Silence,* p. 186. It may be that wool was the only fabric that could be permanently dyed in ancient Israel, whereas linen was the whitest available fabric. Indeed, B. Yevamot 4b indicates that *tekhelet* is *always* to be made of wool: **תכלת עמרא הוא**.

[94] http://learn.jtsa.edu/content/commentary/noah/5774/why-did-god-flood-world

[95] עיין תלמוד בבלי מסכת סנהדרין דף קח עמוד א. כי השחית כל בשר את דרכו על הארץ, אמר רבי יוחנן: מלמד שהרביעו בהמה על חיה, וחיה על בהמה, והכל על אדם, ואדם על הכל. בראשית רבה (תיאודור-אלבק) פרשת בראשית פרשה כח ד"ה [מאדם עד בהמה. ר' עזריה בשם ר' יהודה הכל קילקלו מעשיהם בדור המבול, הכלב עם הזאב תרנגול עם הטווס ה"ה כי השחית כל בשר וגו' (בראשית ו יב). ובמיוחד מדרש תנחומא (בובר) פרשת נח סימן יא. כשם שפרע מן האדם שחטאו, כך פרע מן הבהמה והחיה והעוף, ומנין שנפרע מהם, שנאמר ויאמר ה' אמחה וגו' (שם /בראשית/ ו ז), וכל כך למה, ללמדך שאף הם ערבו משפחותיהם, והיו הולכין על מין שאינו שלהן, כל מין ומין על מין שאינו שלו, וקרא הקדוש ברוך הוא לנח ויאמר לו בחר לך בהמה וחיה ועוף [מאותן] שלא ערבבו את משפחותיהן, שנאמר מכל הבהמה הטהורה (שם /בראשית/ ז ב), טהורה כשם שנבראת, וכיון שיצאו מן התבה העיד עליהן הקדוש ברוך הוא שלא ערבבו משפחותם, שנא' למשפחותיהם יצאו (שם /בראשית/ ח יט).

assume that new technologies match old prohibitions. Rather, we must carefully consider the legal and moral ramifications of each new technology before determining the proper halakhic ruling.

IV. A Values-Informed Halakhic Analysis

When it comes to novel questions of halakhah that are not addressed in our ancient sources, we may choose between two broad approaches: legal formalism, and values-informed or purposive legal interpretation.[96] While formalism has an austere reputation, and indeed leaves little room for the evolution of established law, in novel areas it may lead to lenient results. If a contemporary practice is not precisely forbidden by a halakhic precedent, then it may be permitted.[97] A non-formalist or values-informed interpretation of halakhah considers both precedent and the stated *telos* or purpose of the law, incorporating moral as well as legal statements of the tradition in producing a just decision. Tamar Ross describes the relative advantages of each approach:

> If, for the formalist, the room for judicial discretion lies in the areas *not covered* by law and its formal prescriptions, for the nonformalist it lies in the application of those general principles *within* the law in a manner that realizes their purposes to perfection.[98]

Sometimes the non-formalist approach may lead to leniencies, as halakhists consider the broader goals of an area of law, narrowing problematic precedents to make room for deeper and more prevalent strands, while in other cases the result may be stricter than a purely formal analysis of

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[96] For a survey of contemporary theories of halakhah, see Elliot Dorff's, *The Unfolding Tradition: Jewish Law After Sinai* (NY: Aviv Press, 2005). On pp.212-221 Dorff introduces Joel Roth's halakhic approach, which he deems deductive and positivist, with attendant strengths and weaknesses, and then provides a self-critical discussion of his own philosophical approach to halakhah, pp.327-337. These examples accord with what we are calling formalism vs. values informed analysis. In general legal theory, see Aharon Barak, *Purposive Interpretation in Law,* trans. Sari Bashi (Princeton UP, 2005), which presents a universal theory for the role of self-conscious interpretation in secular law, and then Frederick Schauer, "Formalism," in *Yale Law Journal* 97:4 (March, 1988) pp.509-548. I thank Yoni Braffman of JTS for these sources.

[97] Haym Soloveitchik argues in an influential article, "Rupture and Reconstruction: The Transformation of Contemporary Orthodoxy," *Tradition* 28:4 (1994), that since about 1950 non-Hasidic Orthodoxy has shifted from a mimetic to a textual model of religious transmission, in the process losing the sense of divine intimacy ("the touch of His presence") and replacing it with strict obedience ("the pressure of His yoke"). This shift may be related to the primarily formalist halakhic responses to technology among Orthodox authorities observed in this section and their reluctance to engage in theological and moral reasoning in response to genetic engineering.

[98] Tamar Ross, *Expanding the Palace of Torah: Orthodoxy and Feminism* (Waltham: Brandeis UP,2004) p.64-66.

precedent would indicate.[99] In either case, the halakhah is respected as a multifaceted literature that offers nuanced moral and spiritual instruction in addition to practical guidance in the cultivation of religious virtue.

An important basis for halakhic formalism is found in Tiferet Yisrael, the Mishnah commentary of Rabbi Yisrael b"r Gedalya Lipshuetz (Germany, 1782-1860), to M. Yadaim 4:3. This chapter records the dramatic decisions made בו ביום, on the fateful day that the Sanhedrin deposed Rabban Gamliel and installed Rabbi Elazar b. Azariah in his place as chief justice. Mishnah 3 presents an extended debate between Rabbi Tarfon and Rabbi Elazar b. Azariah about tithing practices, during which Rabbi Yishmael charges the latter with bearing the burden of proof, since his position is more stringent. On this point Tiferet Yisrael (יכין) comments:

> שכל דבר שלא נדע טעם לאסרו, מותר הוא בלי טעם, דלא הזכירה התורה דברים המותרים כולן, רק דברים האסורין:
>
> *For regarding any matter where there is no known reason to forbid it, then it is permitted without [necessitating] a reason, for the Torah did not mention the entire range of permitted actions, only those things that are prohibited.*

Rabbi Yishmael's assertion that stringent positions in halakhah bear the burden of proof is a much-neglected principle in contemporary practice. Indeed, some contemporary halakhists such as bioethicist Dr. Avraham Steinberg cite Tiferet Yisrael's reading to establish that, absent any precise prohibition, new scientific and technological advances should be cautiously adopted.[100] Discussing the permissibility of cloning, he argues (based on dominion theology from Genesis 1:28) that humanity is ordered to subdue the earth, and concludes that modifications of creation are permitted, with three conditions:

> a) There is no *inherent halakhic prohibition* in the particular acts involved in the technological advancement; b) The effort towards improvement of Creation does not *result in an irremediable prohibition;* c) The *benefit/harm ration* for humans is positive.[101]

From this formalistic perspective one could argue that while the Torah vigorously prohibits the blending of *seeds in the field*, which the Sages extended to *grafting plants* together, and also the interspecies *mating* of animals, only these precise activities ought to be considered forbidden. Because neither the Torah nor the ancient sages were familiar with DNA, they could not prohibit

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[99] An example of the former result is the responsum that I co-authored with Elliot Dorff and Avram Reisner on homosexuality; the latter result includes my responsum on electricity and Shabbat.

[100] Avraham Steinberg, *Encyclopedia of Jewish Medical Ethics* (NY: Feldheim, 2003), Volume II, "Human Cloning," p. 513.

[101] Steinberg, p. 514. Emphasis in original. He is discussing cloning here, not transgenics.

what they did not know. Therefore, while it is strictly forbidden to breed, for example, a horse and a donkey by causing them to mate, it would not be forbidden to combine the DNA of a horse and a donkey *in vitro* in order to create a mule. According to Steinberg, one still must engage in a rational cost/benefit analysis before adopting a new technology, but even a radical innovation such as human cloning need not be forbidden if there is no specific precedent.

Rabbi J. David Bleich likewise adopts a formalist approach in his survey article on genetic engineering.[102] Citing the Hazon Ish to Kilayim 2:6, he states (p.71) that "artificial insemination designed to produce an interspecies is not forbidden," and continues, "it is quite obvious that genetic manipulation, since it does not entail a sexual act involving partners who are members of different species, cannot be regarded as forbidden." Rabbi Bleich considers a number of halakhic concerns, such as whether the fruit of an *etrog* tree which was pollinated by a lemon tree would be acceptable for use on Sukkot (yes), and whether fruits grown on a young sapling that was grafted onto a mature rootstock would nevertheless be prohibited as *orlah* (no). He is aware of the theological concerns expressed by Ramban, but sets them aside based on a broader mandate for humans to conquer the world and complete the work of the Creator, as explained by the Maharal text studied above. Since modern methods of genetic engineering are distinct from the activities banned by the Torah and Jewish sages as *kilayim,* there is no need to ban the creation of new hybrid species.

In a sense, the distinction between *in vitro* fertilization in a lab and the sexual breeding methods employed on the farm is similar to the distinction made in kashrut between naturally occurring animal products and chemically altered substances such as rennet and gelatin. The latter have been identified as a "new entity," דבר חדש, with some *poskim* finding that their transformation into an inedible state nullifies their kashrut status.[103] With this comparison in mind we may argue that the blending of genetic materials in a laboratory is not halakhically comparable to sexual mating, even if the cellular mechanics and the end result of *in vitro* fertilization are identical to *in vivo* method found in nature.

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[102] J. David Bleich, "Survey of Recent Halakhic Periodical Literature: Genetic Engineering," *Tradition: A Journal of Orthodox Jewish Thought,* 37:2 (Summer 2003) pp.66-84. See discussion above in Section II. Avram Reisner cites this source at pp.107-108 and comes to similar conclusions.

[103] See for example Rabbi Isaac Klein's chapter 6 on the kashrut of cheeses, and chapter 7 on the kashrut of gelatin, in his volume, *Responsa and Halakhic Studies* (NY: Ktav Publishing House, 1975), pp. 43-83. Klein cites among other sources the Rema's comments at SA YD 87:10, עור הקיבה, לפעמים מולחים אותו ומייבשין אותו, ונעשה כעץ, וממלאים אותו חלב, מותר; דמאחר שנתייבש הוי כעץ בעלמא, ואין בו לחלוחית בשר (ב"י בשם שבולי לקט), and the responsum of R' Hayim Ozer Grozinsky, שו"ת אחיעזר, 3:33 and 4:11.

An even more audacious approach for setting aside concerns with genetic engineering is to declare microscopic phenomena to be of no halakhic relevance. Rabbi Yehiel Michel Epstein (1829-1908), author of *Arukh Ha'Shulḥan*, does just this when considering the kashrut implications of microscopic organisms that are prevalent in rainwater and in the air. He concludes, האמת הוא דלא אסרה תורה במה שאין העין שולטת בו דלא ניתנה תורה למלאכים, "In truth, the Torah did not forbid anything that the [naked] eye cannot perceive, for the Torah was not given to angels…."[104] This is an important principle in modern kashrut, restraining some of the excessive restrictions that modern technology makes possible, but it is uncertain whether Rabbi Epstein would have approached genetic engineering in the same way.

Does it make sense to use such broad declarations of the insignificance of microscopic structures in order to declare the Torah's regulations of breeding to be utterly inapplicable to fertilization techniques in the lab? After all, lab workers are highly proficient at working on the microscopic level using ever more sensitive tools. Perhaps it would not exactly be incest for the harvested semen and eggs of a brother and a sister to be mixed in a petri dish, but surely the Torah's concern with incest is not only in the sexual act but also in the creation of a child whose parents are siblings. While it would be a mistake to view DNA as a pristine "code of life" that functions independently of the environment, it would also be implausibly naïve to ignore the significance of genetic inheritance and its implications for a normative religious system such as halakhah.

Rabbi Shlomo Zalman Auerbach rejects the "naked eye" argument regarding genetic engineering, since lab workers work regularly and quite effectively with microscopic materials:

> בענין שאלתו בדבר הנדסה גנטית, שמכניסים חלקיקי תאים מבריה אחת לשניה, ובזה משנים את תכונותיה של השניה, ועי"ז להתיר איסור כלאים מכיון שאין חלקיקים אלו נראים לעין האדם, כיון שאנשים מטפלים בחלקיקים האלה ומעבירים אותם ממין אחד לשני הרי זה חשיב ממש כנראה לעינים ולא דמי כלל לתולעים שאינם נראים.[105]
>
> Regarding his question regarding genetic engineering, where they insert cellular materials from one organism to another, and in so doing transform the structure of the second, whether this action can be exempted from the prohibition of *kilayim* since these cellular materials are not visible to the [naked] eye: [In my opinion,] since the workers are manipulating these materials, and transferring them from one species to another, this should certainly be considered as "visible to the eyes,"

[104] ערוך השולחן יורה דעה סימן פד סעיף לו. I thank Jeremy Kalmanofsky for directing my attention to this source, which is also discussed by Avram Reisner on p.103.

[105] שו"ת מנחת שלמה תנינא (ב - ג) סימן ק, אות ז'.

and it is not comparable to [the permission to eat] microscopic worms, which are not seen.[106]

He then differentiates between the prohibition of הרבעה, which involves the physical mating of two species of animals, and כלאים, which involves the blending of their genetic materials. In his opinion, *in vitro* fertilization avoids the first prohibition, but leaves the second one intact. This novel distinction allows him to honor both the formal precedent (interspecies sexual intercourse is forbidden) and the targeted value (the genetic integrity of species should not be compromised). However, Rabbi Auerbach does not address the question of whether the prohibition of כלאים should be invoked when only a snippet of DNA is involved, rather than the blending of the entire genomes of two different species to form a dual-species chimera. We will return to this important question below.

In contrast to legal formalism, a values-informed legal analysis considers the purposes of the laws, whether or not they are made explicit.[107] Regarding our very subject, *kilayim*, Rashi on Leviticus 19:19 states, חקים אלו גזרות מלך שאין טעם לדבר, *these laws are a royal decree, and there is no reason for them*.[108] This formalistic-sounding comment elicits a vociferous response from Ramban, which we have cited in part above: While the common people might not understand the divine will, every word of God has a purpose which must be discerned. As we have seen, Ramban understands the rationale for the mitzvah of *kilayim* to be respect for the divine creation. He writes, והמרכיב שני מינין, משנה ומכחיש במעשה בראשית, "*And one who breeds together two species alters and undermines the work of [God's] creation."* To apply the law without seeking to understand its values is literally to devalue the Torah, and to strip it of its purpose. Halakhic observance then becomes a matter of obsequious conformity. While obedience is a necessary stage of Jewish devotion, it alone is not sufficient. The declaration of נעשה ונשמע, "*we shall heed and hear!"* (Exodus

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[106] I thank Avram Reisner for directing me to this source. Auerbach continues in the next paragraph to make the case that the offspring of an impure species remains impure, even if it is raised somehow by a pure species.

[107] Influential practitioners of values-informed halakhic interpretation include Eliezer Berkowitz, Daniel Sperber, Elliot Dorff and Gordon Tucker. See, for example, Elliot Dorff's essay, "The Philosophical Foundations of My Approach to Bioethics," an appendix to his book, *Matters of Life and Death: A Jewish Approach to Modern Medical Ethics* (Philadelphia: Jewish Publication Society, 1998) pp.395-417, cited above in *The Unfolding Tradition.*

[108] Yet in his Talmud commentary to Bavli Kiddushin 39a, Rashi offers an explanation of the law that is not so distant from Ramban's formulation:

רש"י מסכת קידושין דף לט עמוד א . חקתי תשמרו - מדלא כתיב ושמרתם את חקתי משמע את חקתי אשר מעולם תשמרו מלמד שהזהיר את נח ובניו עליהן ואלו הן החקים בהמתך לא תרביע שדך לא תזרע ואיזו זריעת כלאים שאני אומר שחקקתים לך כבר דומיא דבהמה דבר המסויים והיינו הרכבה ומהכא נפקא לן בסנהדרין (דף ס) דבני נח הוזהרו עליהן והכא אתה מוסיף ללמוד מהיקש זה דומיא דבהמה אפי' בח"ל דהא חובת הגוף היא אף שדך בח"ל .

24:7) gives priority to compliance but follows it immediately with comprehension. In our case, to assess the permissibility of genetic engineering on strictly formalistic grounds—whether the modern lab procedure is the physical equivalent of the ancient methods of farming—is to ignore the theological concerns expressed across the centuries of Jewish interpretation of the Torah's ban on *kilayim*.

Even the halakhic texts that we have cited give reason to consider new methods for blending DNA with caution. The sages required that fields with blended crops be weeded into homogenous plots, even if the farmer had not intentionally sown them together (they may have grown together, or seeds from a prior season may have sprouted). And while the strongest prohibition on breeding different species of animals together may have been reserved for "hands-on" mating, Jewish farmers were warned not to verbally encourage their animals to mate between species, and were forbidden to bring their animals to a non-Jewish breeder for such purpose.[109]

Does the ban on cross-breeding apply to non-Jews as well as to Jews? In B. Sanhedrin 56b, Rabbi Eliezer states that the ban on cross-breeding animals and grafting plants (but not the wearing of *shatnez* or sowing seeds together) applies to gentiles.[110] It is unclear on what basis Rabbi Eliezer extends this rule beyond Israelites. As Meiri points out, the ban on cross-breeding does not derive from the seven Noachide laws, which are discussed on the same page.[111] On Sanhedrin 60a, the Bavli answers this question with the statement of Shmuel from Kiddushin 39a. The ban on *kilayim* is part of **חוקים שחקקתי כבר**, the natural order that God established from the creation and entrusted to all descendants of Noah.[112] Rabbi Ovadiah Yosef traces this line of reasoning through the generations in his collection of responsa, *Yabia Omer*.[113] The establishment of *kilayim* as a meta-principle that applies to all people from the time of creation reinforces the idea that the ban on

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[109] Avram Reisner, however, cites (p.107) Radbaz's commentary to MT Kilayim 1:6 as proof that not all *poskim* have maintained the traditional ban on hiring a non-Jew to cross-breed species.

[110] תלמוד בבלי מסכת סנהדרין דף נו עמוד ב. רבי אלעזר אומר: אף על הכלאים. מותרין בני נח ללבוש כלאים, ולזרוע כלאים, ואין אסורין אלא בהרבעת בהמה ובהרכבת האילן. רמב"ם הלכות מלכים פרק י הלכה ו. מפי הקבלה שבני נח אסורין בהרבעת בהמה ובהרכבת אילן בלבד, ואין נהרגין עליהן.

[111] בית הבחירה למאירי מסכת סנהדרין דף נו עמוד ב .בני נח אסורים בהרבעת בהמה בשאינה מינה וכן בהרכבת אילן בשאינו מינו אלא שאין אלו משבע מצוות ואינו נהרג עליהן ושאר מיני הכלאים מותרין בהן:

[112] As the Bavli considers, this logic might indicate that gentiles are therefore liable for all laws that God has decreed. The distinction is made based on word order in the verse, את חקתי תשמרו; *kilayim* are part of the statutes established from the beginning of creation, and are thus applicable to all people.

[113] שו"ת יביע אומר חלק ה - אורח חיים סימן יט. גבי ז' מצות שנצטוו עליהם בני נח, ר' אליעזר אומר אף על הכלאים, ומותרים בני נח ללבוש כלאים ולזרוע כלאים, ואינם אסורים אלא בהרבעת בהמה ובהרכבת האילן, וס"ל לרבינו דאע"ג שאין הלכה כר"א משום דא"כ הו"ל ח' מצות לב"נ שנהרג עליהם, ואנן קי"ל שרק על ז' מצות ב"נ נהרג, מ"מ כיון דשמואל מפרש לה בגמ' (סנהדרין ס), משום דאמר קרא את חקותי תשמורו, חוקים שחקקתי לך כבר (לבני נח), בהמתך לא תרביע כלאים שדך לא תזרע כלאים, מה בהמתך בהרבעה אף שדך בהרכבה. אלמא דס"ל לשמואל שב"נ אסורים בכלאים אף על פי שאין נהרגים עליהם.

inter-species breeding ought to be understood as a theological value for all God-fearing people, not a narrow legal regulation imposed on Jews alone.

Returning to halakhic formalism, Rabbis Steinberg and Bleich see no inherent difficulty in genetic engineering. A values-informed interpretation reads precedent somewhat differently, understanding the ban on *kilayim* as Ramban did, as a foundation for limiting human interventions in the natural world, preserving extant species and preventing the creation of new hybrids. Rabbi Avram Reisner generally follows the line of the formalists in permitting genetic modifications of species, yet he too is troubled by the possibility of "gross modifications." He writes (p.109),

> The burden of this paper is להקל [lenient] and would permit even such a genetically engineered plant. Still, when we are able to change not a single trait, but much of the genome of a creature, to create, as it were, a creature of our own devising, then we must ask, is that the point at which we must stop?

It appears to us that the sages conceived a broad prohibition of blending different species, which they understood to be a measure of respect for the creation. While they were unfamiliar with DNA, and could not know how the genes of two parents were blended in their children, they understood well enough that the Torah intended to keep species distinct, at least when it came to fruits, vegetables and animals, and that this mandate was the collective responsibility of all people.

The sages were also concerned with the imposition of animal suffering as a result of *kilayim*. Rabbi Jacob ben Moses Moellin, known as Maharil (1360-1427, Germany) writes in Responsum #124 that it is forbidden to force a bird to nest on the eggs of a bird of a different species because of the ban on causing animal suffering.[114] Western governments are belatedly developing stricter standards for the humane treatment of laboratory animals.[115] Observant Jews are responsible for minimizing animal suffering, even if needed for medical research.

Although the sages were vigilant in preserving and indeed expanding the ban on interspecies mating, they were nevertheless quite lenient in concluding that the *produce* of hybrid fruits (other than vines, given Deuteronomy's phrasing) is permitted for cultivation and consumption. Moreover, Rambam offers a significant exception in permitting cross cultivation of "bitter

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[114] שו"ת מהרי"ל החדשות סימן קכד. ולהושיב עוף על ביצים שאין מינו כגון תרנגולת ואווזות אמ' שהוא אסור משום צער ב"חא.

[115] See this policy page from the National Institutes of Health OLAWS (Office of Laboratory Animal Welfare) web site: http://grants.nih.gov/grants/policy/air/NIH_ensure_welfare.htm

grasses" for medicinal purposes, and this exception is restated in the Tur and Shulhan Arukh as established law.

Judaism's ban on *kilayim*, mixing species of plants and animals, is understood to apply to all people, places and circumstances. *It would seem therefore that the default position of halakhah is to forbid the blending of genomes of different species, for much the same reason*. Our ancestors were well aware of possible benefits of such crossbreeding, but they nevertheless forbade Jews from engaging in such practices or in asking non-Jews to do so.

However, the Sages were also clear in permitting the produce of such forbidden efforts. It was permitted to ride a mule, for example, to eat the fruit of a grafted tree, and to replant cuttings from such a hybrid. Thus contemporary Jews may certainly benefit from the hybridized products on the market, whether they are apples or mules, or even from transgenic animals such as the GloFish.

Moreover, Rambam makes a significant exception for medicinal purposes, and his narrowing of the prohibition of cross breeding or grafting plants to apply only to food is significant. Even if the ban on *kilayim* did apply to medicinal herbs, the great principle of *pikuah nefesh,* rescuing human life would override such concerns. This point is made dramatically in B. Yoma 82b:

> תנו רבנן: עוברה שהריחה בשר קודש או בשר חזיר תוחבין לה כוש ברוטב, ומניחין לה על פיה. אם נתיישבה דעתה - מוטב, ואם לאו - מאכילין אותה רוטב עצמה, ואם נתיישבה דעתה - מוטב, ואם לאו - מאכילין אותה שומן עצמו, שאין לך דבר שעומד בפני פקוח נפש חוץ מעבודה זרה וגילוי עריות ושפיכות דמים .
>
> *Our Rabbis taught: If a woman with child smelt the flesh of holy flesh, or of pork, we put for her a reed into the juice and place it upon her mouth. If thereupon she feels that her craving has been satisfied, it is well. If not, one feeds her with the juice itself. If thereupon her craving is satisfied it is well; if not one feeds her with the fat meat itself, for there is nothing that can stand before [the duty of] saving life, with the exception of idolatry, incest and bloodshed* [which are prohibited in all situations]. [Soncino translation]

While this text describes an intense craving for forbidden food, the same leniency would apply to medicines derived from forbidden sources. If for example, it were possible to use porcine DNA in a therapy that induced a human autoimmune response to attack a life-threatening tumor, halakhah would certainly favor such an intervention. Likewise, researchers are making progress in xenotransplantation (cross-species transplantation) by, for example, genetically modifying pigs so that their organs may be transplanted into humans without triggering an organ rejection

response.[116] This too would be justifiable in halakhah under the rubric of *pikuah nefesh*, an action that might save human life. Even absent such a life-or-death scenario, the use of genetically modified organisms to, for example, enrich the nutritional value of rice, which is a subsistence crop for billions of humans, would seem to be indicated, so long as the concerns over health side-effects and ethical issues can be satisfactorily resolved by responsible agencies. There are certainly valid concerns about the health and economic consequences of introducing GMOs, and in large swaths of the world such as Europe, Africa and South Asia, a broad consensus against the genetic modification of food crops has taken root. Yet many experts argue that the fears upon which this consensus is based are tragically mistaken, and that GM crops will be a necessary component of any successful strategy to feed the rapidly growing human population, which could rise to ten billion by century's end.

While the blending of two species to form a new hybrid is forbidden under the rubric of *kilayim*, it is not evident that this prohibition should apply to the transfer of sequences of DNA from one organism to another. As we have seen, the human genome already has 147 "foreign" genes, and we are aware that humans share the preponderance of their genetic material with members of other species.[117] Plants and animals that have had DNA sequences from the human genome inserted so that they may produce insulin, lysozyme and other useful products remain modified plants and animals. They may be transgenic, but they have not become human/plant hybrids. *As such, we would limit the application of kilayim to the full blending of genomes to form a dual species chimera, as in sexual reproduction, whether in the barn or in the lab*.[118] Halakhic formalists exclude such

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[116] See Burcin Ekser and David KC Cooper, "Overcoming the barriers to xenotransplantation: prospects for the future," in *Expert Rev Clin Immunol*. 2010 March; 6(2): 219–230. They write, "The most significant advances to date have been the production of pigs expressing a human complement-regulatory protein (e.g., human decay accelerating factor [CD55], membrane cofactor protein [CD46] or CD59 [44-48]) and pigs in which the gene for α1,3-galactosyltransferase has been knocked out (α1,3-galactosyltransferase gene-knockout [GTKO] pigs) [49-52]." I thank patent judge Jeff Fredman for bringing this source to my attention.

[117] The genetic difference between humans is estimated to be on average .1%, whereas the genetic difference between humans and chimpanzees and bonobos is about 1.2%. Counted a different way, with missing sequences included, the human-chimp gap is considerably larger, more like 4-5%. See this overview from the Smithsonian. See also this June 28, 2012 letter in *Nature*: "The Bonobo Genome Compared with the Chimpanzee and the Human Genomes."

[118] In September 2015 the National Institutes of Health proclaimed a moratorium on "Research Involving Introduction of Human Pluripotent Cells into Non-Human Vertebrate Animal Pre-Gastrulation Embryos. See http://grants.nih.gov/grants/guide/notice-files/NOT-OD-15-158.html. On Nov. 6, 2015 it conducted a workshop on this subject, which is of intense interest to biomedical researchers eager to grow human-compatible tissue, and has raised deep concerns among bioethicists. In this paper we endorse such concerns, which do meet the standard of *kilayim* as we understand it.

genetic modifications from the ban of *kilayim* since the mixing is not sexual, but even a values-informed analysis recognizes that the mitzvah of *kilayim* is intended to prevent the creation of new hybrid species, not the minor modification of organisms to produce proteins or develop other qualities which might produce tangible benefits for humans and other species.

Ethical Concerns with Genetic Engineering

Before we offer a broad-based exception to permit genetic modifications (but not chimera) whenever there is a plausible human benefit, whether for health or hunger, we must pause to consider some of the ethical and theological values that suffuse Jewish teaching. From the opening chapters of the Torah we learn that there is something distinctive about human identity, something that reflects God. It is this sensibility that underlines the prohibition of murder (Gen. 9:6), and it is this same belief that animates the Torah's great mandate to protect human life by nearly all possible means. Saving human life trumps all other Jewish values, save the prohibitions of murder, idolatry and sexual acts categorized as *ervah.* Our contemporary challenge is that some life-saving therapies may paradoxically undermine the sanctity of life, specifically through the popularization of what has come to be called "consumer eugenics."

While most people are familiar with the horrors of Nazi ideology and the mass murder of Jews and others whom they considered to threaten the genetic stock of their supposed Aryan race, eugenics was a popular concern for scientists and leading legal and political figures in the United States and other countries by the late nineteenth century.[119] Indeed, practical eugenics was a common practice in America in the first half of the twentieth century, leading to the institutionalization and forced sterilization of citizens who were epileptic or deemed to be "feeble-minded."[120]

The current project of sequencing and then modifying the human genome may be motivated by therapeutic concerns, but there is danger that our market-driven society will also allow for a new market-driven eugenics that promises the enhancement of human offspring.[121] It is or will soon

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[119] See Daniel J. Keeves, *In the Name of Eugenics* (Cambridge, MA: Harvard UP, 1995), and Michael Sandel's chapter 4, "The Old Eugenics and the New," in *The Case Against Perfection* (Cambridge, MA: Belknap, Harvard UP, 2007).

[120] For a disturbing history of eugenics in New Jersey, see the work of my father, Michael A. Nevins, M.D., *A Tale of Two Villages: Vineland and Skillman, NJ* (iUniverse, 2005). Some of these institutions remained active until the 1970s.

[121] Mark Popovsky's 2008 CJLS responsum, "Choosing our Children's Genes: The Use of Preimplantation Genetic Diagnosis" argued against using PGD for the purpose of selecting embryos based not only on aesthetic traits but also on genetic health (with a narrow exception for severe disability) on grounds similar

become possible to design humans with DNA that not only limits susceptibility to cancers and other diseases,[122] but also adjusts physical qualities such as height, eye and hair color and skin tone. The temptation to "borrow" from the genomes of other species in order to integrate some of their physical attributes is becoming overwhelming.

Enhancements may not be limited to external looks, but may also make possible the improvement of musculature, vision, hearing, and even memory. For example, current research focused on multiple sclerosis, a disease which impairs neurological function, seeks to create therapies that would promote functional remyelination, allowing MS patients to establish new neuronal connections; such a therapy if successful might also benefit healthy people who seek improved intellectual performance.[123] Likewise, genetic research into cell senescence is focusing on ways to prevent cells from "turning off" and thus extending both cell life and the life of the person. These proposed enhancements are not "eugenic" in nature, but are intended to cure disease and enhance health for all people.

While efforts to date have been on somatic gene therapies which affect only the present person, it is also possible to intervene with germ lines that will alter future generations. The motivation to repair a mutation such as the one that causes sickle cell anemia, and to prevent its transmission to future generations, is considerable. Some people have a genetic mutation which apparently confers natural immunity to HIV. Should this mutation be introduced to the population at large? It is difficult to anticipate what side effects might follow from such permanent alterations of the human genome. Moreover, human diversity is an important biological, social and theological asset.

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to those of Sandel (see below). However, Avram Reisner and Marilyn Wind filed a persuasive dissent defending the consideration of avoiding disease (but not selecting for the sex or other traits) in choosing which embryo to implant. Popovsky's concerns over the arrogance of PGD strike me as weaker than are their arguments for health (even though I did vote for his responsum).

[122] George Church and Ed Regis describe a speculative approach to modifying the human genome to impart multi-virus resistance or even complete immunity in chapter 5 of their book *Regenesis*, "-60 MYR, Paleocene: Emergence of Mammalian Immune System. Solving the Health Care Crisis Through Genome Engineering." Recent reports of IGT, immunoprophylaxis by gene transfer, cited above, indicate clinical progress in this field. See also, "Synthetic biology devices and circuits for RNA-based 'smart vaccines': a propositional review," by Oliwia Andries, Tasuku Kitada, Katie Bodner, Niek N Sanders, and Ron Weiss in *Informa*, February 2015, Vol. 14, No. 2 , pp. 313-331.

[123] I thank Isaac Zentner, a PhD candidate in genetics at Drexel University, for providing these examples. Biogen Idec is developing a drug to reverse MS damage known as anti-LINGO. See "Drug-based modulation of endogenous stem cells promotes functional remyelination *in vivo*," letter published in *Nature* Vol 522, p.216, June 11, 2015. doi:10.1038/nature14335.

Germline genetic therapy is banned in many countries (including Israel), and is regulated in others (including the United States) since the impact on future generations is unknown.[124] However, it has recently been reported that researchers in China used Crispr-Cas9 technology to "edit" the DNA of human embryos.[125] Although the experiment was on non-viable embryos, and failed in its goals, it is alarming to consider that the editing of humans in ways that could affect future generations has already begun. Indeed, a group of prominent researchers led by Nobel laureate David Baltimore has called for an open discourse on genetic engineering, while, "strongly discouraging, even in those countries with lax jurisdictions where it might be permitted, any attempts of germline genomic modification for clinical application in humans, while societal, environmental and ethical implications of such activity are discussed among scientific and governmental organizations."[126]

Philosopher Michael Sandel mounts a broad argument against genetic enhancement therapy in his 2007 book, (expanded from a 2004 article of the same title in *The Atlantic*) called, *The Case Against Perfection: Ethics in the Age of Genetic Engineering*. Sandel concedes that genetic engineering might be considered comparable to other, noncontroversial interventions made by people to improve their bodies and minds, or those of their children or clients. Not only medical interventions but also education and athletic training are all efforts to augment human performance. We do not leave much in our lives to chance, at least not when we have the ability to improve outcomes. Genetic engineering may be considered to be just another method used for such ordinary purposes. Still, Sandel is concerned with what he calls hyperagency, "a Promethean aspiration to remake nature, including human nature, to serve our purposes and satisfy our desires. The problem is not the drift to mechanism but the drive to mastery. And what the drive to mastery misses and may even destroy is an appreciation of the gifted character of human powers and achievements" (26-27).

Sandel, who is Jewish, does not refrain from appealing to a religious sense of "giftedness," but he also identifies in genetic engineering threats to three secular foundations of morality: humility, broad responsibility, and social solidarity (85). Of course, these secular values are also very much

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[124] See subheading "Human Genetic Engineering" in the Wikipedia article, "Gene Therapy." (8.31.15)

[125] See "CRISPR/Cas9-mediated gene editing in human tripronuclear zygotes" by Puping Liang, et al., in *Protein and Cell,* April 18, 2015. Reported by Gina Kolata, "Chinese Scientists Edit Genes of Human Embryos, Raising Concerns," in *NY Times*, April 24, 2015. The acronym CRISPR stands for "clustered regularly interspaced short palindromic repeat."

[126] See article by David Baltimore et al, "A prudent path forward for genomic engineering and germline gene modification," published in *Science* (3 April 2015: Vol. 348 no. 6230), pp. 36-38.

Jewish values. Belief in God, specifically in God as our creator and teacher in the path of holiness, is the religious foundation for humility, causing us to accept responsibility for the lives and well-being of others, and giving us a sense of communal solidarity, both within the covenanted community of Israel, and with all of God's creation. Sandel (94) anticipates criticism that his approach is "too religious" and offers the work of John Locke, Immanuel Kant and Jürgen Habermas to buttress the philosophical basis for the giftedness of life. Yet he does not contend with a religious-based critique that would defend genetic engineering as a form of *imitatio dei*, imitating God by acting to protect and strengthen life (as seen above in texts from Rambam, Tur, and Maharal).

Judaism has been willing to permit nearly anything to protect human life, although there are some limits (again, one may not murder, commit idolatry or sexual crime to protect life). We would be wise to recall Ramban's teaching that the ban on *kilayim* is an indication of respect for the Creator, and a necessary restraint upon God's most audacious creatures. Yet Sandel's preference for chance over choice (92) does not resonate deeply with Jewish sources. The story of King Asa, who turned to physicians rather than God to heal his leg (2 Chronicles 16:12),[127] is accepted in Jewish sources as reasonable if not virtuous conduct.[128] Both halakhic formalism and values-informed analysis provide ample precedent for the modification of human bodies to improve function and extend lifespan.

The Torah itself anticipates that affluence can cause humans to forget the giftedness of life, leading them to say, "My own power and the might of my own hand have won this wealth for me."[129] Likewise, the Torah is concerned with the human tendency to abandon personal responsibility and to break with communal solidarity, but these are ancient human proclivities, and are not uniquely triggered by genetic engineering. Human perfection may be an unrealistic goal, but the improvement of our physical and spiritual abilities is, as Rambam writes in *Hilkhot De'ot*, chapter 3, the essential human endeavor.

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[127] דברי הימים ב פרק טז, יב. (יב) וַיֶּחֱלֶא אָסָא בִּשְׁנַת שְׁלוֹשִׁים וָתֵשַׁע לְמַלְכוּתוֹ בְּרַגְלָיו עַד־לְמַעְלָה חָלְיוֹ וְגַם־בְּחָלְיוֹ לֹא־דָרַשׁ אֶת־יְקֹוָק כִּי בָרֹפְאִים׃

[128] אבל עיין שו"ת הרשב"א חלק א סימן תיח ד"ה וחכמת הרפואה. וגם כי יש בה בהתרפאות מחכמי בני האדם קצת מבוא להסרת הבטחון מהאלהים כמו שנתפש מלך ישראל בזה הענין (ד"ה ב' ט"ז) וגם בחליו לא דרש את ה' כי אם ברופאים. ולזאת הסבה שובח חזקיה מאנשי דורו כשגנז ספר רפואות לחולשת אמונות אותו הדור. עם רוב הספר ההוא באותה חכמה ואמתתו וקלות השגת התועלת ממנו עד שהיה מביא להסרת בטחונם. ואם תהיה התשובה כי באלו תכונות תתחזק אמונת האל בלבבות ולא נחוש להסרת הבטחון עם הצורך הגדול להתרפאות הגופות אשר הוא הכרחי לנו. הנה לא נמלט בשום פנים מהמשיך התשובה הזאת בעצמה בכל הענינים שנרצה. והוא שכבר נתפרסמו אמונות התורה האמתיות בחדוש העולם והשגחה והגמול והתחזקו בהם הלבבו'. ואין ראוי שנחו' על שום אדם שיפקפק עליהם בעבור החכמות עם הצודק גם כן להשיג מתועלת החכמה התרפאות נפשותינו. כי איך תהיה רפואת הגופות עלינו יותר חביבה מרפואת הנפשות?

[129] Deuteronomy 8:17, JPS trans. of וְאָמַרְתָּ בִּלְבָבֶךָ כֹּחִי וְעֹצֶם יָדִי עָשָׂה לִי אֶת־הַחַיִל הַזֶּה.

Physician and ethicist Jeffrey Burack provides a close examination of Jewish perspectives on enhancement, emphasizing the importance of humility (ענוה) in Jewish thought.[130] He challenges Sandel's argument that genetic enhancement poses a unique threat to these foundational values. After all, we already make many radical adaptations to the human body through corrective surgeries, organ transplants and mechanical implants, not to mention cosmetic surgeries. While distinctions can be made between interventions that are demanded (and deserve insurance coverage), and those that are merely to be tolerated, we do not perceive these remarkable interventions as a form of "hyperagency" that threatens our sense of the giftedness of life. Rather, Burack argues that our emphasis should always be on humility. Are our motivations consistent with our duties to be stewards of the human body for God?

Burack raises an important concern that we have already discussed: are we confident that we understand the consequences of genetic engineering for both the current and future generations? Western researchers have sought to limit gene therapy on humans to somatic cells, avoiding modifications to the germline that could be inherited by future generations. Yet, there is some evidence of "leakage" of viral vectors used to deliver gene therapy that are later detectable in semen, making the genetic interventions possibly heritable.[131] For Burack, these questions point to a Jewish paradox—we are responsible to repair the world, but are warned to maintain appropriate humility about its unknowable ends. Likewise our halakhic examination leads to conflicting imperatives—both to preserve life and to improve it, to use our gifts of mind and spirit, and also to remain humble about the limits of our comprehension.

Philosopher Alan Mittleman concludes his 2015 book, *Human Nature and Jewish Thought* with a reminder of the importance of limiting the human drive to mastery:

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[130] Jeffrey H. Burack, "Jewish Reflections on Genetic Enhancement," in *Jews and Genes: The Genetic Future in Contemporary Jewish Thought, ed.* Elliot N. Dorff and Laurie Zoloth (U of Nebraska Press/ JPS, 2015), pp.310-341.

[131] Burack discusses this on p.334: "With present technology there is no absolute guarantee that a somatic gene therapy intervention will not inadvertently result in germ line changes." Jeff Fredman called my attention to an article by Masanori Takehashi that provides evidence for Burack's concern by demonstrating that adenovirus, a standard gene therapy viral vector, "may inadvertently integrate into a patient's germ line." Masanori Takehashi, et al. "Adenovirus-mediated gene delivery into mouse spermatogonial stem cells," in *PNAS* (104:8, Nov. 2007). The abstract concludes, "These results suggest that adenovirus may inadvertently integrate into the patient's germ line and indicate that there is no barrier to adenovirus infection in spermatogonial stem cells."

> We have the creativity and freedom to remake the world, and now, increasingly, to remake ourselves. Our own survival might well depend on cultivating anew a sense of limits. Adam and Eve were expelled from the Garden of Eden for transgressing a limit. Limits there will always be, many imposed by human nature. Our dignity inheres in knowing when and how to master them, and when and how to accept them with respect.[132]

Rabbi Aaron Mackler offers the biblical concept of creation in the divine image, **נברא בצלם**, as the core principle for considering the ethics of genetic engineering.[133] It implies "a general commitment of respect for persons, and that, "care must be taken not to treat a person as an object." (281). Mackler cautions at the beginning of his article that we are both too early and too late to make final determinations on this subject. Genetic engineering has already accomplished dramatic changes in the genomes of plants and animals, but we still know quite little about what developments the near and not so near future will bring us.

We are both early and late in the development of genetic engineering. Knowing that determining halakhah to govern genetic engineering will remain an unfinished task, we nevertheless have sought to add to the Jewish discourse. We have examined the key texts and values that are currently at stake. It is now time, with due humility, to offer our conclusions.

V. Halakhic Conclusions

In this responsum we have discovered many causes for concern with genetic engineering, whether from a theological sense of humility toward the Creator, an imperative to observe the mitzvah of *kilayim*, or worries about the safety of GMOs. Each of these concerns has practical applications. Nevertheless, we have not established a general prohibition on the genetic modification of DNA in plants, animals or indeed in humans. Most modern methods of genetic engineering are not directly comparable to the actions forbidden as *kilayim* by the Bible and rabbinic literature, since recombinant DNA generally includes just snippets of foreign genomes that function as widgets in their recipient. Even if the creation of transgenic organisms were to be considered halakhically equivalent, based on a values-informed analysis, to the forms of *kilayim* forbidden by our tradition, the fruits of such efforts would remain permitted after the fact (**בדיעבד**). And even before the fact (**לכתחילה**), the motivation to save human lives and enhance health with therapies that use genetic engineering to combat cancer, feed the rapidly expanding human population, or produce medications, would suffice to permit that which might otherwise be

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[132] Alan Mittleman, *Human Nature and Jewish Thought: Judaism's Case for Why Persons Matter* (Library of Jewish Ideas; Princeton and Oxford: Princeton UP, 2015) p.184.

[133] Aaron Mackler, "Genetic Enhancement and the Image of God," in *Jews and Genes*, pp.274-284.

forbidden. Still, we remain responsible for the prevention of animal suffering, and for the possible health dangers to humans and other animals posed by GMOs. Because biotechnology is a revolutionary field, with real benefits and also real risks that cannot always be anticipated, halakhic considerations indicate the importance of vigilant attention to the emerging technology and its applications.

Piskei Din Regarding the Genetic Modification of Plants and Animals

1) The Torah's ban on כלאים, the physical blending of different species of plants or animals, does not extend formally to the modification of gene sequences via the introduction of foreign DNA in order to convey a specific capability in the new organism. Jews may benefit from the fruits of hybridized plants and animals, but they should not intentionally create entirely new species.

2) The health implications of genetically modified foods must be examined on an individual basis, without making broad assumptions that all GMOs are either salubrious or dangerous. The Torah's command (Deut. 4:15) that we guard our health requires vigilant attention to the safety of our food supply.

3) When considering the genetic modifications of organisms, Jews must, as informed and engaged citizens, seek to minimize animal suffering (צער בעלי חיים) and to protect extant species (קיום המין).

Piskei Din Regarding the Genetic Modification of Humans

4) The creation of dual species human/animal chimera is forbidden.

5) Modifications of the human genome intended to combat illness are permitted, for they may promote human health and protect human dignity.

6) Genetic modifications intended to enhance the aesthetics of otherwise healthy humans are forbidden, for they violate Jewish teachings about the sanctity of human life. Modifications to the human genome must be limited to changes needed to restore health. Because the line between therapy and enhancement is often ill-defined, consultation with a scholar versed in the halakhic, ethical and biological considerations is required before such therapy is commenced.

וכן נלפענ"ד

Appendix: Study Sheet of Major Primary Sources

1. Biblical Texts on the Mingling of Species (*Kilayim*):
   Leviticus 19:19.
   אֶת-חֻקֹּתַי תִּשְׁמֹרוּ בְּהֶמְתְּךָ לֹא-תַרְבִּיעַ כִּלְאַיִם שָׂדְךָ לֹא-תִזְרַע כִּלְאָיִם וּבֶגֶד כִּלְאַיִם שַׁעַטְנֵז לֹא יַעֲלֶה עָלֶיךָ׃
   You shall heed my statutes: you shall not let your cattle mate with a different kind; you shall not sow your field with two kinds of seed; and clothing made of two kinds of yarn you shall not put on yourself.[134]

   Deuteronomy 22:9-11.
   לֹא-תִזְרַע כַּרְמְךָ כִּלְאָיִם פֶּן-תִּקְדַּשׁ הַמְלֵאָה הַזֶּרַע אֲשֶׁר תִּזְרָע וּתְבוּאַת הַכָּרֶם׃ (י) לֹא-תַחֲרֹשׁ בְּשׁוֹר-וּבַחֲמֹר יַחְדָּו׃
   (יא) לֹא תִלְבַּשׁ שַׁעַטְנֵז צֶמֶר וּפִשְׁתִּים יַחְדָּו :
   9. You shall not sow your vineyard with a second kind of seed [else the fullness from the seed you have sown, and the yield of the vineyard, may not be used]. 10. You shall not plow with an ox and ass together. 11. You shall not wear cloth combining wool and linen.

2. Talmud Yerushalmi, Tractate *Kilayim* 1:1 (Venice ed., 27a).
   מניין שאין מרכיבין עץ סרק על גבי עץ מאכל ולא עץ מאכל על גבי עץ מאכל מין בשאינו מינו מניין תלמוד לו' את חקותי תשמורו ר' יונה ר' לעז' בשם כהנא דר' לעזר היא משום חוקים שחקקתי בעולמי מעתה אסור לאדם הראשון ר' יוסי בשם רבי הילא דברי הכל היא משום חוקים שחקקתי בעולמי מעתה אסור להרכיב תאינה שחורה על גבי תאינה לבנה.
   How do we know that one may not graft a barren tree onto a fruit tree, nor a fruit tree onto a fruit tree of a different species? Because it [the Torah] states: Guard my statues. R' Yonah [quotes] R' 'Lazar in the name of Kahana: It is in accord with R. 'Lazar's saying—"the statutes—are those that I have established in My world." Henceforth it is forbidden [to blend species] since Adam the First. R' Yosi in the name of Rabbi Hila [says], all agree that [the prohibition derives from the word] "statutes" that I have established in my world. Henceforth it is forbidden to graft a black fig [tree] onto a white fig [tree].

3. Maimonides (Rambam, 1139-1205), *Mishneh Torah*, Laws of Kilayim 1:4.
   אין אסור משום כלאי זרעים אלא הזרעים הראויין למאכל אדם, אבל עשבים המרים וכיוצא בהן מן העיקרין שאינן ראויין אלא לרפואה וכיוצא בהן אין בהן משום כלאי זרעים.
   The prohibition on mixed seeds is limited to species fit for human consumption, but bitter grasses and such from roots which are not fit except for [eating, but only for] medicine, and similar [plants] are not included in the ban on mixed seeds.

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[134] Translations of this and the following text from Deut. 22 are from Jacob Milgrom, *The Anchor Bible, Leviticus 17-22: A New Translation with Introduction and Commentary* (New Haven: Yale UP, 2000), p. 1657. Remaining translations are mine unless otherwise indicated.

4. Nachmanides (Ramban, 1194-1270), *Torah Commentary*, Leviticus 19:19.

Lev. 19:19. *Guard my statutes*—and what are they? *Do not cross-breed your animals, etc.* In the words of Rashi, "These statutes are royal decrees, and there is no reason for the matter." But the sages have not mentioned that the reason [for this mitzvah] should be hidden, so that the evil inclination, and the nations of the world would be able to refute them—[this is so] only in regard to *shatnez* [mixed-cloth garments], and not regarding interspecies breeding.

And it is not intended regarding that the royal decree would be without reason in any instance, for *all the words of God are refined* (Proverbs 30:5). However, the statutes are royal decrees which He decrees in His sovereignty without revealing their benefit to the people, and the people do not benefit [from knowing their purpose] but they contemplate them in their hearts, and accept them out of reverence for His sovereignty. And so with [all] the statutes of the Blessed Holy One are His secrets in the Torah that the people do not enjoy knowledge of their reasons, as with the laws. However, all of the [statutes] do have a proper reason and full benefit.

The reason for Kilyaim [the ban in mixing species] is that God created the species in the world—all life forms among the plants and moving animals—and placed within them the power of reproduction, so that the species would persist forever, [at least] so long as the Blessed One should desire that the world exist. And He made in them the capacity to replicate themselves and never change, as it says of them all, *according to their species* (Genesis 1). And this is the reason for sexual intercourse that animals mount one another to sustain their species, just as men and women have intercourse for the sake of reproduction. But when one grafts two different species, he alters and undermines the work of creation, and it is as if he thinks that the Holy One did not complete the work as needed, and now he wants to help in the creation of the world by adding new creatures to it. And [furthermore] the species are not fertile with members of other species, and even the closely related species in nature that are able to produce [hybrids] together, as with mules—their stock will cease, for they are sterile. And for these two reasons, the creation of hybrid species is despicable and futile….

And I have already written in the Order of Creation (Genesis 1:11) that the plants all have their source in the heavens, and from there God gave them their blessing to live forever. But a person who blends together species undermines, and mingles the work of creation.

(יט) את חקותי תשמרו - ואלו הן "בהמתך לא תרביע כלאים" וגו', חקים אלו גזרות מלך שאין טעם לדבר, לשון רש"י. ולא הזכירו רבותינו שיהיה הטעם נעלם ושיהיו יצר הרע ואומות העולם משיבים עליהם, אלא בלבישת שעטנז, לא בכלאי הבהמה:

ואין הכונה בהם שתהיה גזרת מלך מלכי המלכים בשום מקום בלא טעם, כי כל אמרת אלוה צרופה (משלי ל ה), רק החקים הם גזירת המלך אשר יחוק במלכותו בלי שיגלה תועלתם לעם, ואין העם נהנים בהם אבל מהרהרין אחריהם בלבם ומקבלים אותם ליראת המלכות, וכן חוקי הקדוש ברוך הוא הם הסודות אשר לו בתורה שאין העם במחשבתם נהנים בהם כמשפטים, אבל כולם בטעם נכון ותועלת שלימה:

והטעם בכלאים, כי השם ברא המינים בעולם, בכל בעלי הנפשות בצמחים ובבעלי נפש התנועה, ונתן בהם כח התולדה שיתקיימו המינים בהם לעד כל זמן שירצה הוא יתברך בקיום העולם. וצוה בכחם שיוציאו למיניהם ולא ישתנו לעד לעולם, שנאמר בכולם "למינהו" (בראשית א), והוא סיבת המשכב שנרביע בהמות זו עם זו לקיום המינין כאשר יבואו האנשים על הנשים לפריה ורביה. והמרכיב שני מינין, משנה ומכחיש במעשה בראשית, כאילו יחשוב שלא השלים הקדוש ברוך הוא בעולמו כל הצורך ויחפוץ הוא לעזור בבריאתו של עולם להוסיף בו בריות. והמינים בבעלי חיים לא יולידו מין משאינו מינו, וגם הקרובים בטבע שיולדו מהם כגון הפרדים יכרת זרעם כי הם לא יולידו. והנה מצד שני הדברים האלה, פעולת ההרכבה במינים דבר נמאס ובטל: וכו'...

וכבר כתבתי בסדר בראשית (א יא) שהצמחים כולם יסודותם בעליונים ומשם צוה להם השם את הברכה חיים עד העולם, והנה המערב כלאים מכחיש ומערב מעשה בראשית:

5. *Sefer HaHinukh* (anonymous, 13th century, Barcelona), #545, *Sending off the Mother Bird*.

משרשי המצוה לתת אל לבנו שהשגחת האל ברוך הוא על בריותיו במין האדם בפרט, כמו שכתוב כי עיניו על כל דרכי איש וגו', ובשאר מיני בעלי חיים במינין דרך כלל, כלומר שחפצו ברוך הוא בקיום המין, ועל כן לא יכלה לעולם מין מכל מיני הנבראים, כי בהשגחת החי וקיים לעד ברוך הוא על הדבר ימצא בו הקיום, ובהניח האדם דעתו על זה יבין דרכי ה' ויראה כי המשכת קיום המינין בעולם שלא כלה ואבד אחד מכולם מביצי כנים ועד קרני ראם מיום שנבראו הכל במאמרו וחפצו על זה. וכו'

The purpose of this commandment is to make us aware that God's providence is over all His creatures—especially over humanity, as it says, "*for His eyes are upon the ways of humanity*" (Job 34:21). And over other living species [God's providence] is general. That is to say, that He, may He be blessed, wills the existence of the species, and therefore not one of the created species will ever go extinct, for it is within the providence of the blessed One who lives and lasts forever, over each thing that exists. And when a person contemplates this, he will know the ways of God, and see [God's glory] in the continued existence of the species in the world, that not one of them goes extinct and is lost, from eggs in the nest to the mighty horned-ram, from the day that they were created—all that exists is according to [God's] word and will.

6. *Sefer HaZohar* (c. 13th century, Spain), P' Kedoshim, III: 86b. Translation by Daniel Matt, *The Zohar: Pritzker Edition* (Stanford UP, 2014), Vol. 8, pp.39-40.

ועל דא כתיב את חקותי תשמרו בגין דכל חד וחד ממנא על מלה ידיעא בעלמא בההוא חק, ובגין כך אסיר למחלף זינין לאעלא זינא בזינא אחרא בגין דאעקר לכל חילא וחילא מאתרייהו ואכחיש פמליא דלעילא, ואכחיש פומבי דמלכא.

Thus it is written *huqqotai, My statutes you shall keep. [Your cattle you shall not mate kilayim with a different kind; your field you shall not sow kilayim, with two kinds; two kinds of threads—shatnez--shall not come upon you]* (Lev. 19:19)—because every single one is appointed over a specific object in the world by that hoq. Consequently, it is forbidden to switch species, to insert one species into another, because one thereby uproots each power from its place and negates the celestial family, falsifying the royal solemnity.

7. Rambam, *Guide of the Perplexed* III: 18, trans. Shlomo Pines (U Chic., 1963), pp.474-5.

After what I have stated before about providence singling out the human species alone among all the species of animals, I say that it is known that no species exists outside the mind, but that the species and the universals are, as you know, mental notions and that every existent outside the mind is an individual or a group of individuals. This being known, it is also known that the divine overflow that exists united to the human species, I mean the human intellect, is merely what exists as individual intellects…. Accordingly, divine providence does not watch in equal manner over all the individuals of the human species, but providence is graded as their human perfection is graded….

8. Maharal (R' Yehudah Loeb b. Bezalel, c.1520-1609), *Be'er HaGolah*, 2:10.

ומה שהם תמהים על הרכבת שני מינין, בודאי לפי התורה שנתן הקדוש ברוך הוא לישראל הדבר הוא אסור משום כלאים (ויקרא יט, יט). אבל אדם הראשון היה עושה דבר זה, כי הדבר הזה ראוי שיהיה בעולם, עד שיהיה נשלם העולם. ואף כי לפי התורה שנתן השם יתברך דבר זה אסור מפני שהוא כלאים, דרך התורה לבד. וכמה מינים שנברא בעולם והתורה אסרם באכילה, ועם כל זה נבראו בעולם, שבהם יושלם העולם. ואין איסור כלאים משום ערוה וזנות, שהרי אסרה התורה אף להנהיג אותם ביחד, ומזה תראה כי איסור כלאים הוא משום שאין לחבר המינים המחולקים יחד, וזה דרך התורה. וכבר אמרנו דרך התורה בלבד, והשלמת העולם לבד.

As for those who are surprised by [God's instruction to Adam for] grafting of two species, certainly according to the Torah given by the Holy One to Israel this practice is forbidden as *kilayim* (Lev. 19:19). But Adam the First was to do this act, because this [new species] deserved to be in the world, so that the world would be completed. And even though the Torah that the blessed God gave forbids this [mixing] as *kilayim*, this is only according to the way of Torah. There are many species that were created in the world, and the Torah forbade [Jews] from eating them, and yet they were made in the world to complete the world. And the prohibition of *kilayim* is not a matter of sexual perversion, for the Torah also prohibited plowing with them together. This indicates that the prohibition of *kilayim* is only about [not] joining two separate species together, according to the way of Torah. And we have already explained that the way of Torah is one thing, and the completion of the world is another.

9. Psalm 8 and *Midrash Bereshit Rabbati*, *Vayetze* (p.129).

(ה) מָה־אֱנוֹשׁ כִּי־תִזְכְּרֶנּוּ וּבֶן־אָדָם כִּי תִפְקְדֶנּוּ: (ו) וַתְּחַסְּרֵהוּ מְּעַט מֵאֱלֹהִים וְכָבוֹד וְהָדָר תְּעַטְּרֵהוּ: (ז) תַּמְשִׁילֵהוּ בְּמַעֲשֵׂי יָדֶיךָ כֹּל שַׁתָּה תַּחַת־רַגְלָיו: (ח) צֹנָה וַאֲלָפִים כֻּלָּם וְגַם בַּהֲמוֹת שָׂדָי: (ט) צִפּוֹר שָׁמַיִם וּדְגֵי הַיָּם עֹבֵר אָרְחוֹת יַמִּים: (י) יְקֹוָק אֲדֹנֵינוּ מָה־אַדִּיר שִׁמְךָ בְּכָל־הָאָרֶץ: תהלים פרק ח

What are humans, that You have been mindful of them, mortals, that You have taken note of them, that You have made them little less than divine, and adorned them with glory and majesty; You have made them master over Your handiwork, laying the world at their feet, sheep and oxen, all of them, and wild beasts too; the birds of the heavens, the fish of the sea, whatever travels the paths of the seas. O LORD, our Lord, how majestic is Your name throughout the earth! (Psalm 8: 5-10)

ותחסרהו מעט מאלהים (תהלים שם ו') זה יעקב שנאמר ויחמו הצאן אל המקלות. א"ר הושעיא היה צר צורה וכשם שהיה צר נעשו המים זרע בתוך מעיהם וכך היו יולדות, מלמד שלא היה חסר אלא לתת בהם נפשות.

That you have made them little less than divine—This refers to Jacob, for it says (in Genesis 30:39), *and since the goats mated by the rods*…. Rabbi Hoshaya explains, "He would draw an image, and just as he drew, so the seed formed in the water of their wombs, and so did they give birth. This teaches that [Jacob] lacked only the ability to give them a soul."

10. *Arukh HaShulḥan* of Rabbi Yehiel Michel Epstein, *Yoreh De'ah* 84:36.

האמת הוא דלא אסרה תורה במה שאין העין שולטת בו דלא ניתנה תורה למלאכים.

In truth, the Torah did not forbid anything that the [naked] eye cannot perceive, for the Torah was not given to angels….

11. Responsa of R' Shlomo Zalman Auerbach, *Minḥat Shlomo* II, 100:7.

בענין שאלתו בדבר הנדסה גנטית, שמכניסים חלקיקי תאים מבריה אחת לשניה, ובזה משנים את תכונותיה של השניה, וע"ז להתיר איסור כלאים מכיון שאין חלקיקים אלו נראים לעין האדם, כיון שאנשים מטפלים בחלקיקים האלה ומעבירים אותם ממין אחד לשני הרי זה חשיב ממש כנראה לעינים ולא דמי כלל לתולעים שאינם נראים.

Regarding his question regarding genetic engineering, where they insert cellular materials from one organism to another, and in so doing transform the structure of the second, whether this action can be exempted from the prohibition of kilayim since these cellular materials are not visible to the [naked] eye: [In my opinion,] since the workers are manipulating these materials, and transferring them from one species to another, this should certainly be considered as "visible to the eyes," and it is not comparable to [the permission to eat] microscopic worms, which are not seen.