Considering Chimeras
The Confluence of Genetic Engineering and Ethics

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Mythological chimeras were human-animal combinations resulting from the mating of different orders of beings: humans with animals or gods with animals.¹ Legend has it that the conduct of chimeras in ancient Greece included behavior that ranged from wise to wild to wicked deeds. Unless one is a student of Greek mythology, recollections about the deeds of the chimeras are usually imprecise and devoid of distinctions of good and bad. The lingering association is often fear of these unnatural amalgamations, which gives rise to a pervasive but largely ungrounded uneasiness about chimeras in general.

Rather than simply rejecting scientific endeavors to produce chimeras because they are strange or threatening, society is better served by being scientifically and ethically equipped to make difficult choices in this arena. This article will present several examples from the voluminous scientific literature on chimeras in order to illustrate the scientific and ethical distinctions among them. I will then propose three diverse perspectives as a starting point for ethical deliberation about genetic engineering. I will use the term genetic engineering broadly to include any technology that directly modifies human genes or introduces plant, animal, human, or “designer” genes or cells where they have not occurred before in an individual or the human population. The guidelines propose Thomas Aquinas’s reflection on the integrity of the human person, a lesson from evolution about the risks inherent in manipulating complex genomes, and Immanuel Kant’s caution concerning the limits of human

knowledge. The rapid advances in genetic engineering mandate that we adopt a far-reaching view of the biotechnological future, ask the larger questions, and consider the broad ethical issues in our analysis.

**Contemporary Chimeras**

One way in which contemporary chimeras differ from their mythological counterparts is that the scientific term *chimera* broadly designates the blending of material from two different organisms into one. The term encompasses both intra-species and inter-species creatures composed of cellular or genetic admixtures, or both. Thus, clinicians create a human-human chimera when they perform an allogeneic bone marrow transplant, which is a combination of cells from two separate individuals (the bone marrow cells from the donor being transplanted into the recipient). In comparison, scientists create a human-animal chimera when human embryonic stem cells are integrated throughout an animal system. For the purposes of this discussion we will use the term *chimera* inclusively to indicate a creature produced by the transfer of genes, chromosomes, cells, or organs from one organism to another.

Like our Athenian predecessors, we will evaluate chimeras ethically and morally on the basis of their origins and purposes and how they affect humanity. The purposes of mixing genes of different animals are to learn more about human biology, to create safer and more effective therapies, and to cure diseases through transplantation. Chimeras produced for these purposes have already greatly benefited human health, but it is also possible that this technology could be used for potentially disastrous ends.

This section will present a brief discussion of contemporary chimeras in order to make two central points. First, a current and accurate analysis of the procedures and purposes of scientific research must inform a credible ethical analysis. Good facts make good ethics. Second, rapid advances continue to transform our ideas about what science can and cannot do. Former notions about fixed demarcations between and among species are no longer correct. Recent research has demonstrated that lines between species are malleable and genes are interchangeable.

**Microbial Factories**

Therapeutic insulin is a widely used pharmaceutical product in the treatment of type 1 diabetes, commanding annual global sales in excess of $4.5 billion in 2002, with projected sales of $7.9 billion in 2007.² Innovations in the methods of insulin production include its production by genetic engineering. This is an example of a technological advance that involves the production of human-nonhuman chimeras. Insulin therapy is essential to the survival of most persons with type 1 diabetes, and controls the symptoms of a small percentage of persons with type 2 diabetes. Diabetes mellitus kills approximately 3.2 million people annually.³ Conventional insulins were animal-derived and were weakly immunogenic in humans, meaning that anti-insulin antibil-

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ies were detected in some diabetics to whom insulin had been administered. In 1960, the amino acid sequence of human insulin became known, and scientists confirmed that the sequence of human insulin differs slightly from that of animals.4

The advent of recombinant DNA technology in the 1970s was a significant advance in that it provided the technology to synthesize insulin with the human DNA sequence. Human insulin was the first human protein produced by the insertion of genes into bacteria (Escherichia coli) in the late 1970s and yeast (Saccharomyces cerevisiae) in the early 1980s.5 At that time, animal-derived insulin could not meet the growing demand for insulin therapy, necessitating recombinant production to meet existing and future patient needs. Recent advances include the production of genetically engineered insulin analogues, which are either short- or long-acting products and which more closely mimic individual secretion patterns.6 The future demand for insulin products is potentially enormous; nearly 171 million people suffered from diabetes mellitus in 2004, and that figure is likely to double by 2030.7 Human-nonhuman chimeras created in projects such as these entail a process and a purpose that are ethically imperative.

*Mice with Human Hematopoietic Stem Cells*

In the clinical setting, autologous stem cell transplantation is becoming a standard therapy for many diseases, including hematopoietic malignancies and diseases of the immune system. Human hematopoietic stem cells (hHSCs) are obtained from adult bone marrow, peripheral blood, or umbilical cord blood. They are renewable cells with the potential to give rise to the various types of blood cells normally found in the body. Scientists recently produced a human-animal chimera by the insertion of hHSCs from human peripheral blood into immunodeficient mice to study hHSC function. They reported that this mouse model supported high levels of engraftment and multilineage differentiation following injection with peripheral hHSCs.8 Engraftment is the process by which the body accepts an infusion of stem cells and produces the different types of blood cells usually present. The research proved successful engraftment by demonstrating the model’s ability to produce a wide variety of T cells needed to respond to many different potential targets, and the ability of the immune cells to multiply normally.

This new humanized mouse model mimics the development of a functional human immune system, and thus can provide important insights into how the immune system functions, how it kills cancer cells, and how it responds to radiation and chemotherapy. It can also facilitate the testing of experimental human vaccines and can clarify the development of human autoimmune diseases. The data suggest that

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4 Walsh, “Therapeutic Insulins,” 152.
5 Ibid., 151–159.
6 Ibid., 155.
these chimeric mice will be a good model for studying hHSC engraftment, differentiation into multiple human blood components, and analysis of human immune responses to drug regimens without exposing patients to risky procedures.

At first, it may seem that the creation of humanized mice is strange or even precarious. However, an analysis of the methods and purpose of the study reveals that this procedure is an ethically acceptable means for researchers to study the human immune system. It avoids the use of embryonic stem cells (ESCs) and tissue from aborted fetuses. This breakthrough allows researchers to investigate means to increase the success rate of hHSC transplantation, and potentially benefits patients suffering from blood cancers and certain genetic and immune disorders.

Rodents with Human Neural Stem Cells

Mice with traumatic spinal cord injuries regained much of their ability to move normally after receiving injections of human central nervous system stem cells (hCNS-SCs) taken from fetal brains.9 Neural stem cells are self-renewable primordial cells with the capacity to give rise to all neural cell lineages. Scientists injected hCNS-SCs in four places around the injured spinal cords of mice nine days after the mice sustained identical contusions to the spine. The mice were subsequently euthanized at twenty-four hours, forty-eight hours, four weeks, or seventeen weeks. Within twenty-four hours, the hCNS-SCs had traveled into the injured spinal cords. Sixteen weeks later, the mice demonstrated agility and leg coordination and scored significantly better on agility tests than similarly injured mice that had not received the cell injections. The study mice also scored significantly better than similarly injured mice that had been injected with human liver fibroblasts.

The researchers who conducted the agility tests did not know which mice had received the hCNS-SC injections. Microscopic analysis showed that most of the hCNS-SCs had developed into neurons and oligodendrocytes in the spinal cord, and a few had developed into astrocytes, which contribute to scar formation and are undesirable around injuries. These human-nonhuman chimeras demonstrate the functional integration of transplanted hCNS-SCs into the spinal cords of mice and show that, in some cases, the hCNS-SCs even become replacement neurons. These data suggest that hCNS-SCs might possess therapeutic potential for central nervous system injury and disease. The scientists conducting this study claim that it is only the first in a long series of steps before a clinical study in humans can begin.

A second study of rodent chimeras with hCNS-SCs derived from sixteen-to-twenty-week fetal brain tissue sought to characterize the survival, migration, and differentiation of these cells when transplanted into the cerebral cortex of immunosuppressed ischemic rats.10 The transplanted cells remained viable in naive and is-


chemic brains of adult rats four weeks following transplantation. In naive brains the cells migrated little; in ischemic brains the cells migrated extensively toward the lesion, indicating a potential for human stem cells to repair stroke lesions.

The clinical benefit is still to be determined, but this study raises moral questions for Catholics. It is possible that the fetal brain tissues used in this study came from spontaneously aborted fetuses; if that is the case, the procedures are licit according to Catholic teaching. However, one unconfirmed report suggested that the source of the brain tissue was sixteen- to eighteen-week aborted fetuses. Procedures utilizing tissue from aborted fetuses are unethical according to Catholic teaching. John Paul II in an address to the World Medical Association in 1983 stated, “The person’s right to life—from the moment of his conception till his death—is the first and fundamental right, the root and the source, as it were, of all other rights.” This teaching is fundamental to Catholic moral assessment of genetic engineering. Those procedures that destroy the human embryo or fetus or use them merely as tools of research are immoral.

In the studies described above, the potential cures for suffering patients would initially depend on a supply of human fetal brain tissue. A patient undergoing this therapy would reject fetal cells in the absence of immunosuppressive treatment. This means that, if this procedure were successful, it would require tissue from a number of fetuses to produce different lines of hCNS-SCs, to match them as closely as possible to each individual patient in order to mitigate the immunogenic response. The problem of rejection of autologous stem cell treatments (fetal or embryonic) and the significant side effects of the accompanying immune suppression drugs is a noteworthy issue that is rarely addressed in the literature touting the potential clinical benefits of embryonic stem cell research. The development of alternative approaches to treating neurodegenerative disease, which avoid the dual problems of immune suppression and the destruction of human embryos, could include the dedifferentiation of adult cells and other means of producing the treatment cells.

A second ethical concern about the study by Kelly et al. is that the placement of hCNS-SCs in rats might create some sort of nonhuman animal with a strong animal-like appearance but a very low level of human-like intelligence. Given that a rat brain is one thousandth the size of a human brain and is structured very differently in its twenty-day gestation period, the possibility of anything near human intelligence in a rat is extremely remote. That said, there are ethical concerns when there is a slight chance of human thought-like function being produced in an animal form. Because scientists know so little about what constitutes the human mind, it is extremely difficult to offer any clear guidance as to where to draw the line in experiments such as this. I will

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address the limits of human knowledge in more detail below. However, the use of other adult stem cell types, tested in the treatment of stroke and myocardial infarction with similar results (including human bone marrow cells\textsuperscript{14} and human umbilical cord cells\textsuperscript{15}), avoids these concerns and provides a potential means to the same therapeutic goal.

**Nonhuman Primates with Human Neural Stem Cells**

In an effort to study how human neural stem cells (hNSCs) segregate during development, scientists grafted fetal hNSCs into the developing brains of fetal bonnet monkeys (*Macaca radiata*). The purpose was to determine the fate of hNSCs transplanted at a time when cells that form the brain are migrating and differentiating in the developing embryo.\textsuperscript{16} With ultrasonic guidance, bonnet monkey fetuses at twelve to thirteen weeks’ gestation received a single in utero injection of undifferentiated labeled hNSCs into the left cerebral ventricle. Pregnancy continued until sixteen to seventeen weeks gestation, when the fetuses were delivered by cesarean section and their brains were processed for analysis. The investigators determined that the injected hNSCs distributed themselves throughout both hemispheres of the primate brain. The researchers could not quantify the percentage of grafted cells that survived, but images showed a large number of hNSCs in all primate fetuses. The data demonstrate that migration may be a stem cell property that is important for cell replacement in diseases that involve many different abnormalities or injuries. The human-nonhuman primate chimeras were sacrificed as part of the study.

This study is ethically unacceptable according to Catholic teaching, for the reasons discussed above. A recent scientific perspective on the transfer of neural cells into developing animal brains also deemed studies like this one unethical on a different premise. Foreseeing the spread of chimeric models, the research guidelines of the National Academy of Sciences (NAS) defined two specific cases in which the creation of human-animal chimeras raises ethical issues. One guideline opposes those interventions that involve the transfer of human embryonic stem cells into nonhuman primate blastocysts or human blastocysts (partly because such ES cells could give rise to germ-line cells), and another opposes the mating of chimeric animals (to prevent two human gametes joining and gestating in an animal body).\textsuperscript{17} The guidelines also mention concerns that apply broadly to interventions like that described in the bonnet monkey


\textsuperscript{17}Committee on Guidelines for Human Embryonic Stem Cell Research, *Guidelines for Human Embryonic Stem Cell Research* (Washington, D.C.: National Academies Press, 2005), 39, 55, and 99, sections 1.2(c)(2) and 1.2(c)(3).
study. The authors of the guidelines deem any experiment that could potentially result in human-like thought in an animal body to be a cause for concern.\textsuperscript{18}

**Ethics Looking Forward:**
**Where Should We Go from Here?**

These examples of contemporary chimeras provide ample evidence of the speed with which the field is moving and the virtually endless possibilities for novel genetic combinations. The biotechnology industry will be fully capable of altering the human genome in significant ways in the near future. The transfer of human genes into animals frequently causes concern because it raises ethical questions involving the uniqueness of the human species, the point when a chimera would become too human, and what moral obligations we would have if it did become more human.\textsuperscript{19} The examples indicate that human research trials and clinical applications will occur before long. The widespread acceptance of related biomedical interventions, such as mind-altering and performance-enhancing drugs, suggest that those who can afford it will want access to genetic engineering as soon as it appears to be safe and effective. The demand for genetic engineering that will have some utilitarian justifications will be far reaching, and I will argue that some of its implications will be beyond estimation.

**Totality and Integrity of the Human Being**

A recent article in the in-flight magazine of American Airlines, titled “The Devil Inside,” describes the success of the human genome project and its probable applications. It quotes a prominent geneticist as saying, “What won’t be available? A genome contains all the instructions for how our body behaves, is structured, and functions. We will find the genes that cause disease.”\textsuperscript{20} This prevalent attitude tends to “reduce” humankind to a carrying case for genes, cells, and organs that are available for transfer or transplant or anything else. It relies on a “Genes-R-U” orientation that fosters a popular, but mistaken, notion that causation of human function and disease is purely genetic. Human traits and most human diseases are more complicated than genetics alone, and markers for identifying and predicting disease do not always translate easily, if at all, into practical information about a disease’s causation or treatment. Any argument for a monicausal explanation of any human trait or disorder, possibly excluding single-gene disorders like Huntington’s disease, disregards the deeply interconnected nature of molecular biology, the influence of the environment on phenotype, and the power of the human spirit to shape how human beings function.

In contrast, Aquinas is the champion of the integrity of the human person. His complementary principles of totality and integrity maintain that the good for human-kind equates with the unity of the human person in the interaction of the person’s bodily, affective, intellectual, and spiritual dimensions. The principle of totality em-

\textsuperscript{18} Ibid., 39–40, 50.


phasizes the preservation of the physical whole of the body, and the principle of integrity delineates the hierarchical order of members of the body. For Aquinas, unity encompasses the good of lower bodily functions as well as that of higher intellectual activities, with the role of each organ or function subordinate to the whole. This principle should not be misconstrued to require a quantifiable set of features or functions—quite the contrary. It is the good of the whole person, regardless of his or her attributes, that is the focus of this principle. Aquinas maintained that health is integral, rather than instrumental, in the fulfillment of the good for persons and in the development of each person’s capacity for moral virtue.

Aquinas argued that anything that endangers the overall function of a person, such as the surgical removal of a healthy limb, is prima facie impermissible. Conversely, those interventions that are intended to preserve the unity of the body are permissible. Following from that, the removal of a diseased part of the body is moral, because serious damage to bodily function is remedied by surgical removal of the organ.21 Likewise, the removal of a healthy body part that serves no known role in effective human biological functioning, like the appendix, is consistent with the principle of totality, in that it neither suppresses or harms the integrity of the body. Organ, tissue, and blood donations are also morally permissible under this principle, as long as the purpose is charity and the donation does not impede adequate biological function. Thus, the emphasis falls on the preservation of unified bodily function, rather than a narrow interpretation of anatomical wholeness.

Applying the principle of totality to genetic engineering, the human-human or human-nonhuman transfer of organs, cells, or genes involved in lower anatomical functions, excluding germ-line cells as discussed above, is prima facie permissible. Interventions that are not permissible include those that entail immoral means or distort one anatomical function to the detriment of the whole. When the principle is applied to higher intellectual functions, a transfer of human-human or human-nonhuman cells or genes that accentuates or separates the role of the intellect from the integral whole could thwart the good for human beings. For example, interventions that adjust intellectual function as an end in itself are prima facie not permissible.

The principle of totality is an important guideline for assessing the broad range of present and future innovations in genetic engineering, because it emphasizes the good in life that supersedes current socially constructed standards of perfection. It distinguishes between moral interventions that preserve or restore the integral function of the human being and immoral ones that disrupt or denigrate it. The principle of totality brings to the discussion a means to assess interventions based on the premise that the attempt to maximize or degrade some human trait or function has the potential to deform other vital traits and destroy the good of the human whole. In this way, the principle of totality provides a reasoned measure by which we can evaluate practical applications of genetic engineering and consider the possibility of real human enhancements.22


22 John Paul II, “The Ethics of Genetic Manipulation.”
The Value of Evolution

We have argued elsewhere that there is a nonobvious value in our genetic heritage as shaped by evolution that is pertinent to the assessment of the multitude of novel genetic variants proposed by genetic engineers. Science cannot answer practical questions about the moral life, but the process of evolution has a great deal to teach us about the nature of human biology and the profound challenges of managing the risks inherent in manipulating complex genomes. The value of evolution lies in the appreciation of how our genetic heritage was shaped and the intricate role it plays in the development of organisms. That recognition should generate caution among those who regard genetic engineering as just another means of manipulating nature.

As scientists learn more and more from the sequence and annotation of the human genome, they gain a greater appreciation of the tremendous intricacy of human traits and anatomical functions. Added information from advances in the field of epigenetics indicates that it is not merely the gene sequences and their products, but also gene-gene and gene-environment interactions, which influence biological development. The complexity of genomics and the subsequent uncertainty involved in transferring and manipulating genes will make the consequences of genetic engineering particularly difficult to evaluate until scientists accumulate sufficient data on the risks and benefits in animal models, which may take a long time to become apparent.

The interaction between and among genes, combined with the multiple functions of most human genes, makes it extremely difficult to produce safe and effective changes in human or animal genomes. The response of a foreign gene in a chimera is determined by the entire genetic composition of the host organism; thus, minor changes in one gene can, by virtue of the complex interactions of genes, have completely unexpected consequences in activities of the organism that were thought to be unrelated to the function of the gene. By definition, the production of a chimera entails the departure from naturally occurring and well-studied genetic combinations. Thus, scientists must correctly predict the phenotypic consequences of previously unobserved genetic or cellular mixtures in novel organisms and their interactions with the environment, a task that is extremely difficult in evolved systems.

The existing products of evolution are not optimal or flawless. Nevertheless, the successes and failures of evolution over untold numbers of years indicate that scientists, with their partial knowledge of genetics and finite temporal scope, will have limited capacity to predict the consequences of their newfound ability to alter our genetic heritage. The directive garnered from the process of evolution is that caution is essential when manipulating complex and interdependent genomes in the


production of novel organisms through the blending of cells and genes of species that have developed as reproductively separate entities. Moreover, an appreciation of evolution renders those endeavors of genetic engineering that promise dramatic improvements on nature as mere hubris.

This discussion should not be misconstrued as a signal to “proceed with caution.” Safe and successful new combinations, similar to the microbes that produce human insulin, will be discovered and yield tremendous benefit. However, other novel combinations will have the potential to cause irreversible harm, and still others will fall into the gradations between. Scientists and the public should be prepared through oversight and regulatory mechanisms to analyze each innovation on a case-by-case basis, reject those that are likely to entail unethical methods or harmful consequences, and prudently suspend those that cannot be evaluated responsibly.

It may seem strange that I would recommend evolution as a guideline for the ethical assessment of genetic engineering in a Catholic journal. Rather than ignore the possibility of using evolution as a guideline, a very brief discussion of the Church’s position on evolution may be informative. The Catholic Church has no formal doctrine on evolution. In a now-famous statement made in a letter to the Pontifical Academy of Sciences in October 1996, John Paul II stated, “new knowledge leads to the recognition of the theory of evolution as more than a hypothesis.” This statement indicates that there is no inherent contradiction between Catholic teaching and at least some theories of evolution. Rather, what is mandated by the Catholic faith is the direct creation of the human soul by God. Certain theories of evolution that endeavor to comment on metaphysical issues contradict science, because judgments about metaphysics are outside the empirical realm of science, and vice versa.

Limits: Finitude and Freedom

This brings me to a third principle for the evaluation of genetic engineering that I have addressed in greater detail elsewhere: the acknowledgment of the lack of commensuration between human ability to act and the ability to predict the consequences of our actions. Many aspects of this new technology take us beyond the limit of our experience from a causal standpoint into assumptions based on predictive foreknowledge. Immanuel Kant, the eighteenth-century philosopher, placed limits on knowledge based on the difference between what we can know and what we can merely think. The basis of his distinction was the notion that the thing-in-itself is an object that is thinkable, but not knowable. Reason is aware of the appearance of an object of experience and synthesizes its meaning through the understanding, but the knowledge of the thing-in-itself as it really is eludes us. For Kant, this precludes a claim to

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knowledge of anything beyond possible objects of experience. It follows that when reason reaches beyond the confines of time and space, it cannot claim knowledge of entities outside those established boundaries. What is metaphysical—for example, God or the good for humankind—falls into the category of the thinkable but not knowable, because metaphysical truths are nonspacial and nontemporal. Kant maintained that it is not only acceptable but characteristic of reason to want this complete freedom of thought, but it is essential to acknowledge the limitations in this endeavor.30

Clearly, Kant is not in the tradition of Aquinas, who maintained that there is an order in the world that is knowable by human reason and justifies principles of morality.31 Following from that basic premise, Aquinas asserted that reason transcends the empirical realm and, therefore, can apprehend metaphysical truths. While I espouse the Thomist position on human reason and metaphysics, the discussion here is about science and the acknowledgment of the limits of human knowledge in the scientific realm. For that reason, I will draw upon Kant for a philosophical approach that limits itself to the experiential, and thus provides practical insight for thinking within the confines most comfortable to contemporary scientific researchers. The practical application of Kantian philosophy for genetic engineering is that one may contemplate the consequences that certain policies or actions entail, but one should do so with acknowledged limitations, because there is no way to be certain about what is beyond experience. Acknowledging this limit is an important step in an ethical approach to policies and guidelines developed to guide genetic engineering.

In an obscure appendix to his book *The Critique of Pure Reason*, titled “Amphiboly of the Concepts of Reflection,” Kant used “the concept of nothing” to clarify the limitations of knowledge.32 The concept of nothing emphasizes the difference between the perception of an object and the object itself, without deeming the object totally unknowable conceptually. This notion does not reject the possibility of an asymmetrical relationship between an object and observer’s concept of it, but it calls attention to human limitations in the presence of difference. The practical application of nothing is that the risks of genetic engineering are unknown and the future applications of the technology, in particular, are undetermined. Kant’s notion of nothing underscores the fact that we can think about risks and future applications, but we cannot know them with certainty.

Kant further defined the concept of nothing with a fourfold articulation.33 I will discuss only two of these. First, the notion of quantitative reflection indicates awareness that certain concepts that we can think about will be inadequate for their intentional objects. This is because the proposed object will always exceed the concept that we use to comprehend it.34 The practical application of quantitative reflection is the

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33 Ibid., 295.
34 Ibid.
acknowledgment that the complexity of the genome and its interconnection with the environment transcends any concept that we can have of it, because scientific concepts are inadequate for their objects. Scientists are only beginning to understand the information that the genome holds, and that knowledge will increase exponentially in the future. There are virtually no limits to what science can perceive, but it is important to acknowledge that there are some limits to what it can know.

The second articulation of the concept of nothing is relational reflection; it is a schema for recognizing the limits of our abilities to accomplish certain aims or ends. The emphasis in relational reflection is on the difference between our intentions in space and time and our ability to bring them to realization. This notion emphasizes our inability to determine our spatiotemporal existence definitively. The applications to genetic engineering are the stated goals of the eradication of genetic disease and the complete control of the mechanisms of ageing; in reality, both are imaginable but elusive. Each new advance reveals new obstacles and challenges, and each scientific success entails scientific, social, and ethical ramifications—some predictable and others largely unknown. The risks and benefits of genetic engineering are incomprehensible in their entirety. Kant probably would say that there is likely to be an unbridgeable gap between the intentionality of biotechnology and its realization in spatiotemporal terms. This concept defines the gap between conceptual and sensible knowledge and expresses the limits of our ability to bridge that gap. The notion of nothing and its articulations reveal the limitations of the ability to achieve the goals of science completely and predict the consequences with certainty. As a guideline, it calls scientists, entrepreneurs, and society to understand the human finitude and to acknowledge it in ethical analysis and the pursuit of policy formation.

Who Will Benefit?

The stated purpose of the Human Genome Project from its inception to the present has been the translation of genomic knowledge into improved human health. The objective is to use the new understanding of genetics to develop new ways of preventing and treating diseases and to personalize the use of drugs to maximize benefits and minimize potentially harmful side effects for individual patients. The studies discussed here address this goal through a focus on specific diseases. Future studies are likely to explore the whole spectrum of human health and disease from the perspective of genome science.

An analysis of genetic engineering is remiss unless it takes into account the likely beneficiaries of promised improvements. Will the potential clinical applications benefit only those with financial resources, or will they address the health-care needs of those on the margins of society as well? If we disregard this question in the early phases, it is unlikely that the neediest will ever benefit from genomic medicine. There is ample evidence that socioeconomic level is a significant indicator of health status; the poor experience greater mortality and morbidity than their well-off counterparts.35 The development of new therapeutics rarely focuses on the morbidities found predominantly

among the poor, because the motivators of fame and fortune are reduced or absent in research for that population. Profits are necessary components of advances in health care; without financial resources, there will be no advances in medicine, and everyone will lose as a result. However, if profit alone sets the direction for genetic technology, it could disregard the good for human beings that health makes possible.

Catholic tradition has a long-standing and rich history of commitment to the principle of social justice, or rendering what is owed to each person. Hence, members of our tradition are well positioned to raise the consideration of social justice in deliberations about genetic engineering. Justice is determined not merely according to financial status, but includes both material and nonmaterial components of the common good. Health care is one of the common goods that everyone requires, regardless of position in society. Social justice in genomic medicine requires that all members of society have access to it and that its distribution occurs fairly in the overall use of society’s resources. Attention to this principle would direct genetic engineering away from costly high-tech interventions that would benefit only a few and toward innovations that would improve access to therapeutics for impoverished or rural populations.

It is hard to deny the wide-ranging potentials for benefit and harm that are inherent in genetic knowledge. The challenge for society is to maximize the advantages and minimize the risks fairly. In addition, the future will require all that is best in human wisdom to overcome the dual fallacies that human beings are merely a carrying case for genes and that science will someday transcend the boundaries of human finitude and become limitless. The tasks for ethics in the genomic era are to expand the ethical domain beyond a mere utilitarian analysis of new technologies, promote philosophical judgment about what is truly good for humankind, and foster recognition of those interventions that are beyond the limits of science to evaluate or judge. The tasks are formidable but essential!