
THE IMAGE OF GOD IN THE POST-GENOMIC AGE

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Introduction

On June 26, 2000, a special press conference was held at the White House where the leaders of two competing research groups came together with President Bill Clinton and Prime Minister Tony Blair to announce the publication of the human genome. In many ways, for biologists this is a milestone in our field. From now on, people will talk about the *pre-genome* and the *post-genome* ages in much the same way that people divide history using B.C. and A.D.—it is that significant. You are I are living in the beginning of the 21st century, which already has been called the century of biology.

In this lecture, I would like to introduce you to the Human Genome Project, as well as to highlight some of insights it has given to us in our understanding of who we are as human beings, made in the image and likeness of God.

My lecture is divided into three parts.

- First, I will begin with a short presentation of the biology of the human genome. For some of you it has been many years, even decades, since you have had biology. For some of my Dominican brothers, it was probably a time before the discovery of DNA in 1953! I will begin by giving you an outline of what exactly the human genome is.
- Second, I would like to explore how the Human Genome Project has helped us to better answer the question of origins and the relationships that we have with each other within the human population, and even more intriguingly, the relationships between our species and the many other species that the Lord has created in this world.

- Third, I will talk about how genetic science has impacted our understanding of human behavior. This is really a reflection on the nature-versus-nurture controversy, and I would like to suggest that in many ways the controversy can be reconciled by some recent discoveries in genetics.

Finally, throughout my lecture, I will comment briefly on how these biological discoveries can potentially impact philosophical and theological reflection.

The Human Genome

The human genome is made up of deoxyribonucleic acid, more popularly known as DNA. DNA encodes a sequence of chemical molecules that can be represented by four letters, G, A, C, and T. When someone talks about a genome, he is talking about the sequence of molecules that specifies the information that is necessary to build a particular organism. Our genome, the human genome published in 2000, is made up of three billion letters, a sequence of G, A, T, C. To give you a sense of the enormity of the information encapsulated in the genome, if you type the sequence as a single sentence in New Times Roman font, 12 point size, you would discover that the sentence would stretch from Washington, D.C., to Houston, Texas, and that the information would fill up the equivalent of two hundred New York City size telephone books. The challenge of the next century will be to try to understand and to make sense of this information.

Moving to the organization of the human genome, the three billion letters can be divided into twenty-three volumes. Each volume, which we call a chromosome, is a single piece of DNA. There are twenty-two non-sex chromosomes, and then there are the special sex-determining chromosomes, X and Y. Each one of us receives one copy of each chromosome from our father and one copy from our mother. Thus, each human being has forty-six chromosomes in each one of his or her cells that specify the information needed to make the human cell the cell that it is.

Each volume of the human genome, each chromosome, can be further subdivided into sentences, where a sentence

represents a gene. One of the surprising discoveries of the Human Genome Project is that we only have around 25,000 genes. Why is this surprising? It is surprising because of the following facts: If you sequence the genome of the ordinary fruit fly, the fly has 14,000 genes. If you sequence the genome for rice, on the other hand, rice has 38,000 genes. So one of the fundamental questions in biology is how can so little do so much? How can 25,000 human genes explain a Mozart Symphony? What makes us fundamentally different from a fly and from a rice plant? Clearly the number of human genes cannot account for our complexity.

I would like to suggest that this opens up a possibility for philosophy. For many years, there has been a tendency to reduce everything to genes. This is changing. There is a new field called *systems biology*, which is attempting to understand the organization of life, looking at molecules organized in three-dimensional space. What many of these scientists have concluded is that it is not simply the identity of the molecules that is important for biological function. How they interact in a dynamic fashion is also significant. I would like to suggest that this opens up a conceptual space in biology for the reintroduction of the formal cause. Formal causality and the study of molecular organization will allow us to recover a much deeper understanding of life precisely because modern biological science has demonstrated that you cannot simply explain life on the basis of material or efficient cause alone.

Biological Origins and Relationships

What are we going to do with the human genome now that we have it? One of the priorities of biologists involves what is called *comparative genomics*. We are simply going to take this human genome and we are going to compare it to the genomes of other species and try and figure out what this can tell us.

At this point, let me clarify one thing. There is no one human genome that all of us share identically. One of the genomic sequences published in 2000 is actually the genome of one man, J. Craig Venter, who at the time happened to be the President and CEO of Celera Genomics, the privately-funded company that sequenced the genome. His genome and the second genome described by the International Human Genome Project, the publicly funded research group, now constitute what is called the standard human genome.

Contemporary biology is attempting to explain how each of us differs. Clearly, we are all human and yet we are

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different. What accounts for this difference at the genomic level? A study published in the prestigious journal, *Nature*, which was described in *The New York Times*, suggests that a significant portion of human genomes differs within every human population [Redon et al., *Nature*, 2006].¹ This is not difference in terms of “I have one gene and he doesn’t.” One major difference between individuals is that one person may have three copies of one gene—three copies of the same sentence—while another may only have one copy. This difference in the number of copies of the same gene might be responsible in some partial way for the individuality that makes a person who he is. It is fascinating that the regions of the genome that appear to be duplicated are those areas associated primarily with disease. This might give us some hint as to why individuals are more prone to one disease than to another.

Moving forward from comparing individuals, we can compare populations of human beings. In a study published a few years ago, a group of scientists identified a thousand people from fifty-two different populations scattered around the planet.² To their surprise, the computer was able to group these thousand or so individuals into six genetic groups. Five of these groups corresponded to major geographic regions and to the surprise and distress of some were associated with race. Race has been a very divisive issue in our society here in the United States. A significant amount of effort had gone into trying to minimize the differences among races. Yet the genome project has revealed there may in fact be a genetic basis for the different structures—the different races—in human populations. There are individuals from Africa, from West Eurasia, from East Asia, from Oceania, and from the Americas. These individuals constitute unique populations, so unique that in the past few years, physicians have developed what is now called *race-based medicine*. In other words, they prescribe drugs that will only be effective if a patient belongs to a particular ethnic background. This has been a surprising discovery.

I would now like to talk about our species as such. This is where genomic science has made some fascinating discoveries about the origins of the human species. First, I

am going to focus on the Y chromosome, the chromosome that is responsible for determining sex in our species. Males have a Y chromosome; females do not. Therefore, a son inherits his Y chromosome only from his father. There was a study published some years ago that compared the Y chromosomes of men scattered throughout the planet in much the same way that Fr. Alobaidi, who is a scripture scholar here at the House of Studies, compares manuscripts of a particular text to see whether they are related. The study showed that all of the men on the planet are descended from a single man.³ The original Y chromosomal Adam is thought to have lived in East Africa about 60,000 to 90,000 years ago. In other words, all of the men in this room are brothers, brothers separated by thousands of generations.

In a parallel study, scientists have looked at a piece of DNA in every human being that is called the mitochondrial genome that we inherit only from our mothers. Again, comparing the mitochondrial genomes from individuals scattered around the planet has revealed that every single human being, every single man and woman and child, is descended from one woman, who has been called “Mitochondrial Eve.”⁴ She is thought to have lived in the Eastern part of Africa, some 140,000 years ago.

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Just to add a little confusion, though, I have to say this. To say that every single man is descended from one man, and to say that every man and woman is descended from one woman, is not to say that they were the only man and woman who lived at the time. In fact, looking at the genetic diversity, the differences in the genomes of the six billion people who live today, we can calculate that the ancestral human population, the population that gave rise to the six billion people living today, was approximately 5000 in size.

How do we reconcile this? How can we reconcile the observation that all men are descended from one man with this apparently contradictory conclusion that there were probably 2000 to 2500 other men who lived with him? Let me illustrate an example to help you understand this. Imagine an island and that there are three couples on this

island: the Smiths, the Whites, and the Greens. In the first generation, Mr. and Mrs. Smith have ten sons; Mr. and Mrs. White have ten daughters; and Mr. and Mrs. Green have no children. What you would immediately see is that all the males living on the island would have inherited the Smith family name in the same way they would have inherited the same Smith family Y chromosome. However, this would not mean that Mr. Smith was the only man who lived on that island in his time. It simply suggests that the other men who lived on that island were not able to have sons that would carry on their name. This example illustrates how we can say both that all men today are descended from one man and that this one man was not the only man who was living at the time. Having said that, it is fascinating that we can still say that all men are descended from one man and that all men and women are descended from one woman. This certainly was not expected.

I would like to suggest that this poses a contemporary challenge to theology in this way: How can we reconcile these discoveries of genomic science with a really robust account, a theological account, of the origins of the human person made in the image and likeness of God? In 1950, Pope Pius XII taught that it is “in no way apparent” how polygenism—the opinion which maintains that either after Adam there existed on this earth true men who did not take their origin through natural generation from him as from the first parent of all, or that Adam represents a certain number of first parents—could be reconciled with the sources of faith.⁵ In particular, how would you reconcile polygenism with the doctrine of original sin? To speculate, would it be possible to propose that an original couple committed the original sin that was transmitted throughout the original ancestral human population through culture in the same way that Eve convinced Adam to sin as well?

Finally, I would now like to move to the relationship between our species and other species on the planet.

How can we reconcile these discoveries of genomic science with a really robust account, a theological account, of the origins of the human person made in the image and likeness of God?

Comparing our genome with the genomes of other species—and there are currently over five hundred genomes published on the National Institutes of Health database on the Internet—has revealed that every living organism on this planet is related to the other in the same way that you are related to all of the other human beings in our species. We are all descended from a common species that lived billions of years ago.

It is a fascinating discovery that has medical consequences because it explained why genes are interchangeable among species. For example, my research students and I at Providence College are looking at a gene called BAX-inhibitor, a gene that, when mutated, when broken, leads to different human cancers. It turns out that the simple yeast cell, the Fleischman yeast that you can buy off the shelf of the super market, also has a copy of this gene and that these two genes are interchangeable. If I take a copy of the BAX-inhibitor gene from Brother Dominic and introduce it into yeast cells lacking their own version of this gene, his gene will replace the gene that was lacking in the yeast cell. This facilitates the study of cancer because my students can study the function of human genes without doing research with patients. They can study human genes in the context of yeast cells, or other labs in the context of flies or worms or mice. This discovery also helps us to see that Creation has a certain integrity and a certain beauty because of the relatedness of all living things.

The Genetic Basis of Behavior

Now I would like to move to studies that are looking at the genetic basis of behavior. In many ways this is an area of biology that could profoundly impact how we understand ourselves.

About fifty years ago, there was a great push to reduce behavior to genes. Not surprisingly, there was also a counterpush to identify behaviors that would not be affected by genes whatsoever. The publication of the human genome and subsequent studies in genetics seem to have favored the original proposal. Many studies being published today are identifying genes that influence behaviors that you and I would not have associated with genetics. I would like to describe a few studies to illustrate this trend.

First, there are studies of the gene, *FOXP2*. It was identified because it was found in a family in the United Kingdom



where several members are incapable of learning grammar.⁶ These individuals have problems using or understanding grammar. Families that carry a mutation in the *FOXP2* gene are incapable of learning basic grammatical rules like the rule to make plural nouns from a singular noun by adding an “s”. They simply memorize every single plural verb in order to communicate. But the amazement does not end there. It turns out that mice also have a *FOXP2* gene, and that mice without *FOXP2* were not able to vocalize properly at the ultrasonic range.⁷ It turns out that mice pups need to squeak in the ultrasonic range in order to communicate with their mother. It is incredible that you and I have a gene that we share with mice and that mutating this gene affects communications in a species-specific way.

Next, there is the gene *Mest*. Mice that have a normal copy of this gene are able to build nests, nurse their pups, and bring their pups back when the pups wander off from the nest. If this gene is mutated, if it is broken, the mother ceases to be a good mouse mother.⁸ She does not know how to build a nest and how to care for her pups. They eventually die. It is not yet clear how one gene can have such a profound influence on nesting behavior in mice. Given the similarity between species, it is not surprising that humans have a version of this gene as well. There is an enormous amount of interest in trying to discover what this gene does in us. Would mutating it affect the ability to of a woman to be a mother?

Finally, I want to talk about this gene called D4DR found on Chromosome 11. There are two versions of this gene in the human population. For simplicity’s sake, I will call one “short” and one “long.” The long version is associated with risk-taking or novelty-seeking behavior.⁹ What does this mean? It means it is more likely than not that those “crazy” individuals who enjoy bungee-cord-jumping carry the long version of this gene rather than the short version. Why? Because this gene is important for the body’s use of a molecule called dopamine, a molecule associated with the pleasure center of the brain. One hypothesis is that the long form of the D4DR decreases the sensitivity of the human being for dopamine. Therefore, there is a constant need to experience a dopamine high because this particular mutation diminishes the capacity of

that human being to sense the presence of what would be a normal amount of this dopamine pleasure molecule. This suggests that genes affecting dopamine production play a role in influencing human perception of pleasure. In contrast, genes associated with serotonin have been associated with depression. Individuals who have low levels of serotonin are depressed. High levels of serotonin produce an increased preponderance of being excitable.

What does this have to do with the real world? It turns out that many criminals and incarcerated individuals have, in a way that is not explainable in terms of chance alone, versions of genes associated with low levels of serotonin production. There are ethicists and philosophers who have argued that these individuals are not free to choose what they were incarcerated for. They suggest that they are not truly culpable for their criminal actions.

However, the genome project has also revealed that you and I can actually influence the behavior and activity of genes, so we cannot really say that genes determine behavior. Rather, nature and nurture work together. To illustrate this, I go back to serotonin. As I noted above, genes associated with low serotonin production have been linked to depression. However, to increase your serotonin levels and to activate genes important for the production of serotonin, all you need to do is to eat carbohydrates. In other words, if you are depressed, have a cookie! The cookie will actually change the behavior of your genes. This is probably why people like chocolate. There is a thought that when people are depressed, women who are depressed tend to eat a lot. One possible explanation for this is that eating certain foods changes the behavior of the genes involved in serotonin production. Nature influences nurture but nurture influences nature.

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I want you to leave this chapel knowing that genes do not determine who you and I are. They are intrinsically part of what it means to be human, but they do not

determine what we are simply because we can influence what genes do or do not do.

Conclusion: The Effort to Sequence the Neanderthal Genome

Finally, I would like to conclude my lecture by commenting on one ongoing genome project that fascinates me. This is the attempt in the next three years to sequence the genome of the Neanderthal. Neanderthals are hominids, human-like organisms, individuals like you and me. If you go out to our planet, you rarely find an animal that belongs to a species that is radically unique. For example, for squirrels, there are different cousin species—black squirrels and red squirrels—and these constitute different species. At the present point in history, you and I are a unique hominid species. There are no other hominid species walking on the planet. However, this was not the case 35,000 year ago. In the Holy Land, in the area called the Levant, there are the remains of camps, settlements, where *Homo sapiens*—our species—appears to have lived alongside another human-like species, *Homo neanderthalis*, known as Neanderthal man.

First, I have to give you a sense of how difficult this project is. There are no living Neanderthals around, so where do we get that DNA? Neanderthal fossils have minute amounts of DNA. In the past year or so, however, we have developed the technology not only to isolate but also to actually determine the sequence of this DNA. A paper published three months ago described one million letters of the Neanderthal genome.¹⁰ Within three years, scientists hope to have the approximately three billion letters of the Neanderthal genome sequences, so that we will be able to compare it to other genomes including our own.

The Neanderthal genome project seeks to answer many questions. Two include the following: First, do Neanderthals and human beings belong to the same species? There is a dispute about this at the moment. If we belong to the same species then the two genomes should share similarities that are remnants of interbreeding.

Second, could Neanderthals speak? There is a question of the origins of language and the capacity to communicate as we communicate. Scientists would like to sequence the *FOXP2* gene for the Neanderthals. Why? Because it turns out that we have already determined that there are only two changes in thousands of letters that distinguish the chimp version of *FOXP2* from our version of *FOXP2*. Scientists hypothesize that sequencing the Neanderthal *FOXP2* should tell us something about the linguistic capacities of

Neanderthals. If they had the version of the *FOXP2* gene found in the chimp, it is unlikely that they were able to speak. If, on the other hand, they had the version of the *FOXP2* gene associated with you and me, it is thought that they would have had the capacity to speak.

I would like to close by recalling a paper I had to write as a first year philosophy student at the Dominican School of Philosophy and Theology in California. As a scientist, I did not know why I had to study philosophy. I was the arrogant individual who thought that science had the answer for everything. However, for my anthropology class, I decided to write a paper on whether the Neanderthals had an immaterial soul. At that point eight or nine years ago, the only evidence was to be found in archeological sites. In particular, I focused on the fact that Neanderthals buried their dead. What does it mean that they did so? Does this in some way reveal the nature of his soul? I anticipate the publication of the Neanderthal genome in three years, and I hope that genome will give us insight not only into the different species that God has created. In many ways I hope that the genome will give theologians and philosophers food for thought. For instance, if the Neanderthal *FOXP2* gene is in fact the language-capable version, the human version, what would it say about the

soul of this now extinct hominid species? Did Christ die for them as well? ♥

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Created in the Image of God

The human being is created in God's image and likeness (Gn1:26–27). In the human being heaven and earth touch one another. In the human being God enters into his creation; the human being is directly related to God. The human being is called by him. God's words in the Old Testament are valid for every individual human being: "I call you by name and you are mine."

Each human being is known by God and loved by him. Each is willed by God, and each is God's image. Precisely in this consists the deeper and greater unity of humankind—that each of us, each individual human being, realizes the one project of God and has his or her origin in the same creative idea of God. Hence the Bible says what whoever violates a human being violates God's property (Gn 9:6).

Human life stands under God's special protection, because each human being, however wretched or exalted he or she may be, however sick or suffering, however good-for-nothing or important, whether born or unborn—each one bears God's breath in himself or herself, each one is God's image. This is the deepest reason for the inviolability of human dignity, and upon it is founded ultimately every civilization. When the human person is no longer seen as standing under God's protection and bearing God's breath, then the human being begins to be viewed in utilitarian fashion. It is then that the barbarity appears that tramples upon human dignity. And vice versa: When this is seen, then a high degree of spirituality and morality is plainly evident.

Source: Pope Benedict XVI. *God and the World: A Conversation with Peter Seewald*. Trans. Henry Taylor. 2002. San Francisco: Ignatius Press.