DNA: Form, Function, and Ethics

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Saint Gabriel Respect Life
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Introduction: Science and Life

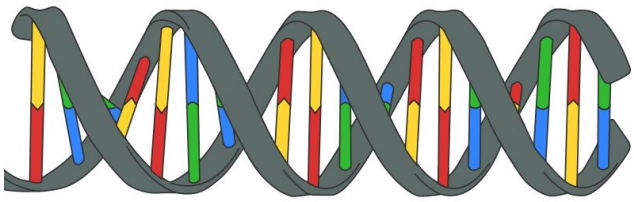
Human-animal chimeras,[1] amateur biohackers editing yeast genes to create better beer,[2] researchers altering the genes of everything from rice and wheat to human embryos.[3] As the science of genetics burgeons, how can we orient ourselves within this bewildering context? DNA, RNA, chromosomes, genes, codons, amino acids, proteins**:** for many of us, these terms linger in the dim recesses of our minds as hazy high school memories. Most of us are familiar with the double helix shape of DNA, but we might wonder**:** what is it? Where exactly is it located in the body? How can a string of molecules direct the body to grow blue or brown eyes, black or blond hair, a slim or muscular build?

For those of us who are not scientists, even as news reports of scientific wonders surround us, genetics might seem a remote concern. Why should we care about how DNA functions? First, Dr. Francis Collins, director of the Human Genome Project which "read" the entire sequence of human genes, refers to our DNA as the "language of God."[4] Even a cursory glance at this molecular wonder reveals beauty and symmetry in its form. All of nature reveals the hand and mind of God, but DNA is unique in revealing the directions He wrote into our most intimate spaces to grow and sustain the only creature made in His image.

Additionally, we should care because we need to make decisions about gene management, on both a personal and a policy level. Is it worth spending extra money at the grocery store for GMO free food? Do we want to be screened for genetic markers for disease, now that this is possible? Can we accept genetic modification of human embryos, which is already occurring elsewhere in the world, or will we work to prevent it? Although genetic modification of our offspring might sound like science fiction, *Nature*, the most frequently cited scientific journal in the world, recently published an article entitled "Should You Edit Your Children's Genes?"[5] These essential questions will drive decisions about genetics, decisions which increasingly reach into our daily lives.

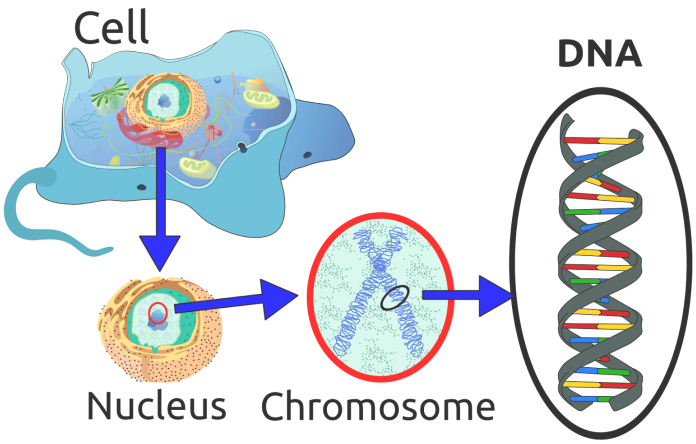
What is DNA?

Every cell in the body contains a library of instruction books for making body parts. Instead of ink printed on paper, these books are made from a molecule known as DNA (**d**eoxyribo**n**ucleic **a**cid).

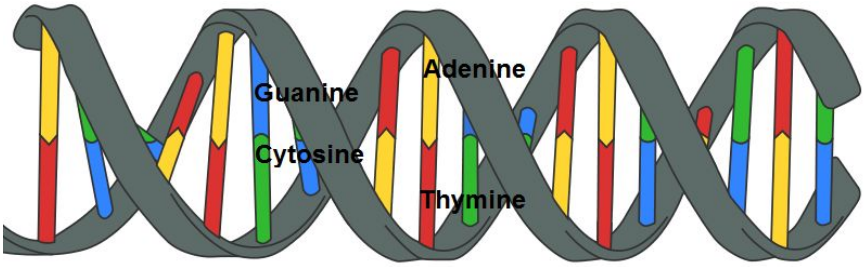


[1] Antonio Regalado. "Human-Animal Chimeras Are Gestating on U.S. Research Farms." *MIT Technology Review*. 06 Jan. 2016.
[2] Heidi Ledford. "Biohackers Gear Up For Genome Editing. *Nature.* 26 August 2015.
[3] "Nature Special: CRISPR." *Nature*. March 2016.
[4] Francis Collins. *The Language of God*. New York: Simon and Schuster, 2006.
[5] Erika Check Hayden. "Should You Edit Your Children's Genes?"*Nature*. 23 February 2016.

The cell has a central directing area called the nucleus, where the body's DNA reference books are stored.[6]



As shown above, DNA is constructed like a ladder. The rungs of the ladder are where the information is stored. Each rung consists of two molecules held together by the attraction of positive and negative charge between them. There are only four possible components: the molecules **Adenine**, **Thymine**, **Guanine**, and **Cytosine**, known as nitrogen bases. These bases fit together in an extremely specific way: A and T can only bond with each other. G and C can only bond with each other. Each grouping, A/T and C/G, is known as a base pair.[7] A base plus its connected region of the side of the DNA ladder is known as a nucleotide.



[8]

How Do Cells Read the DNA Library?

In order to be read by the cell, the DNA ladder needs to be separated into two: the rungs must be broken apart. Each half of the ladder is like a series of open, connected pages of a molecular instruction book written in Braille. The nucleotides A,T,G, and C act as letters imparting instructions for constructing body parts to the cell. Since nucleotide pairing is so specific, the entire ladder can be replicated from the information contained in one half: where A exists on one side of the rung, T must necessarily reside on the opposite half, and so on.[9] Thus each cell can receive its own unabridged copy of the DNA reference library.

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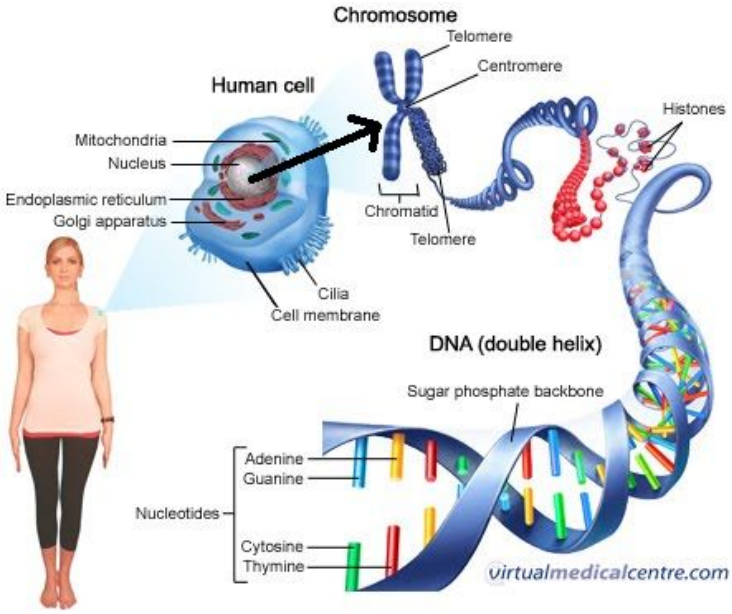
[6] "Where is DNA Found?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.

[7] "What is DNA Made Of?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.

[8] I would like to thank artist John Smith for his indispensable graphic arts advice, assistance, and mentoring in procuring and editing images for this document.

[9] "DNA Replication and RNA Transcription and Translation." DNA As the Genetic Material.Khan Academy www.khanacademy.org, Retrieved Mar. 20, 2016.



How Large Is the Library?

Your entire DNA library, known as your genome, contains six billion nucleotides.[10] DNA is read by the body in molecular words called codons, each consisting of three nucleotide letters, taken from the A,T, G, and C alphabet.[11] These are divided among forty-six molecular books, or chromosomes.[12] Each chromosome contains hundreds to thousands of segments known as genes,[13] like a chain of connected Braille pages.

How Is it Stored?

In order to fit into the tiny nucleus, chromosomes are coiled and stored,[14] like library books on a shelf, until they are needed for reference. Each cell has an identical copy of the DNA library, or genome, in its nucleus, [15] but each cell reads only the pages it needs, and ignores the others.

[10] "How Much DNA is in a Genome? How Much in a Gene?" *What's DNA?* Genome News Network. www.genomenewsnetwork.org. Retrieved Mar. 20, 2016.

[11] "How Does DNA Tell a Cell About Making Proteins?" *What's DNA?* Genome News Network. www.genomenewsnetwork.org. Retrieved Mar. 20, 2016.

[12] "DNA." *DNA As the Genetic Materia*l.Khan Academy.www.khanacademy.org. Retrieved Mar. 20, 2016.

[13] Finegold, Dr. David N. "Genes and Chromosomes." *Merck Manual*. www.merckmanuals.com. Retrieved Mar. 20, 2016.

[14] "Where is DNA Found?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.

[15] "Cracking the Code of Life." *Nova Online*. www.pbs.org. Retrieved Mar. 20, 2016.

Within this library, the chromosomal books are organized into two volume sets. Within each set are two copies of each type of gene, one inherited from your mother and one from your father.[16] This enables the body to follow instructions to construct you so that you are physically like your mother in some ways, and like your father in other respects.

What Do the DNA Reference Books Tell the Body to Do?

DNA is used as a blueprint for biological macromolecules such as RNA (**r**ibo**n**ucleic **a**cid) and proteins,[17] Because the body's parts are largely constructed from various types of protein, storing information about proteins is an essential function.

Proteins are made up of small building block molecules called amino acids. Each of your DNA's molecular words, or codons, consists of three nucleotide letters corresponding to a specific[18] amino acid. The machinery inside your cells uses these codons to construct proteins[19] that make up every part of your body. Proteins vary in size from dozens to thousands of amino acids and are combined or folded into a variety of shapes (tertiary structures) after being built from their component amino acids.[20]

While there are only four DNA nucleotide "letters," they can be used to code for any one of twenty different amino acids.[21] These twenty amino acids are the building blocks used to form any of the billions of unique proteins found in life on earth. You can see how the complexity of DNA quickly scales up from four letters to billions of possible combinations!

Can We Change Our DNA Reference Libraries?

One way scientists have tried to change DNA is to bombard cells with new molecular words and sentences. A device called a gene gun injects DNA segments into cells, hoping these get recopied and incorporated into the reference library.[22] But gene guns can only be used on some types of cells, and they aren't

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[16] "What Are Genes?" *The Genetic Basics: What Are Genes and What Do They Do?* National Institutes of Health. www.nistory.nih.gov. Retrieved Mar. 20, 2016.
[17] "What Are Genes?" *The Genetic Basics: What Are Genes and What Do They Do?* National Institutes of Health. www.nistory.nih.gov. Retrieved Mar. 20, 2016.
[18] "Scitable by Nature Education." *Nature*. www.nature.com. Retrieved Mar. 20, 2016.
[19] "How Are DNA Sequences Used to Make Proteins?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.
[20] "How Are DNA Sequences Used to Make Proteins?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.
[21] "How Are DNA Sequences USed to Make Proteins?" *Deoxyribonucleic Acid*. National Human Genome Research Institute, National Institutes of Health. www.genome.gov. Retrieved Mar. 20, 2016.
[22] "Gene Gun." *Plant and Soil Sciences eLibrary*. www.passel.unl.edu. Retrieved Mar. 20, 2016.

guaranteed to insert the target sequence at the desired location. Many other genetic engineering techniques exist, but like the gene gun, they have limitations that make them useful only within specific contexts.[23]

What if we could, instead, choose a specific word on a specific page which we wanted to change? A technology known as CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) allows scientists to do this. CRISPR is like a pair of molecular scissors: it offers potential to find a specific place in the chain of DNA, send the molecular scissors there, cut it out, and replace it.[24]

Although DNA editing in other organisms (e.g., crops, pigs) has met with significant success,[25, 26] "there are still a lot of technical difficulties to doing precision editing in human embryo cells," explains Xiao-Jiang Lee of Emory University.[27] Scientists in China have already edited the genes of embryos (in the lab, without implanting them in a woman's womb),[28 29] but the modification was successful in only four of the twenty-six embryos targeted. Although we have sequenced the entire human genome, we are still learning what each gene does.[30] Sometimes one gene has multiple effects; sometimes multiple genes affect one trait. In addition, epigenetics, or the interaction of genes with environment, plays a role in gene expression. Changing a trait in a human being is not necessarily as simple as snipping out one gene at the very beginning of life and replacing it with another.

Yet the quest to edit embryonic genes continues, sanctioned in some instances by government authorities. While the United States continues to ban genetic modification of embryos,[31] *Nature* reports that in the case of the Chinese experiments, "a local ethics committee approved them, and the egg donors gave their informed consent."[32] Scientists in the U.K. have likewise received government approval to manipulate embryonic genes.[33] A national and global debate over these permissions has ensued.[34]

Moral and Ethical Principles: Should We Edit Our DNA Libraries?

When considering the morality of editing genes, we must ask which kinds of DNA we are considering editing: plant, animal, or human? If human, are we discussing editing embryonic, or non embryonic (somatic) [35] cells? Is our purpose to restore an organism to its natural healthy functioning, to enhance it beyond ordinary natural boundaries, or simply to learn more about gene expression? Is there a moral difference between enhancing an ear of corn to be disease resistant, and enhancing a human embryo to be more intelligent, attractive, athletic, etc. than it would have been without intervention?

How to edit genes is a question for science. *Whether* to edit genes-- and if so, under which circumstances-- is a question of ethics. As public debate moves forward, we must advocate a sound and comprehensive philosophy of life in order to ensure that gene editing technology will be used wisely.

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[23] I would like to thank biochemistry Ph.D.student Jason Smith for clarifying this process.

[24] *Genome Editing With CRISPR-Cas9*. McGovern Institute for Brain Research, Massachusetts Institute of Technology. https://www.youtube.com/watch?v=2pp17E4E-O8. Video. 5 Nov. 2014.

[25] "GM Crops: Promise and Reality." *Nature.* 02 May 2013

[26] David Cyranoski. "Super-Muscly Pigs Created by Small Genetic Tweak." *Nature*. 30 June 2015.

[27] Gina Kolata. "Chinese Scientists Edit Genes of Human Embryos, Raising Concerns." *New York Times*. 23 April 2015.

[28] backKolata.

[29] Ewen Callaway. "Second Chinese team Reports Gene Editing in Human Embryos." *Nature*. 08 April 2016.

[30] Fukuyama, Francis. *Our Posthuman Future: Consequences of the Biotechnology Revolution*, pp. 77-78. New York: Picador, 2002.

[31] Sara Reardon. "NIH Reiterates Ban on Editing Human Embryo DNA." *Nature*. 29 April 2015.

[32] Callaway.

[33] Ewen Callaway. "U.K. Scientists Gain Licence to Edit Genes in Human Embryos." *Nature*. 01 Feb 2016.

[34] Sara Reardon. "Global Summit Reveals Divergent Views on Gene Editing." *Nature*. 08 Dec 2015.

[35] From the Greek "soma," meaning "body."

Catholic ethical principles do not necessarily preclude genetic modification of plants.[36,37] Even gene therapy to cure disease in people-- on somatic cells, those which affect only the individual targeted by the intervention, but not future offspring-- "can be morally licit."[38] It is crucial that "the person being treated will not be exposed to risks to his health or physical integrity which are excessive or disproportionate to the gravity of the pathology for which a cure is sought." and informed consent exists.[39] Regarding germ line cells, those passed on to offspring, " 'the risks connected to any genetic manipulation are considerable and as yet not fully controllable' and therefore 'in the present state of research, it is not morally permissible to act in a way that may cause possible harm to the resulting progeny' "[40] Genetically manipulating embryos for the sole purpose of research is likewise unethical: "If the embryos are living, whether viable or not, they must be respected just like any other human person; experimentation on embryos which is not directly therapeutic is illicit."[41]

We Must Take Sides

The embryos whose genes have already been edited were unable to advocate for themselves. We must be their voice. In addition to the danger to individual unborn embryos, unfettered human genetic manipulation could render our political freedom precarious. As the eminent scholar Francis Fukuyama explains, our political rights are based on our fundamental equality; human genetic manipulation used for the purpose of enhancement of natural traits could disrupt this equality.[42] We who champion human dignity must be robust advocates of limits which safeguard both the lives of the unborn, and our political equality. It is imperative that we heed the hard won wisdom of Holocaust survivor Elie Weisel, who cautioned, "We must always take sides. Neutrality helps the oppressor, never the victim. Silence encourages the tormentor, never the tormented." [43]

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[36] *Vatican Speaks on Genetically Modified Food.* Catholic Culture. https://www.catholicculture.org/news/headlines/index.cfm?storyid=19468. 24 Oct 2013.

[37] C*ardinal Turkson Calls for Conversation, Not Confrontation, In Solving Agricultural Divides.* U.S. Catholic. http://www.uscatholic.org/blog/201310/cardinal-turkson-calls-conversation-not-confrontation-solving-agricultural-divides-27983 Retrieved June 4, 2016.

[38] *Summary of Dignitatis Personae.* Catholic News Agency. Retrieved May 30, 2016.

[39] Ibid.

[40] Ibid.

[41] *Instruction on Respect for Human Life in its Origin and on the Dignity of Procreation: Replies to Certain Questions of the Day.* Congregation for the Doctrine of the Faith.

[42] Fukuyama, *Posthuman Future*, "Part II: Being Human," pp. 105-180.

[43] Elie Weisel. *Nobel Peace Prize Acceptance Speech*. Oslo, Norway. Audio. Dec. 10, 1986.

[43] I would like to thank Gabriel Marcella for assistance in editing, and for numerous thought provoking ethical discussions.