The Human Genome Project, Modern Biology, and Mormonism: A Viable Marriage?

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Introduction

The world is rapidly changing as new technologies change the way we think, act, and live. This is particularly true with the many changes biology has wrought in our lives over the last few years. Nearly every day new discoveries are made which advance scientific knowledge and enable us to lead longer, healthier lives. This new scientific information is disseminated to the public daily via television, radio, newspaper, and the internet. New words such as cloning, genomics, anthrax, and genetically modified food, are rapidly entering the layperson's vocabulary. Just as the Industrial Revolution changed the world into a mobile, manufacturing, technology-based economy, the "Biological Revolution" will have similarly unimaginable effects upon our world. These include the curing of some of the most dreaded diseases, such as cancer, and the treatment of age-related illnesses to enable longer, more productive lives to be led. Unfortunately, these same techniques can be used for evil, as recently witnessed by the anthrax bioterrorism attacks.

How will these current and future discoveries within the realm of biology affect Mormonism? This essay is an attempt to understand new scientific breakthroughs within the context of the gospel by focusing on molecular biology and the Human Genome Project, since these two enterprises have been important catalysts for the Biological Revolution. First, a brief introduction to the church's historical attitude toward science will be presented to outline the context of the church's relationship with science. Then, a primer on molecular biology and the Human Genome Project will be presented. In addition, the importance of the Human Genome Project to society will be addressed, and some of the ethical issues associated

with the genome data will be analyzed. Finally, these ethical issues will be applied to some doctrinal ideas to show how the Biological Revolution could complicate traditional Mormon doctrines.

The battle between Mormonism and Science

Since the advent of Darwinism in the late nineteenth century, Mormonism and biology have found themselves in a constant battle, particularly over evolution. The church did not have a particularly strong, united anti-science stance in the late nineteenth and early twentieth century when noted Mormon scientists, such as John Widstoe, James Talmage, and B. H. Roberts, were found in the leading councils of the church. Since the deaths of these men in the 1930s, however, the battle between Mormonism and science has been especially strong. From the 1930s until the mid 1980s, Joseph Fielding Smith and Bruce R. McConkie have consistently discussed the evils of evolution and—by extension—science and scientists.[1] In their speeches and through their books,[2] they have clearly stated their positions, implying that these are also the official church position. However, the church says it takes no official position or stand on the issue of evolution except that Adam and Eve were the first humans.[3]

The views of Smith and McConkie have created a conundrum for members of the church. While evolution and the science associated with it have been seen as an inherent evil, the miracles of modern medicine have been seen as blessings from God. For instance, Elder McConkie states, "the Lord...intends that men should use the agency and intelligence He has given them in both preventing and curing sickness."[4] Furthermore, McConkie states, "The promised latter-day increase of knowledge and learning is evidenced by the many inventions....We have already seen the discovery...of medicinal advances, surgical achievements and wonder drugs."[5] However, McConkie harshly criticizes evolution as completely incompatible with the gospel. As a summation to his article on evolution, he states, "There is no harmony between the truths of revealed religion and the theories of organic evolution."[6] Hence, members of the church often have believed that science is inher-

1. Gene Sessions and Craig Oberg, *The Search for Harmony: Essays on Science and Mormonism* (Salt Lake City: Signature Books, 1993).

2. Joseph Fielding Smith, *Man: His Origin and Destiny* (Salt Lake City: Deseret Book, 1954); Bruce R. McConkie, *Mormon Doctrine* (Salt Lake City: Deseret Book, 1993).

3. Trent D. Stephens, D. Jeffrey Meldrum with Forrest B. Peterson, *Evolution and Mormonism: A Quest for Understanding* (Salt Lake City: Signature Books, 2001).

4. McConkie, *Mormon Doctrine*, 573.

5. Ibid., 72.

6. Ibid., 256.

ently evil, unless it is for the direct medicinal benefit of humankind. The problem with this argument is that the same science and often the same scientists make discoveries in both evolutionary biology and modern medicine. These two fields of science are not mutually exclusive. For example, powerful techniques in molecular biology enable scientists to more rapidly discover new drugs, while the same techniques are also used to generate evidence in support of evolutionary processes. This dichotomy will become more apparent in the future as more scientific discoveries are made which treat disease and at the same time strengthen the case for evolution.[7]

What is Molecular Biology?

Molecular biology studies the basic molecules and processes which combine to create a living organism. This field of study has been the impetus for many of the scientific advancements in the last twenty years in many fields of science, including modern medicine and evolutionary biology. A short lesson on some scientific terms will enable a more fruitful discussion. DNA—an acronym for deoxyribonucleic acid—is composed of a long chain of nucleosides. Nucleosides are created by joining a nucleotide (purine or a pyramidine ring) and a deoxyribose molecule (sugar molecule). The purine/pyramidine bases can be one of four molecules: Cytosine (C), Thymine (T), Guanine (G), or Adenine (A). C-G and A-T can form a molecular interaction or bond with one another, which results in the joining of two parallel DNA strands. In this way, a chain of nucleotides can form a simple alphabet comprised of the four letters AGCT. An organized chain of these bases composes a single gene. The average gene is composed of three thousand nucleotide bases.[8] For example, AAGGTCGATTCCAAGCTGGATGCAGAATTC could be the alphabet for a portion of a gene. Every three bases—a "codon"—contain the code for one amino acid. (Three unique codons actually code for a stop, which means that the full length of the protein has already been synthesized.) For example, ATG codes for the amino acid Methionine. Chains of amino acids form proteins, while a single protein is usually encoded by a single gene. For example, insulin is a protein encoded by the insulin gene. All of the genes and non-coding DNA (i.e., DNA containing regulatory elements for genes and other functions not discussed here) found in a single organism make up that organism's genome. Gene-

7. Stephens and Meldrum, *Evolution and Mormonism*.

8. U.S. DOE Human Genome Project. *Human Genome News* 11, no. 1-2 (November 2000).

encoding DNA is first turned into ribonucleic acid, or RNA, as an intermediate step to making a protein. This ensures that only gene-containing DNA is made into protein, as the protein-creating machinery only recognizes RNA. The movement of information from DNA to RNA to protein is called the "Central Dogma."

Molecular biology, as a field of study, began in the 1970s with the discovery of several new technologies. First, it was discovered that RNA could be turned into DNA using a special enzyme discovered in retroviruses (for example, HIV is a type of retrovirus). This enzyme allowed researchers to convert RNA into DNA. RNA is very unstable, and little could be done to identify which particular gene a strand of RNA encoded. Second, the ability to transfer pieces of DNA from one DNA molecule to another using restriction endonucleases (enzymes which cut DNA in specific sites) enabled researchers to chop up long stretches of DNA into smaller pieces and put these smaller strands together again into a desired order. Third, circular DNA molecules (plasmids) could be grown in bacteria to amplify billions of copies of that particular piece of DNA. By this method, individual genes isolated from an organism's genome (through the conversion of RNA into DNA) could be inserted into a plasmid. The bacteria could synthesize many copies of that plasmid, and then the plasmid DNA could be isolated in large, relatively pure quantities. This amplification of DNA can also be performed in a test tube using a technique called the polymerase chain reaction (PCR). Fourth, the ability to sequence DNA, or identify the individual bases (i.e., read the alphabet), allowed researchers to identify which regions of DNA contained genes and which regions contained other DNA elements. These technologies have been combined to create a very powerful method for identifying the genes within an organism. In addition, these techniques allow scientists to understand the roles of the proteins encoded by these genes in creating an organism and in causing disease, while also providing insights into the evolutionary relationships between different species.

What is the Genome Project?

The Human Genome Project has been a distinct catalyst for many recent scientific breakthroughs. It was begun in 1990 with the goal of sequencing all three billion bases (A,C,G,T alphabet) of the human genome by 2005. The project was under the direction of the National Institutes of Health and a consortium of university labs throughout the world. Due to improvements in technology, the sequencing was finished during the summer of 2000, five years early, and below budget (not many government programs accomplish that!). A publicly held company, Celera Gemonics, also sequenced the entire human genome and finished at the same time as the public consortia. (Celera actually began sequencing the

genome in the late 1990s, but quickly caught up with the government consortia.) The three billion sequenced bases (3164.7 million) are found on twenty-three sets of chromosomes which exist in nearly every one of the human body's 100 trillion (100,000,000,000,000) cells. The data from the human genome sequencing was published in the February 15, 2001 issue of *Nature* and in the February 16, 2001 issue of *Science.* [9]

With the sequencing finished, the task of assembling and analyzing the tremendous amount of generated data has begun. The first step was to identify the number of unique genes existing in the human genome. Using powerful computer technology, scientists have come to believe that the actual number of genes will be around 35,000-40,000, barely double that of a primitive roundworm (*Caenorhabditis elegans).*[10] Each gene must be studied individually to learn its particular role in the development, maintenance, and disease processes of our bodies. This is done by first discovering where a particular gene is expressed, when it is expressed, and finally, how its expression is controlled in each region of the body. In addition, each protein produced by these genes (genes can actually encode for a single or many different proteins) must then be studied to learn which other proteins it interacts with and how this interaction is controlled. By creating this large web of interactions and control mechanisms, we will finally understand physiological processes such as embryology, growth, puberty, aging, and disease.

Why is the Human Genome Project important?

In the past few years, we have just begun to understand the importance of the Human Genome Project. Since the project was launched, many thousands of genes have been identified as the sequencing has progressed. In addition, hundreds of mutations in specific genes have been found which can cause a particular disease. Muscular dystrophy, cystic fibrosis, Huntington's disease, and breast cancer are some examples for which disease-causing mutations in a particular gene are now known.

Pharmaceutical and biotechnology companies are focusing upon those genes containing disease-causing mutations. Once researchers have identified such genes, drug design can occur. Drug design involves creating drugs to disable the mutant protein, bypass the mutant protein, or "fix" the mutant protein. This process is known as "rational drug design." It is hoped that this method of drug development will cut down the

9. Entire issue, *Science*, 291, no. 5507 (16 February 2001), see especially, Svante Paabo, "The Human Genome and Our View of Ourselves," 1219-1220; Entire issue, *Nature* 409, no. 6822 (16 February 2001), see especially, David Baltimore, "Our Genome Unveiled," 814ff.

10. US DOE, *Human Genome News* 11:3.

tremendous costs (up to $500 million per drug) and time (between five and ten years) currently associated with bringing a drug to market. This would potentially lower the cost of drugs for patients. The money could also be used to develop additional drugs to cure and treat many diseases, including various types of cancer, age-related illnesses, and other genetic diseases.

In addition, now that the entire complement of genes within the human body is known, scientists can be more precise at analyzing the toxicity of newly designed drugs on the entire genome of an individual, and by inference the individual's body, without actually affecting a patient until the drug is known to be both safe and effective. This would be important, as many thousands of lives are lost each year due to unforeseen drug interactions and toxicity. To analyze drug toxicity, a copy of each gene found within a person's genome is attached to a glass slide. Cells isolated from the person's body can then be tested with potential drugs by first isolating their RNA, converting it to DNA, and testing it with the drug. Some genes will be turned on and others turned off by the drug. By comparing the expression profile of the treated cells with the profile of untreated cells, scientists can identify toxicity and selectivity of drug candidates. The technique also creates a relatively quick, simple, and cheap method for genetic testing. In the future, many tests could be performed using this technique to rapidly assess which drugs would most benefit a particular patient's condition given their unique response profile to a set of drugs.

In addition to the potential "miracle drugs" which may be developed based upon information gleaned from the Human Genome Project, information will also be obtained regarding what makes the human species unique. Some of the questions that could be answered include: Which genes make us different from a mouse or a monkey? Do humans have the same genes as apes? Are there distinct genes that are unique to humans? Are there genes that enable us to have consciousness or emotions? If we have all the genetic information of a human, could a synthetic human then be created? Are there genes that help determine spirituality, kindness, and love? What are the actual genetic differences between men and women? How are these genetic differences manifested in behavioral and physical characteristics? The answers to these questions and many more will come as the data from the Human Genome Project is further studied.

The Human Genome Project and Ethics

The promise of new drugs to cure and/or treat disease may sound wonderful to Latter-day Saints and the world at large, but what are some of the other implications of the Human Genome Project? Should Latter-

day Saints be concerned about these future issues? I would like to highlight a couple which will be a) relevant to members of the church, and b) particularly difficult for the church to formulate a doctrinal response to. This list is not mutually exclusive or collectively exhaustive; rather, it is an attempt to stimulate a thoughtful reflection in the reader's mind.

First, the knowledge gained from the Human Genome Project will allow researchers to know which genetic type ("genotype") leads to certain physical traits ("phenotype"). For instance, the genotypes which lead to above average intelligence, "perfect" physique, eye color, hair color, skin color, etc. could be identified. With the technical ability to perform in vitro fertilization, one could presumably "test" an egg and sperm, or the newly fertilized embryo, to choose traits desired by parents for their offspring. This could lead to a race of people with "perfect" genetic traits. Could this lead to two populations, one that selects for offspring, and one that fertilizes via natural means? (A similar story line was found in the recent Hollywood movie, *Gattaca*.) While such a scenario may seem unfeasible, sex selection does currently occur, and selection for embryos devoid of certain disease genes also occurs. Therefore, the next step would be selection for desirable traits. Clearly, the church would be against such selection for vain purposes, but what if we could select for better leaders, better missionaries, or other desirable traits? Would it be okay to select traits such as compassion, peacemaking, etc.? The church is currently not adamantly against in vitro fertilization when the child will be the biological offspring of its parents (and even when it is not, in vitro fertilization is not considered a sin). Would the official church stance change in the face of such genetic selection? Would the church strike a more conservative ground, as it has with its stance against abortion? (Members are currently allowed abortions in the case of incest, rape, severe deformities which would prevent life after birth, and in cases where the mother's health is in jeopardy.)

Second, genetic testing of individuals for disease genes is already occurring for a select number of diseases. The number of diseases tested and the number of people tested will increase as less expensive, more efficient techniques are developed. Such testing allows individuals to know if they are prone to a certain disease, but what if there is no treatment for the disease? For example, a person could be tested for Alzheimer's disease and learn that she had a fifty percent chance of developing the disease in the next ten years. Unfortunately, there is nothing that can be done to prevent her from developing the disease. Is it ethical to tell someone he or she is a "walking time bomb" for a disease? What effects could these "time bombs" have upon society as a whole?

Third, genetic discrimination toward those who carry disease genes or other "undesirable" genes could occur. This discrimination could take

the form of insurance companies refusing to issue life or health insurance to those with such genes. Furthermore, employers could terminate employees with certain genotypes to keep healthcare costs low. Laws could prevent much discrimination, but experience shows that discrimination will nonetheless occur. If widespread genetic selection occurs, could those who choose *not* to genetically select be discriminated against by employers, schools, insurance companies, etc.? Again, the church would likely be against discrimination in any form, but how would it respond to genetic testing? What if genetic testing were mandated by employers? What about laws that impair the rights of those who refuse to be genetically tested? Will the church still uphold the law?

Fourth, as genes are identified with specific functions in the body, it is entirely probable that some will be found which are linked to homosexuality, alcoholism, and violent behavior. Thus, people who exhibit such behavior could be genetically prone to do so. While being predisposed to a behavior does not preclude one's free agency, would more compassion and perhaps leniency be given to those "afflicted" with such genes? Could homosexuals be "cured" of such behavior, if a genetic mutation is the root cause? Would homosexuality be treated differently within the church or, at least, be more tolerated? Would it be considered a "flaw" to carry these types of genes? Will drugs to "cure" or treat these behaviors be developed? What behaviors should be considered for future drug design?

Fifth, genetic testing for deleterious genes will probably result in an increase in the abortion rate, as fetuses which carry deleterious genes impairing normal life are aborted. This would mean that fewer people would have mental and physical disabilities such as Down's syndrome. It is entirely possible that these disabilities would then exist only in conservative religious groups opposing abortion and strongly discouraging or prohibiting members from participating in abortions. Two key problems occur in this scenario:

First, how would the church interpret its current stance which allows abortion based upon "severe deformities, which prevent life after birth"? What is a "severe deformity"? What is considered "life" after birth? Is living in a vegetative state in an institution "life"? Could abortion be considered an option for some disabilities? If so, which ones? Is there a purpose for children with severe disabilities in families? (Church leaders would most likely say "yes.") Would the increase in abortion of these fetuses result in the loss of blessings for the parents? How would the Lord compensate for the loss of these "special" spirits?

The second conflict concerns the larger societal and financial costs associated with treating disabled individuals who could have been aborted in the first place. Should society as a whole pay for the cost to treat such severely disabled persons? While it seems unfathomable to members of the

church, the sad reality is that money may play a larger role in this than it should. Would parents who choose to have disabled children be forced to pay the costs for treating these children when their insurance or government programs declined to cover the costs? What if governments passed laws mandating abortion of fetuses carrying certain deleterious mutations? Would the Twelfth Article of Faith still be valid in these countries?

Finally, it is only a matter of time before the cloning of a human being occurs. Many different species of mammals have already been cloned, including primates.[11] Therefore, it is probable that someone, perhaps not in the United States or Europe, will clone a human being in the near future. What is the nature of a cloned human's spirit? Did God account for the clone in the preexistence? Does the clone's spirit look identical to the donor's spirit? If so, did God "clone" these spirits to look identical to each other in every way?

Effects upon the Church?

As can be seen from the above discussion, the Human Genome Project can lead to many wonderful advances for humankind, but it also raises some very complex ethical issues for humankind in general and Mormonism in particular. However, nothing has been written in church publications or said in general conferences about the Human Genome Project.[12] In fact, in recent years, very little has been said about science over the pulpit. The leadership of the church appears to have taken a bystander approach to science under the auspices of Presidents Benson, Hunter, and Hinckley. This approach has probably been due to the fact that many within the leading hierarchies of the church do not understand science and have little time to study it, as many other pressing needs of the church must be met. This has been a fair and appropriate response for the leaders of the church to take as the work of the gospel takes precedence over scientific or ethical issues. Yet, as can be seen from the discussion in this article, the ethical issues arising from the Human Genome Project are no longer potential scenarios, but very real situations that will occur and are now occurring. It is critical that leaders of the church become aware of these issues before they become acute, so that appropriate responses are considered. If church leaders are well prepared for the ethical dilemmas imposed by the Biological Revolution, then a hastily developed, poorly considered response to such issues will be averted, and church members will be less bewildered and troubled.

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11. A. W. S. Chan, T. Dominko, C. M. Luetjens, E. Neuber, C. Martinovich, L. Hewitson, C. R. Simerly, and G. P. Schatten, "Clonal Propagation of Primate Offspring by Embryo Splitting," *Science* 287, no. 5451 (4 January 2000), 317-19.

12. Determined by searching the church magazine database found at www.lds.org.

In this section, I have highlighted a couple of previously simple doctrinal issues which have been greatly complicated by the Human Genome Project. First, we now have the theoretical capability to create a human being, based upon the newly mapped blueprint of human DNA. We have the knowledge to synthetically create humankind, a power previously reserved for God! Furthermore, we may soon have the knowledge to create a "perfect" human who would not be susceptible to all the physical ailments we currently experience because of imperfect genes. Such individuals should live longer lives and could potentially live forever. (Perhaps, the resurrection is merely the cloning of someone who has already died, while fixing the imperfections within their DNA to render them immortal.) Are humans treading on ground reserved exclusively for God? Or has God given us this knowledge and capability so that the eventual resurrection will be easier to understand for those still on the earth? In fact, perhaps those on the earth during the Millennium could actually participate in the resurrection of their fellow people and animals.

A second, very complex doctrinal issue involves the makeup of our spirits versus our physical selves. If our spirits resemble our physical selves, and the blueprint for our physical appearance is found within our DNA, then how does a premortal spirit resemble our physical self when our DNA constitution was not known until we were conceived? Two possible scenarios could explain this situation.

First, it is possible that our premortal spirits did not have distinct physical characteristics, but acquired them once the physical makeup of the body was known. For example, a spirit could have a "general" human form without attaining its exact or final form until conception of its body. However, this argument does not fit well with the book of Ether in the Book of Mormon, when the brother of Jared saw Christ's physical presence thousands of years before Christ was born.

The second possible scenario suggests that God knew our physical makeup before we were born, and hence, knew what our DNA genotype would be. This explains why our spirits would resemble our physical bodies. If this is the case, then the random distribution of genotypes during the reproductive processes is not random at all, but controlled by the Holy Ghost under God's direction. This also seems improbable, though not impossible. Perhaps the correct answer is a mixture of these two scenarios. God knows who our parents will be and creates a spirit that is a mixture of traits from the two parents. This spirit can then take on the "detailed" characteristics of its genotype after conception, including whatever flaws may exist within our DNA and, subsequently, our physical bodies.

These two examples illustrate some of the complex doctrinal issues created by the completion of the Human Genome Project. Such issues will continuously be brought to our attention as our world becomes increasingly reliant upon new and ever-changing technological advances.

It will be particularly interesting to watch the response of the church leadership and membership to these complex doctrinal issues.

The Conundrum Revisited

There are two distinct areas with which the church must deal when facing the future of science: ethical problems and doctrinal issues. We may see the church take a very active part politically to ensure that its interests and the rights of its members are not impeded with regard to certain ethical issues. It is unlikely that the church will change its long-held dogmas concerning abortion, homosexuality, or any other non-doctrinal issue. A coalition comprising the church and other conservative religious groups might well be formed to fight against any real or perceived attacks upon these traditional dogmas. It is also possible that new revelation will be received to address some of these ethical issues through doctrinal changes.

The response of the church toward evidence which complicates or negates certain doctrines could take two directions. First, the church could dismiss such evidence as "of the Devil" and false. It could also restate the current doctrine as the truth, even if this doctrine were complicated with new evidence. Finally, a new revelation could be given to clarify or restate such doctrine in light of new evidence. In actuality, a mixture of responses will probably occur, depending upon the nature of the doctrinal "attack" and the importance of the doctrine that is "attacked." One can envision many non-core doctrines being compromised without much communication from church leadership. However, if a core doctrine is compromised in any way, real or perceived, then one can expect a response from church leadership.

Conclusion

The completion of the Human Genome Project is one of the greatest accomplishments humankind has ever achieved. Members of the church should embrace this accomplishment with all its associated fanfare. We should recognize that God has blessed us with the knowledge, talent, and ability to decode the entire human genome. This knowledge gives us insight into how the creation of humans was undertaken. In the future, more knowledge will be gained about what makes humans unique. We will know more about how we think, how we act, and the nature of human consciousness. Should any of these advances frighten Mormons? No. Should these advances be viewed as an attack upon our religion? No. The knowledge obtained is the truth, as we know it. We should therefore embrace it and find ways to learn more about our purpose here on Earth. We have been blessed with this wonderful knowledge about ourselves. What we do with it is up to us.