Case Study Title: Designer Life: The New Frontier

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Summary Statement:

In 1866, Gregor Mendel discovered that pea plants pass certain traits to their offspring. Nearly 80 years later, Oswald Avery proved the hereditary information is stored in deoxyribonucleic acid (DNA). DNA in all organisms is organized into chromosomes resembling a spiral ladder; the ladder's steps consist of four chemicals called nucleotides (abbreviated A, T, C, G). The chromosomes in an organism comprise its genome. We now know the entire nucleotide sequences of over 4000 organisms, including humans. Recent research in pharmacogenetics, the study of genetically determined responses to drugs, has shown that differing nucleotide sequences are a major factor in patients' responses to conventional treatments. Thus giving rise to personalized medicines like ivacaftor, used to treat Cystic Fibrosis (CF). Ivacaftor is only effective in 4% of CF patients—those with a specific genetic mutation.

Genetic modification has been widely practiced since 1972 when Paul Berg, Herbert Boyer, and Stanley Cohen developed a way to cut one organism's DNA and transfer traits to another organism. This DNA technology is used to improve nutritional quality and productivity of food crops.

Using DNA technology, human genes can be put into laboratory animals to further our understanding of the functions of human genes in inherited diseases. This may allow physicians to treat genetic diseases by replacing abnormal DNA. In 1991, the first such gene therapy was used to treat a four-year-old girl for Adenosine Deaminase Deficiency, a genetic immunodeficiency disease.

The invention of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) in 2013 revolutionized the field of genetic engineering. Using bacterial enzymes, DNA can be cut more precisely to remove or insert new pieces of DNA. By editing the genes of an individual, scientists can change a person's genes, opening the possibility of eliminating abnormal genes from the entire human gene pool. This Genetic Surgery holds the promise of curing diseases such as pediatric bone cancer or sickle-cell disease.

Preimplantation Genetic Screening (PGS) and Preimplantation Genetic Diagnosis (PGD) can detect abnormal genes in embryos prior to implantation. These techniques were developed to increase the number of healthy children born to couples who carry genetic disorders. If abnormal chromosomes such as Down's Syndrome or disease genes such as CF, Tay-Sachs, and tuberous sclerosis are detected, parents can decide whether to have the child. In cases where the parents are unable to produce a child due to a mother's mitochondrial disease, using a donor woman's mitochondrial DNA instead of the mother's is possible.

In the 1970s, scientists made genes from scratch, but the technology was restricted to small genes. The technology improved and, by 2008, entire chromosomes could be made. In 2010, Craig Venter and his colleagues made a synthetic chromosome and used it to transform the recipient bacterial cell into a new bacterial species. This technology is being used to genetically modify yeast to make compounds that are naturally made by plants. Growing yeast doesn't require the land, water, and fertilizer of plant crops. Products in progress include an antimalarial drug, food flavors, and perfume fragrances.

Discussion Questions:

1. Malaria kills approximately half million people, mostly children, every year. The protozoan that causes malaria is transmitted to humans by the female *Anopheles* mosquito. Using CRISPR, mosquitoes' genes can be mutated to ensure reproduction only results in male offspring.
   a. Should the technology be used to eradicate *Anopheles* mosquitoes?
   b. What are the ecological implications of bringing a species to extinction?

2. One suggested reason for cloning is that people want to replace children or other loved ones who have died. Could a clone be a replacement for that person?

3. A couple wants to have a child but natural means does not allow them to have one so they decide to have a daughter using in vitro fertilization. The man has a rare X-linked disease that has a 100% chance of being transmitted to a daughter.
   a. Genetic surgery can remove the gene from the embryo. Should the couple agree to do it?
   b. A small additional gene tweaking can make their daughter smarter and taller and, as parents, they want their child to have the best possible tools to succeed. Will agreeing the second time be different than the first?
   c. If genetic editing is allowed in humans, the process will be expensive letting only wealthy people use the technology. What would be the greater implications of human genetic modification to society as a whole? Would using genetic modification to enhance features and ability be considered cheating?

4. CRISPR and Synthetic DNA can be used to recreate the genomes of extinct plants and animals. This DNA, implanted in the cell of a modern species, could bring back the extinct organism.
   a. What are the ecological consequences of bringing back extinct organisms?
   b. What happens if they mate with modern species?

5. CRISPR technology and Synthetic DNA are very promising for treating diseases such as Alzheimer's, Parkinson's, and Huntington's that progress with age. Both technologies open the possibility of slowing the human aging process, which can extend the life span as well as slow the progress of diseases. Discuss the benefits and risks of extending human life.

Future Implications:

The Green Revolution of the mid-1900s that increased use of fertilizers and pesticides is credited with feeding the world population through 2000. However, use of fertilizers and pesticides have documented negative effects on human health and on the environment. Additionally, the rate of crop production has slowed while the human population has grown by a billion people. Genetically modified (GM) crops can decrease the need for pesticides, fertilizers, and water. Moreover, crops can be engineered for improved nutritional value. However, if GM crops cross-pollinate with weeds, pesticide-resistance or insecticide genes could move into those weeds making the GM plant obsolete.

New uses of PGD include screening embryos for susceptibility to cancer, for gender, and for tissue matching to existing children. In 2014, the first fetus had his genome sequenced. This baby was born healthy. But it raises the question of the utility of testing for diseases that only develop in adults, or that have no treatment or cure. Will genetic screening of prospective children move us toward a eugenic society in which children are valued more for their genotype than for their inherent characteristics, eventually ushering in a world of 'designer' children in which genetic engineering of offspring becomes routine?

Additional Resources:

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Green, R. M. *Babies by Design: The Ethics of Genetic Choice.* New Haven, CT: Yale University Press, 2008. Print.

Knox, M. "The Gene Genie." *Scientific American* 311 (December 2014): 42-46. Print.

Presidential Commission for the Study of Bioethical Issues. *New Directions: The Ethics of Synthetic Biology and Emerging Technologies*. U.S. Department of Health & Human Services. December 2010. http://bioethics.gov/synthetic-biology-report.