In previous offerings of BMES Cell Team, the information in this handout was actually part of Module 6. This year, we decided to take it out and include it as supplementary material.

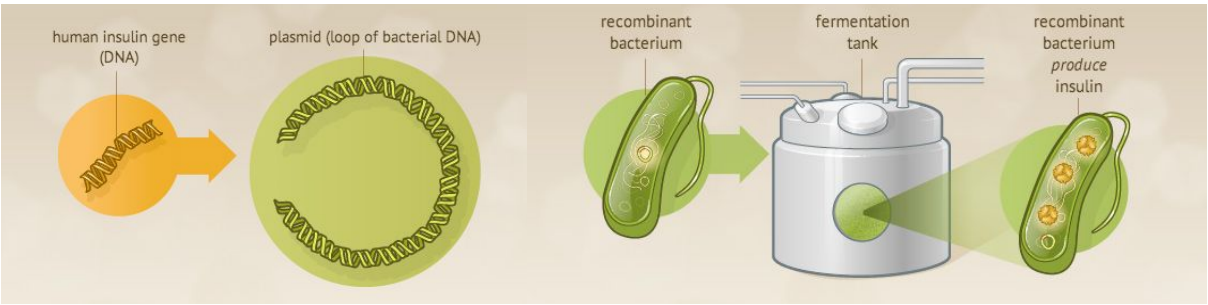
Genetic Engineering in the Real World

Genetic engineering has numerous applications in the fields of biopharmaceuticals, gene therapy, and gene analysis. In this handout, you are going to explore the history and applications of genetic engineering in each of these fields.

1 Biopharmaceuticals

By definition, a biopharmaceutical is any pharmaceutical drug product manufactured in, extracted from, or synthesized from biological sources. The most well-known example of a biopharmaceutical is insulin.

The first synthetic human insulin was produced at Genentech in 1978. Scientists used cloning methods to introduce the human insulin gene into a plasmid. Recombinant DNA was inserted into E. coli bacteria to produce insulin, which was then harvested and purified.



2 Gene Therapy

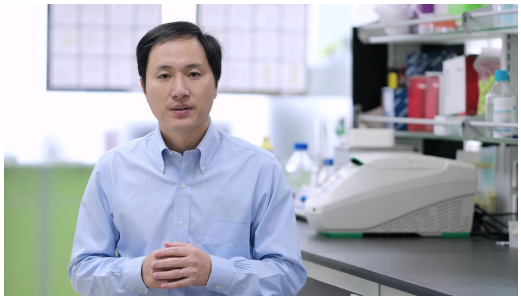
Gene therapy is a technique for correcting defective genes that are responsible for disease development. The first case of gene therapy occurred on September 14, 1990, when a patient named Ashanti DeSilva was treated for severe combined immunodeficiency (SCID). Doctors removed her white blood cells, inserted the missing gene into the white blood cells, and then put them back into her system. This strengthened her immune system, but was only effective for a few months.

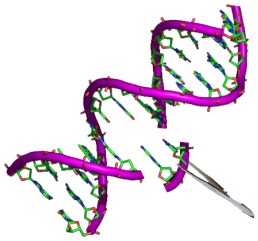
Because of their risks, gene therapy products were not approved by the Food and Drug Administration (FDA) until 2017. Jesse Gelsinger was the first person to die in a clinical trial for gene therapy. He suffered from *ornithine transcarbamylase* deficiency, which results in the inability to metabolize ammonia. This condition is usually fatal at birth, but Gelsinger had a mild form of it, so he could live on a restrictive diet. In 1999, Gelisinger joined a clinical trial at the University of Pennsylvania, which focused on developing a treatment for infants born with the severe form of this disease. He was injected with an adenoviral vector carrying a corrected gene and died four days later at age 18 due to a massive immune response triggered by the viral vector.

3 CRISPR Babies

In the Fall of 2018, He Jiankui used CRISPR-Cas9 genome editing to modify a gene that codes for an important protein in HIV. Jiankui recruited a couple in which the man had HIV, used *in vitro* fertilization to create embryos, edited them, and then implanted them into the woman. The result was that the couple's twin girls, Lulu and Nana, were born without HIV.

Despite Jiankui's success in preventing the couple's twins from having HIV, there was a problem: human gene editing is illegal.† While using CRISPR-Cas9, Jiankui actually generated several other mutations, but implanted them without extensive testing. As a result, Jiankui was fired from his university and sentenced to three years in prison by the Chinese court on December 30, 2019.





4 Concluding Statements

As you saw, many of these breakthroughs in genetic engineering have occurred recently. This is a subset of biotechnology that is constantly evolving and undergoing further research. Many areas of genetic engineering are still unknown.

With every breakthrough in biotechnology and medicine comes ethical criticism. Although CRISPR has the potential to cure patients of genetic disorders, many ethical experts claim that the risks outweigh the benefits. Many animal and human subjects for CRISPR-Cas9 testing have developed dangerous side effects that led to death. Thus, it is important to follow all ethical guidelines when performing genetic engineering experiments.

† If you are interested in learning more about the ethics of stem cell engineering and still need to take a Social Analysis GE, Anya highly recommends **MCDB 50**: Stem Cell Biology, Politics, and Ethics: Teasing Apart the Issues.