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LLNL's Big Science Capabilities Help Spur Over $796 Billion in U.S. Economic Activity Sequencing the Human Genome

J. S. Stewart

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Disclaimer

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Sequencing the Human Genome

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LLNL's successful history of taking on big science projects spans beyond national security and has helped create billions of dollars per year in new economic activity. One example is LLNL's role in helping sequence the human genome. Over $796 billion in new economic activity in over half a dozen fields has been documented since LLNL successfully completed this Grand Challenge.[1]

Figure 1Energy Secretary Bill Richardson (center) touring the Joint Genome Institute with LLNL Scientist and Joint Genome Institute Director Elbert Branscomb (right) in 1999

DNA was discovered in 1869. In 1943, scientist discovered that DNA was a molecule that encodes the genetic instructions used in the development and functioning of living organisms and many viruses. The important role of DNA was established, yet society was a long way off from benefiting. There are billions of DNA molecules. In order for scientists to fully leverage this information, someone needed to sequence DNA which would allow researchers to begin to make direct links to traits in living organisms. Sequencing DNA would allow scientist to find the connection between genetic coding and biological responses; an important step in developing new cures and treatments for humans, predicting genetic predisposition to many illness and improving agricultural productivity. The stumbling block was figuring out how to sequence over 3 billion nucleotides in the human genome.

LLNL formally began its biological research program in 1963. The program was initially launched to study the effects of ionizing radiation on humans. LLNL developed world class expertise in researching cells and DNA leading to important contributions to cell research listed in the timeline below.

1963 LLNL begins a biological research program to investigate the effects of ionizing radiation on humans
1968 LLNL was the first to use a computer to create three-dimensional images of organelles, tiny working parts within the cell nucleus
1973 LLNL Cytophotometric Data Conversion System proved it could measure the DNA in individual chromosomes to great sensitivity
1974 LLNL made history when it successfully measured and sorted hamster chromosomes
1984 LLNL and LANL begin human chromosome-specific DNA libraries
1986 DOE launched a major initiative to completely decipher the human genome.
1988-2002 Federal Government R&D Funding for Human Genome Total $3.2 Billion
2002 Human Genome Project Sequencing Completed by LLNL, LANL, LBNL and Consortium Members

[1] (Tripp & M, 2011)

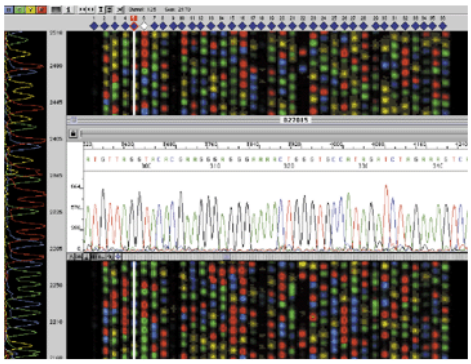
One of the things that make LLNL unique has been its understanding of how High Performance Computing can give its scientists and engineers a major advantage. LLNL scientists, engineers and computer scientists worked together maximizing the use of computations to bring order to what once was believed to be an impossible task, sequencing the human genome.

LLNL developed many of the computer applications that enabled scientists to complete the Human Genome project. Some of these programs are still in use allowing anyone to access the publicly available data from the project.

The result of this grand achievement will be felt in the U.S. and World for the next century or more. Less than ten years after the Human Genome Project was completed, the U.S. economy generated over $796 Billion dollars in economic activity as a result of this achievement. More importantly, the publicly available results have led to an unprecedented economic contribution to the U.S. economy.

Eight major areas (listed below) have seen significant value

and opportunities due to the knowledge and technology discovered by the Human Genome effort.



The four colors in this chromatogram represent the four bases that make up our DNA: green is adenine (A), blue is cytosine (C), yellow is guanine (G), and red is thymine (T). Each fragment of DNA differs from the next fragment by one base, and the dye indicates the terminal base of each fragment. The order of the colors indicates the order of the bases and hence the sequence of the DNA.

Figure 2 Computer Programs allowed researcher to store, order and map the Human Genome

Genetics and Genomics Tools, Technologies, Techniques and Services	Expanding Basic Scientific knowledge	Human Health and Medicine	Veterinary Medicine	Agriculture and Food	Industrial Biotechnology	Environmental Applications	Forensics, Justice and Security

Combined these areas are credited with using the success of the Human Genome project to create;

- *3.8 million job years between 1988-2010;*
- *$796 billion in U.S. economic activity from 1988-2010*
- *2010 alone- 310,000 jobs, $20 Billion in personal income, $67 billion in economic activity*

LLNL's contribution to sequencing the human genome has helped American industry become a world leader in many important DNA related sectors. Examples of these include new and improved techniques in the following areas:

- prenatal and other genetic testing for diseases,
- improved medicines such as cancer drugs based on the genomics of tumors,
- animal vaccines
- increased agricultural yields and faster food safety forensics
- improved law enforcement forensics for justice and security
- new laboratory equipment for researchers to cost effectively conduct DNA test

These industries are working on ways to improve quality of life, agricultural productivity, release innocent victims from incarceration and provide better evidence for law enforcement to identify people of interest.

Industry is just in its infancy of discovering innovative ways the results of the Human Genome Project can translate into improving the quality of life for everyone on the planet as well as spur new job growth and help maintain America's leadership in biotechnology.

The nation's investment in LLNL's research has contributed not only to its security but also its economic competitiveness.

References

Bauer, S. (2014). The FBI Is Very Excited About This Machine That Can Scan Your DNA in 90 Minutes. *Mother Jones*.

Branscomb, E. (2000). The Joint Genome Insitute: Decoding the Human Genome. *Science and Technology Review* .

Cinkosky, M., & Johnson, R. P. (1989, october 12). A Natural Language Query System for Genebank. *Letter*. Livermore, ca, USA: LLNL.

Cook-Deegan, R. (n.d.). *The Gene Wars: Science, Politics, and the Human Genome.*

Eisenstadt, L. (2010). Beyond the Genome: New Uses of DNA Sequencers.

Energy, U. D. (1989, November 3-4). Human Genome Workshop- Contractor/Grantee. *Internal Document*. Sante Fe, New Mexico, USA: DOE.

Heller, A. (2005). Mining Genomes. *Science and Technology*.

Kapitall, A. C. (2011, August 19). DNA Sequencing: The Next High-Growth market in Biotech.

Nanoscale technologies to cut DNA sequencing costs. (2012, September 26). *Kurzweil Accelerating Intelligence*.

Pray, L. (2008). Discovery of DNA Structure and Function: Watson and Crick. *Scitable*.

Science, U. D. (2008). *Joint Genome Insitute 2008 Progress Report.* DOE.

Slezak, T. (2015, May-July). Overview of LLNL History with the Human Genome Project. (J. Stewart, Interviewer)

Staden, R. (1979). A Strategy of DNA Sequencing Employing Computer Programs. *Nucleic Acids Research*, 2601-2610.

Tripp, S., & Gruber, M. (2011). *Economic Impact of the Human Genome Project.* Battelle Memorial Institute.

Tripp, S., & M, G. (2011). *Economic Impact of the Human Genome Project.* Battelle Memorial Institute.

Walter, K. (2002). Biological Research Evolves at Livermore. *Science and Technology Review*.