

2040

- Complete genome-based health care will be the norm.
- Individualized preventive medicine will be available and largely effective.
- Illness will be detected earlier, before symptoms develop, by molecular surveillance.
- Gene therapy and gene-based drug therapy will be available for most diseases.
- The average life expectancy will reach 90 years.
- The debate about the role of humans in taking charge of their own evolution grows louder. Who is to decide what is a good characteristic or trait?

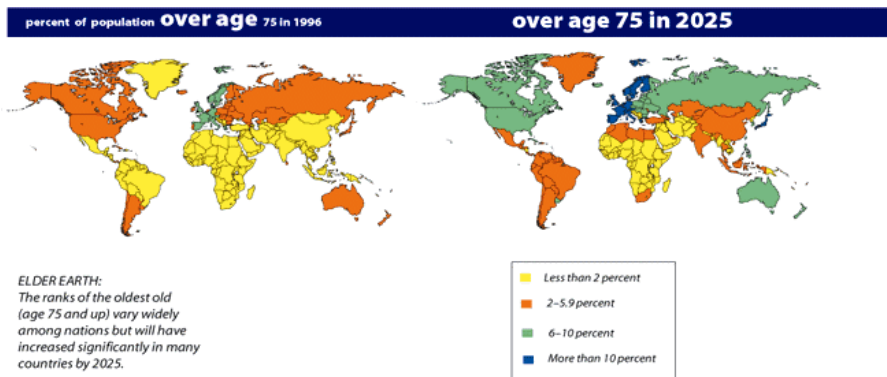


Figure 4. The world growing older. Source: Nature Online, Feb 12, 2001

8 The Test Of Time

Returning to the test of time. Today, with inventions and breakthroughs appearing regularly, and superstars being born almost daily, the common people forget all of these events soon afterwards. Inventors of new gadgets and gizmos are forgotten almost as soon as a better substitute or improvement is developed. Superstars (in sports and Hollywood for example) are purged from memory almost the day after they retire. Great scientists come infrequently and far in between. Their theories are normally so abstract that they will not affect human lives for years to come.

The watershed completion of the first draft of the human genome stands out in these respects. It will be remembered for a long time since it affects directly our very own existence. Reporters liken the human genome project (HGP) with the moonshot. While this metaphor is useful in political and funding purposes, the comparison does not convey the true significance of HGP. The moonshot affected a

negligible number of people substantially and had only negligible effect on a substantial number of people. The impact of HGP will be substantial and it will affect a substantial number of people.

In President Clinton's photo-op analogy, the Lewis-Clark expedition, summoned by President Thomas Jefferson, started from the mouth of Wood River on the Illinois side of the Mississippi, opposite the entrance to the Missouri River on May 14, 1804. The expedition reached the westernmost point of Fort Clatsop at the mouth of Columbia, Oregon in mid November, 1805. By then Clark recorded that 554 days had elapsed and 4,132 miles had been traversed since they left Wood River.

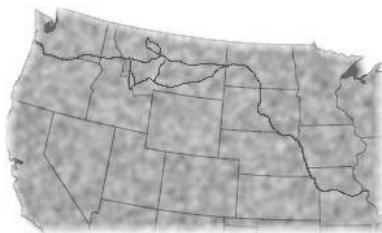


Figure 5. The route of Lewis-Clark expedition, St. Louis to Fort Clatsop.

The human genome expedition, if typed in 10-pitch font, would start in San Francisco (HAL's office) to Chicago, on to Baltimore, Houston, and end in Los Angeles. The sequencing journey officially commenced in 1990, planned to take 15 years, and would end in 2005. In the past few years, due mainly to concurrent technology breakthroughs in computer technology and ultra-high throughput sequencing technology, the sequencing journey reached its destination five years ahead of the original schedule.

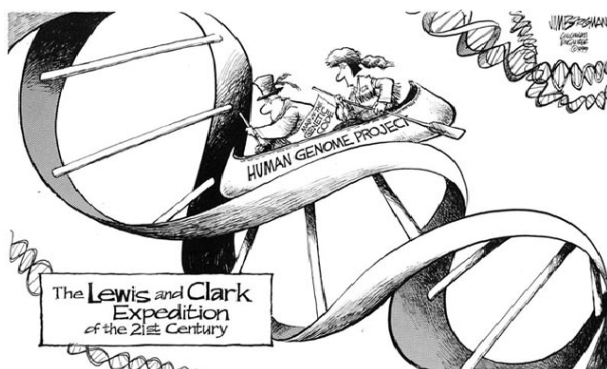


Figure 6. The Lewis-Clark expedition of the 21st Century, reproduced from Cincinnati Enquirer, December 16, 1999. The author thanks Don Halbert of Abbot Laboratories.

So will the group of international contributors be remembered as empire builders, conquerors, or explorers?

These people are not empire builders for when the human genome sequence is digitized or genetized, it lives in cyberspace which recognizes no geo-political borders. These people are not conquerors, for before them there have been many groups and individuals in other disciplines who have slaved through to improve on instrumentation, computer and ancillary technologies. These people are not explorer either. For exploration, the final frontier is unknown. In this case, we know what the end result would be, the sequence of the human genome. These people are not royal family either. Quite the contrary, they help disprove the existence of royal blood. These people are not president. Quite the contrary, presidents love to bathe in the glory of their accomplishment.

But these people certainly have opened a terrain for empire builders for they have opened up the biosphere commons and started the biotechnology century. They have conquered long hours performing the laborious production line repetitive task of sequencing. They have pushed the envelope of our legal system. In the words of Bill Clinton, they have produced "a map of greater significance". If the whole genome were to be written on an average 8½" by 11" paper (U.S. size paper) of average thickness and the sheets of paper were stacked one on top of the other, the entire genome would stack as high as the Washington Monument.

The expedition is just beginning. And bioinformatics will be a big part in the next phase of the expedition. To highlight the significance of bioinformatics, we can perhaps end this chapter by quoting a paragraph from Yoneji Masuda, a leading figure in the Japanese plan to become the first fully developed information society,²⁴

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 Unlike
 material goods,
 information does not
 disappear by being consumed,
 and even more important, the value of
 information can be amplified indefinitely by
 constant additions of new information to the existing
 information. People will thus continue to utilize information
 which they and others have created, even after it has been used.

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This is the major difference between the industrial economy and knowledge-based economy. We have intentionally arranged Matsuda's statement into a pyramid, a wealth pyramid of the information era. This also distinguishes the Human Genome Project from the Lewis-Clark expedition. The race to the finishing line of the map of the human genome between the private and the public sectors,

²⁴ Yoneji Masuda, "Managing in the Information Society: Releasing Synergy Japanese Style", *World Future Society*, Washington, DC, 1980.

particularly the Human Genome Project led by Francis Collins and Celera Genomics led by Craig Venter, was a carefully prearranged tie. Though there was no clear winner between the competitors, the competition has certainly galvanized the public project to finish five years ahead of the original schedule. The biggest winner of all from this race is humankind, the one who is going to enjoy a better quality and more productive life, provided we do not abuse the data.

A good thing about digital revolution is it is status-blind, that electronic mail strikes the highest executive and the lowliest supply clerk alike. After all, that was the promise from the very beginning: e-mail was going to be the great democratizing agent of corporate America, allowing an instant exchange of ideas unimpeded by gatekeepers and protocols. You were either in or you were out in the new corporation and, thanks to e-mail, you could be in anywhere — all distances, whether geographic or hierarchical, would vanish into electronic ether.

Hopefully, in a similar way, once the genomes of organisms, humans inclusive, have been digitized and genitized, all organisms will be democratized. In the language of SNPs, each *Homo sapiens* is not too different from the other, only in 0.1% of the genomes. Similarly, in the language of genes, *Homo sapiens* are not too different from other organisms. The *Homo sapiens* has only one and a half times as many genes as a *Caenorhabditis elegans*. The catch phrase of condescension is “The *Homo sapiens* are just more complex”.