



# Nanotech and Society

January 6, 2005

Doug Klein

Director, Center for

Converging Technologies

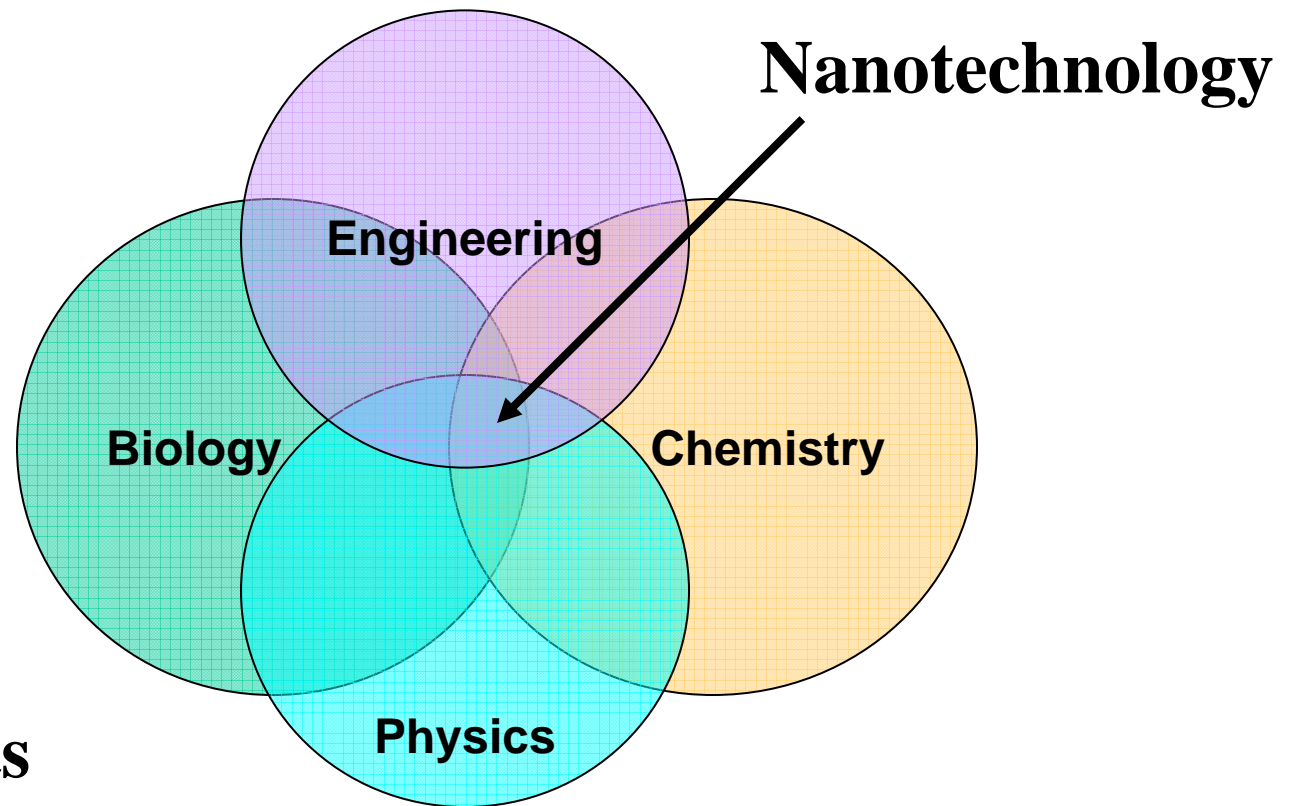
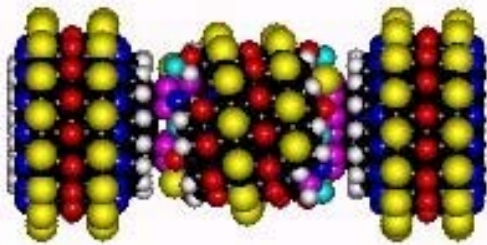
*Zero@Wavefunction: nano dreams & nightmares*

Victoria Vesna

James Gimzewski

Josh Nimoy

# ... a future in NANOTECHNOLOGY



**Liberal Arts  
& Engineering**



**R. Buckminster Fuller**  
***Operating Manual for Spaceship Earth***,  
**1969**

**...scientists began to realize [at the beginning of World War II] that whereas a biologist used to think that he was dealing only in cells and that a chemist was dealing only in molecules and the physicist was dealing only in atoms, they now found their new powerful instrumentation and contiguous operations overlapping. p. 45**

# will nano bring a Diamond Age?

<http://www.complete-review.com/reviews/stephenn/diamond.htm>



Ovid



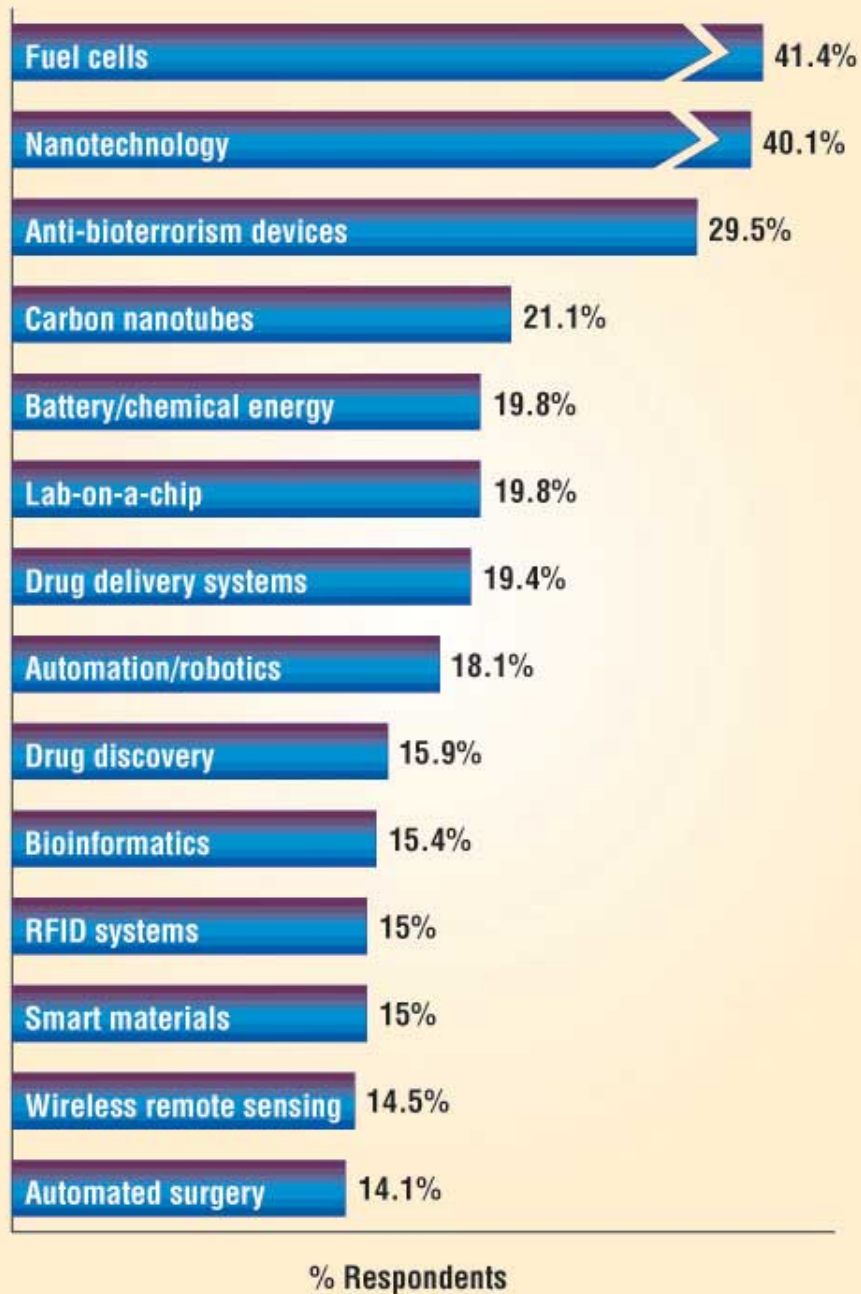
<http://www.geocities.com/Athens/Forum/6946/images/>

Ages of Man  
in Greek mythology

Golden  
Silver  
Bronze  
Iron 1 and 2



## Readers' Hot Technologies in 2005



Source:

**R&D Magazine**

[http://www.rdmag.com/images/0412/chart1\\_lrg.jpg](http://www.rdmag.com/images/0412/chart1_lrg.jpg)

Media coverage of nanotechnology—both positive and negative—is increasingly exponentially.

Mentions of the word “nanotechnology” in the popular press rose from 190 in 1995 to 7,316 in 2003;

Lux Research predicts more than 12,000 mentions in 2004.

<http://www.luxresearchinc.com/>

## 2004 Global Spending on Nanotechnology to Exceed \$8.6 Billion

According to a recently published report from [Lux Research](#), global spending on nanotechnology research will top \$8.6 billion. Of this, government spending will account for over \$4.6 billion, with:

- North America spending approx. \$1.6 billion or 35%
- Asia spending approx. \$1.6 billion or 35%
- Europe spending approx. \$1.3 billion or 28%
- The rest of the world spending approx. \$133 million or 2%

**The New York Times**  
nytimes.com

January 5, 2005

# IBM - Led Group to Invest \$2.5 Bln in Upstate N.Y.



[http://www.semiconductor-technology.com/projects/ibm\\_fishkill/images/2\\_NRLIBM-Fishkill-Figure-0.jpg](http://www.semiconductor-technology.com/projects/ibm_fishkill/images/2_NRLIBM-Fishkill-Figure-0.jpg)





ESC 24/ CHM 24

# Frontiers of Nanotechnology

Winter 2004 - Union College

Course Content

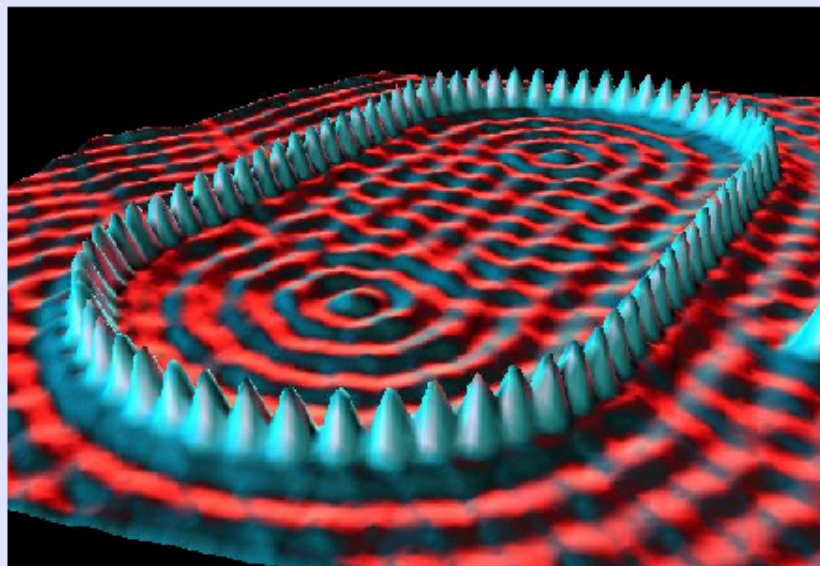
Instructors

Nanotracts

Presentations

Syllabus

Exams



IBM Corral (Fe on Cu)

Last Modified: January 1, 2004



"But like any powerful new technology," says NSF Director Rita Colwell, "nanotech also has the potential for unintended consequences--which is precisely why we can't allow the societal implications to be an afterthought.

<http://www.nsf.gov/od/lpa/news/03/pr0389.htm>

# Nanotechnology in Fact & Fiction



Richard Feynman (1959),  
There's Plenty of Room  
at the Bottom





K. Eric Drexler

*Engines of Creation*

*The Coming Era of Nanotechnology*  
1986

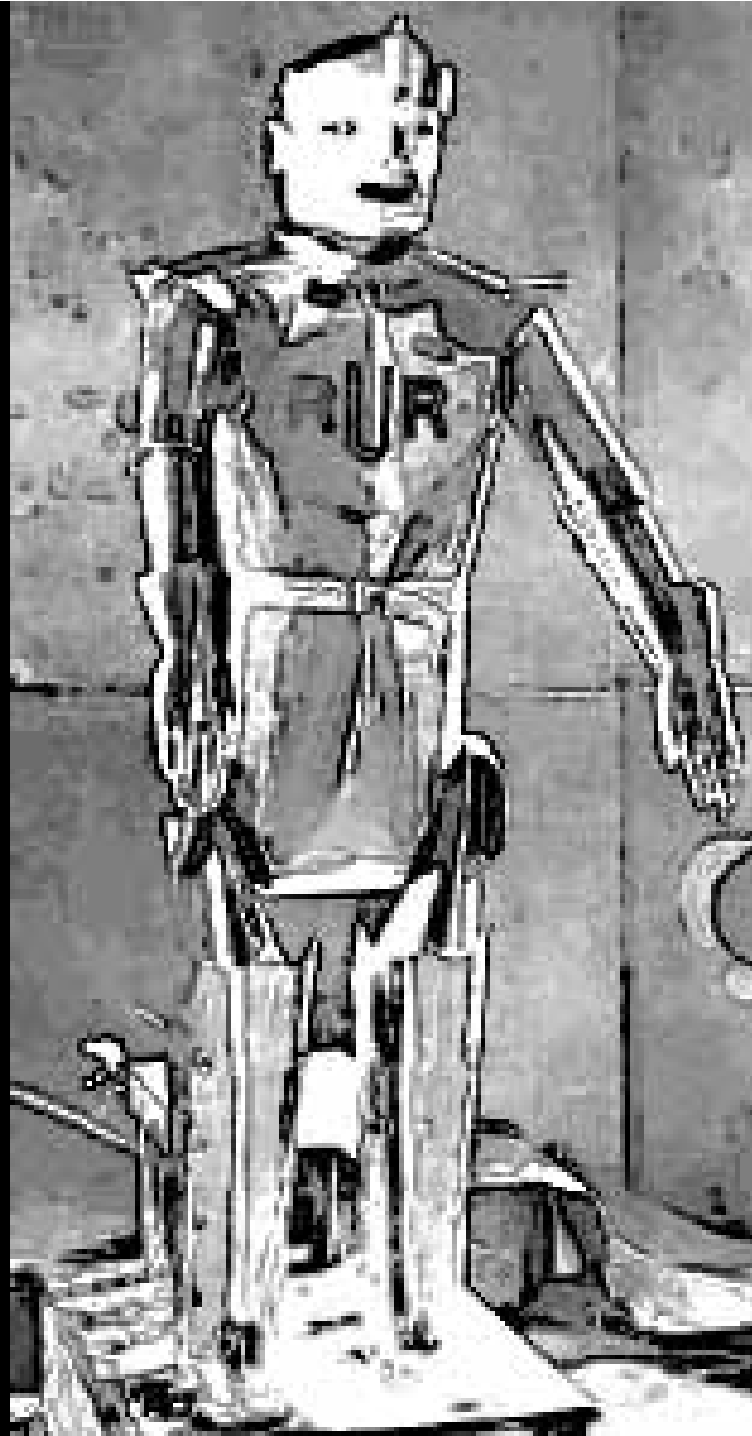
In short, replicating assemblers will copy themselves by the ton, then make other products such as computers, rocket engines, chairs, and so forth. ....

Assemblers will be able to make virtually anything from common materials without labor, replacing smoking factories with systems as clean as forests. They will transform technology and the economy at their roots, opening a new world of possibilities. They will indeed be engines of abundance.

Drexler - <http://www.foresight.org/>

Karel  
Capek

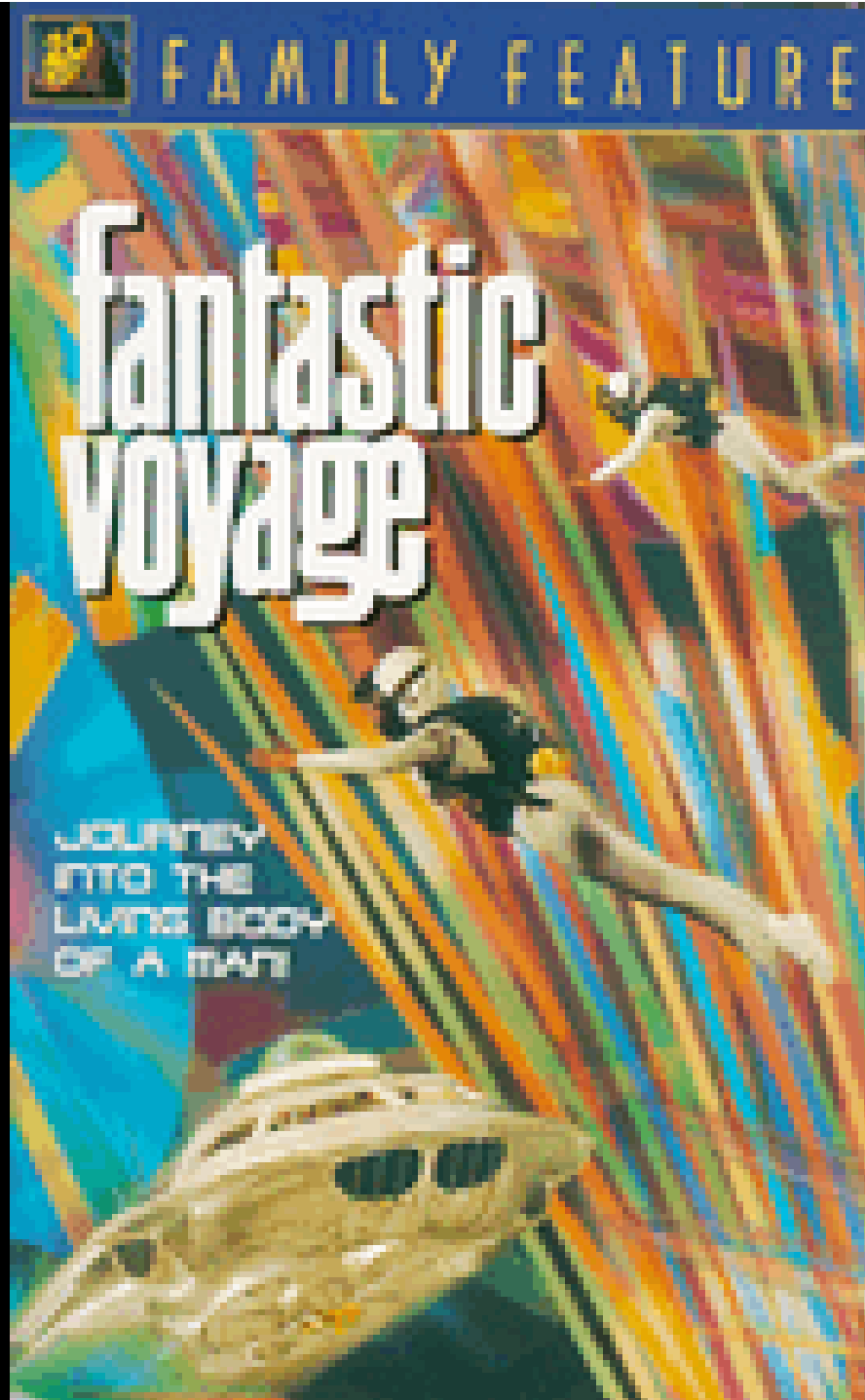
1920



1966



2002



Nano  
run  
amok.

# PREY

A NOVEL

MICHAEL  
CRICHTON



# Nanofallacies

Richard E. Smalley

Self-replicating, mechanical nanobots are simply not possible in our world. To put every atom in its place – the vision articulated by some nanotechnologists – would require magic fingers. Such a nanobot will never become more than a futurist's daydream.

“Of Chemistry, Love and Nanobots,” *Scientific American*, Sept. 2001, p. 77

## COVER STORY

**December 1, 2003**

Volume 81, Number 48

CENEAR 81 48 pp. 37-42

ISSN 0009-2347

POINT  COUNTERPOINT

# NANOTECHNOLOGY

Drexler and Smalley make the case for and against 'molecular assemblers'

RUDY BAUM

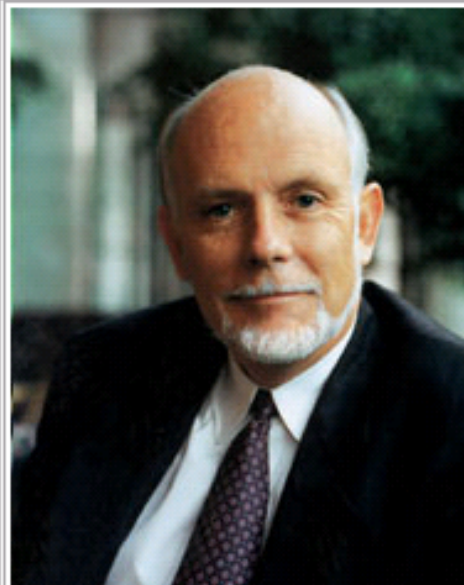


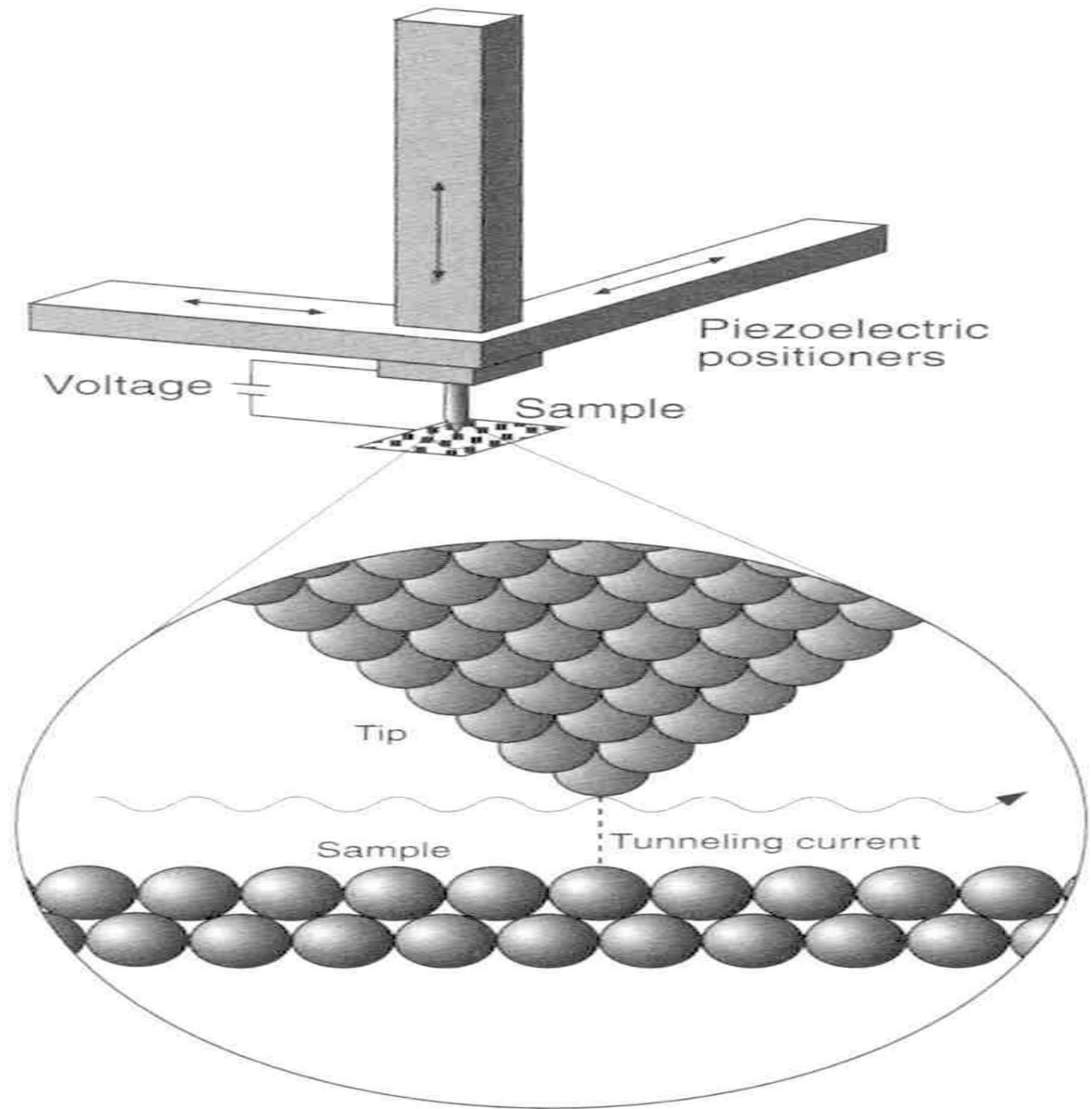
PHOTO BY RUDY BAUM



PHOTO BY LINDA CICERO

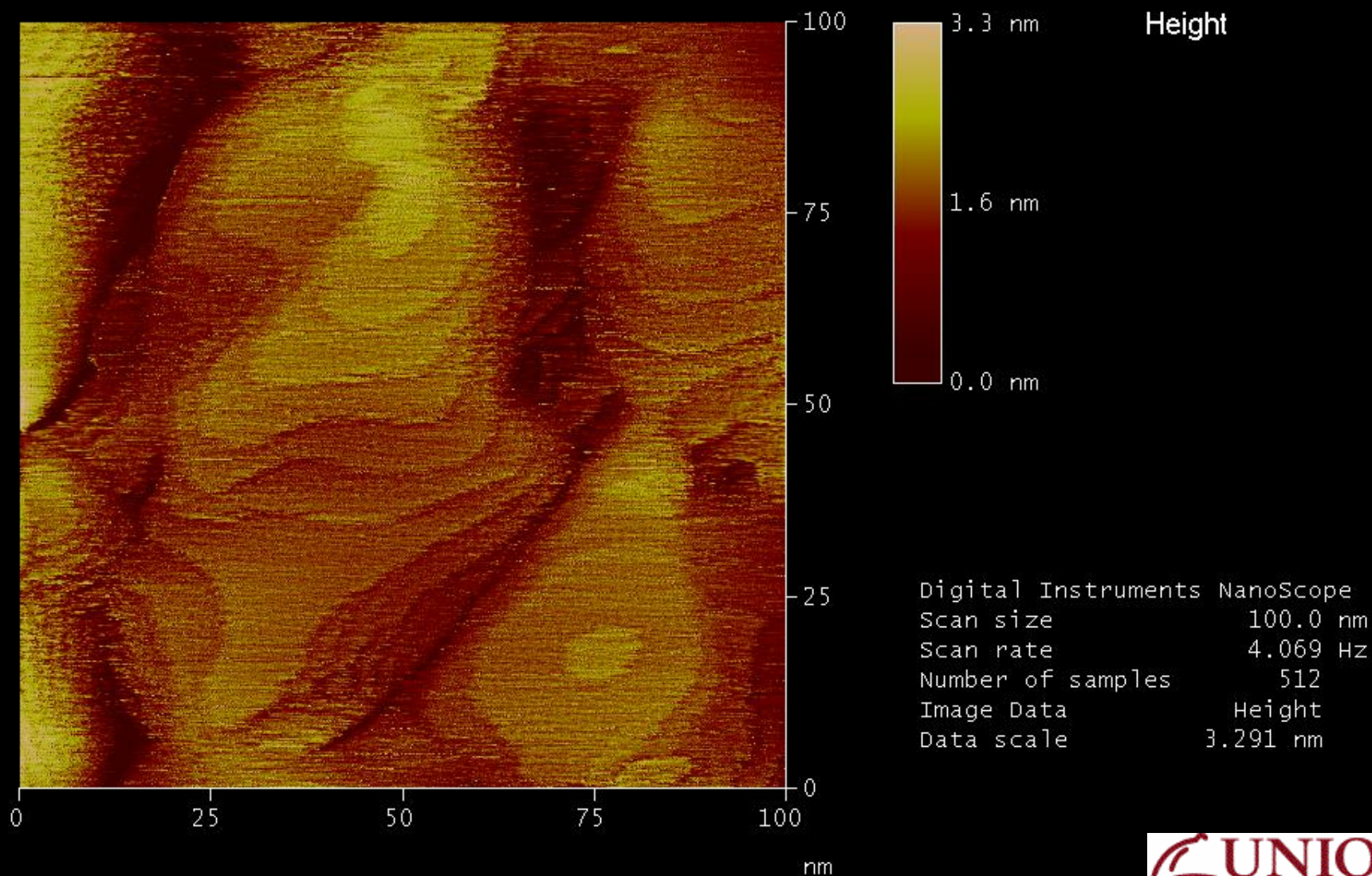
**OPEN DEBATE** Rice University's Smalley (left) takes issue with mechanosynthesis and molecular manufacturing as set forth by Foresight Institute's Drexler.

# Magic fingers of an Atomic Force Microscope



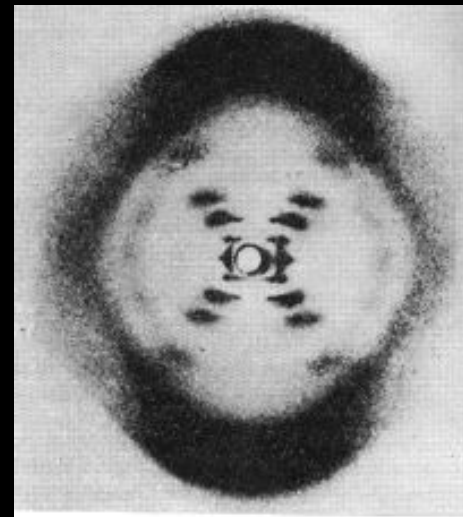
Jason Sloanwaite, '04;  
spent Fall 2002 in a Swedish nanotech lab.

<http://www.vu.union.edu/~slaunwhj/afm/>





Mechanical nanobots may never be practical, but DNA works pretty well.



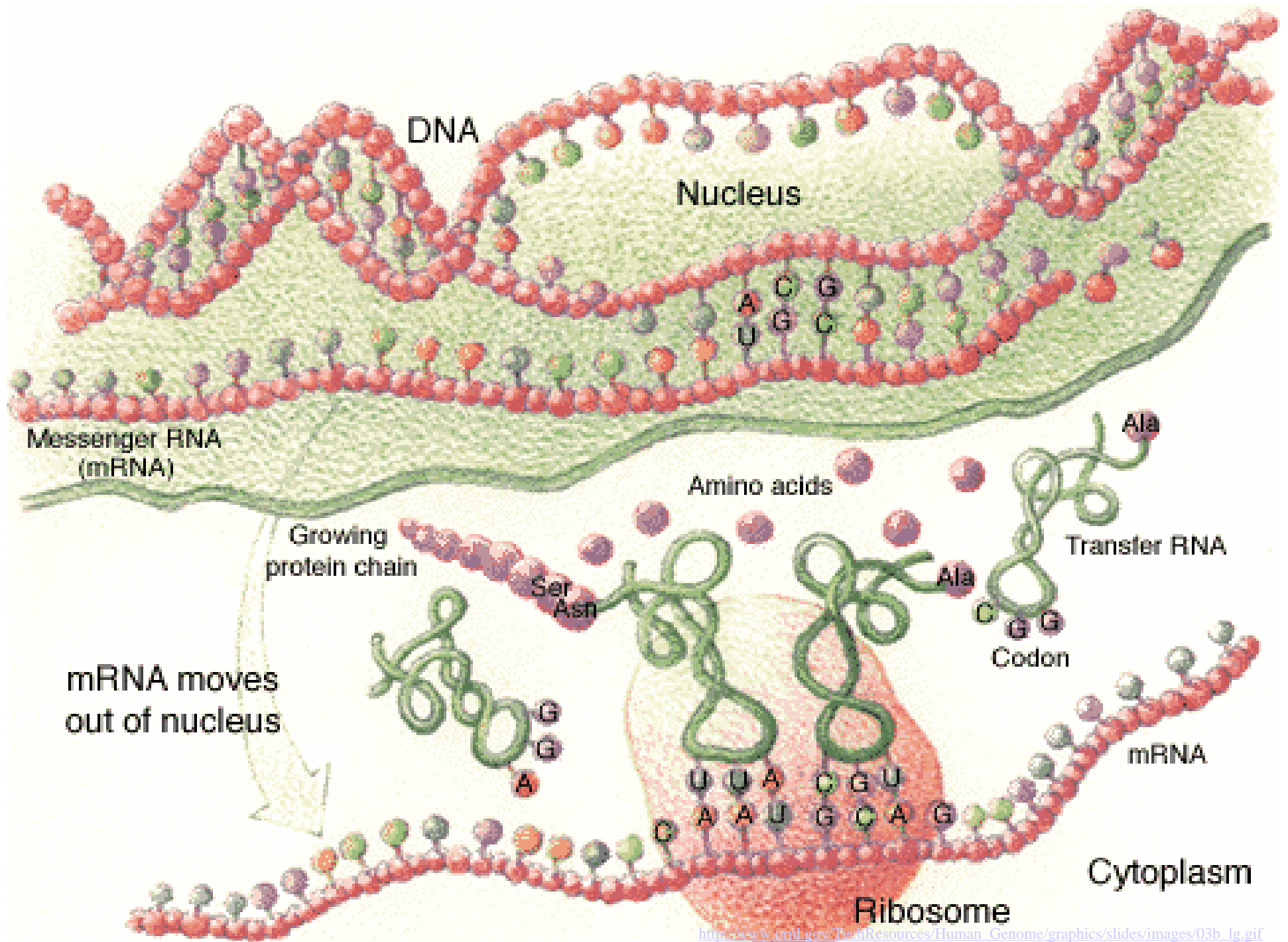
Rosalind Franklin's X-ray diffraction photograph of DNA, 1953



## The RNA Codons

Second nucleotide

|   | U                                           | C                          | A                              | G                           |   |
|---|---------------------------------------------|----------------------------|--------------------------------|-----------------------------|---|
| U | UUU <b>Phenylalanine</b> (Phe)              | UCU <b>Serine</b> (Ser)    | UAU <b>Tyrosine</b> (Tyr)      | UGU <b>Cysteine</b> (Cys)   | U |
|   | UUC Phe                                     | UCC Ser                    | UAC Tyr                        | UGC Cys                     | C |
|   | UUA <b>Leucine</b> (Leu)                    | UCA Ser                    | UAA <b>STOP</b>                | UGA <b>STOP</b>             | A |
|   | UUG Leu                                     | UCG Ser                    | UAG <b>STOP</b>                | UGG <b>Tryptophan</b> (Trp) | G |
| C | CUU <b>Leucine</b> (Leu)                    | CCU <b>Proline</b> (Pro)   | CAU <b>Histidine</b> (His)     | CGU <b>Arginine</b> (Arg)   | U |
|   | CUC Leu                                     | CCC Pro                    | CAC His                        | CGC Arg                     | C |
|   | CUA Leu                                     | CCA Pro                    | CAA <b>Glutamine</b> (Gln)     | CGA Arg                     | A |
|   | CUG Leu                                     | CCG Pro                    | CAG Gln                        | CGG Arg                     | G |
| A | AUU <b>Isoleucine</b> (Ile)                 | ACU <b>Threonine</b> (Thr) | AAU <b>Asparagine</b> (Asn)    | AGU <b>Serine</b> (Ser)     | U |
|   | AUC Ile                                     | ACC Thr                    | AAC Asn                        | AGC Ser                     | C |
|   | AUA Ile                                     | ACA Thr                    | AAA <b>Lysine</b> (Lys)        | AGA <b>Arginine</b> (Arg)   | A |
|   | AUG <b>Methionine</b> (Met) or <b>START</b> | ACG Thr                    | AAG Lys                        | AGG Arg                     | G |
| G | GUU <b>Valine</b> Val                       | GCU <b>Alanine</b> (Ala)   | GAU <b>Aspartic acid</b> (Asp) | GGU <b>Glycine</b> (Gly)    | U |
|   | GUC (Val)                                   | GCC Ala                    | GAC Asp                        | GGC Gly                     | C |
|   | GUA Val                                     | GCA Ala                    | GAA <b>Glutamic acid</b> (Glu) | GGA Gly                     | A |
|   | GUG Val                                     | GCG Ala                    | GAG Glu                        | GGG Gly                     | G |



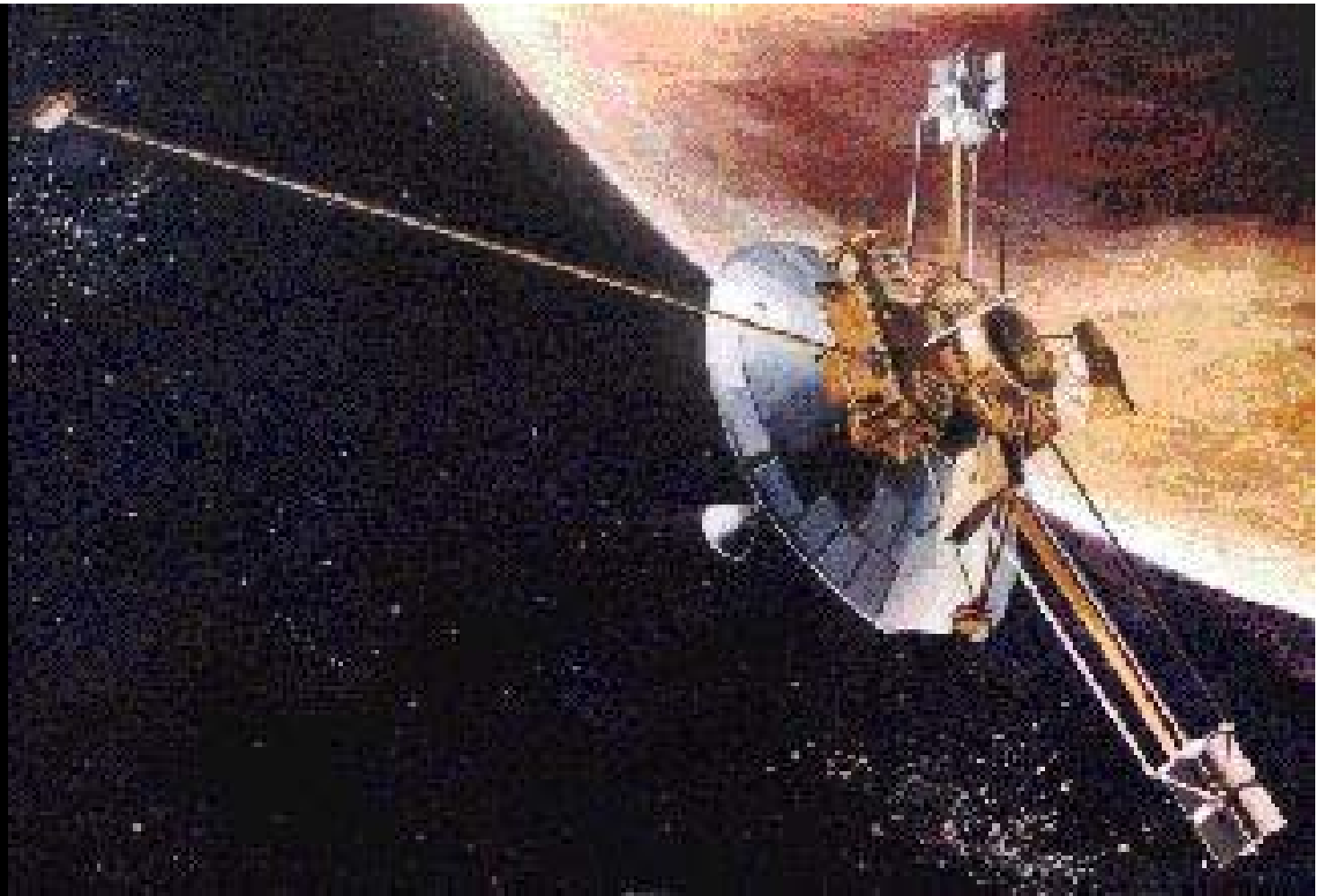
# Genomics and Its Impact on Science and Society The Human Genome Project and Beyond

*a publication of the U.S. Department of Energy Human Genome Program*

March  
2003



[http://www.ornl.gov/sci/techresources/Human\\_Genome/publicat/primer2001/index.shtml](http://www.ornl.gov/sci/techresources/Human_Genome/publicat/primer2001/index.shtml)



Pioneer 10; launched 1972; ~12 billion km away

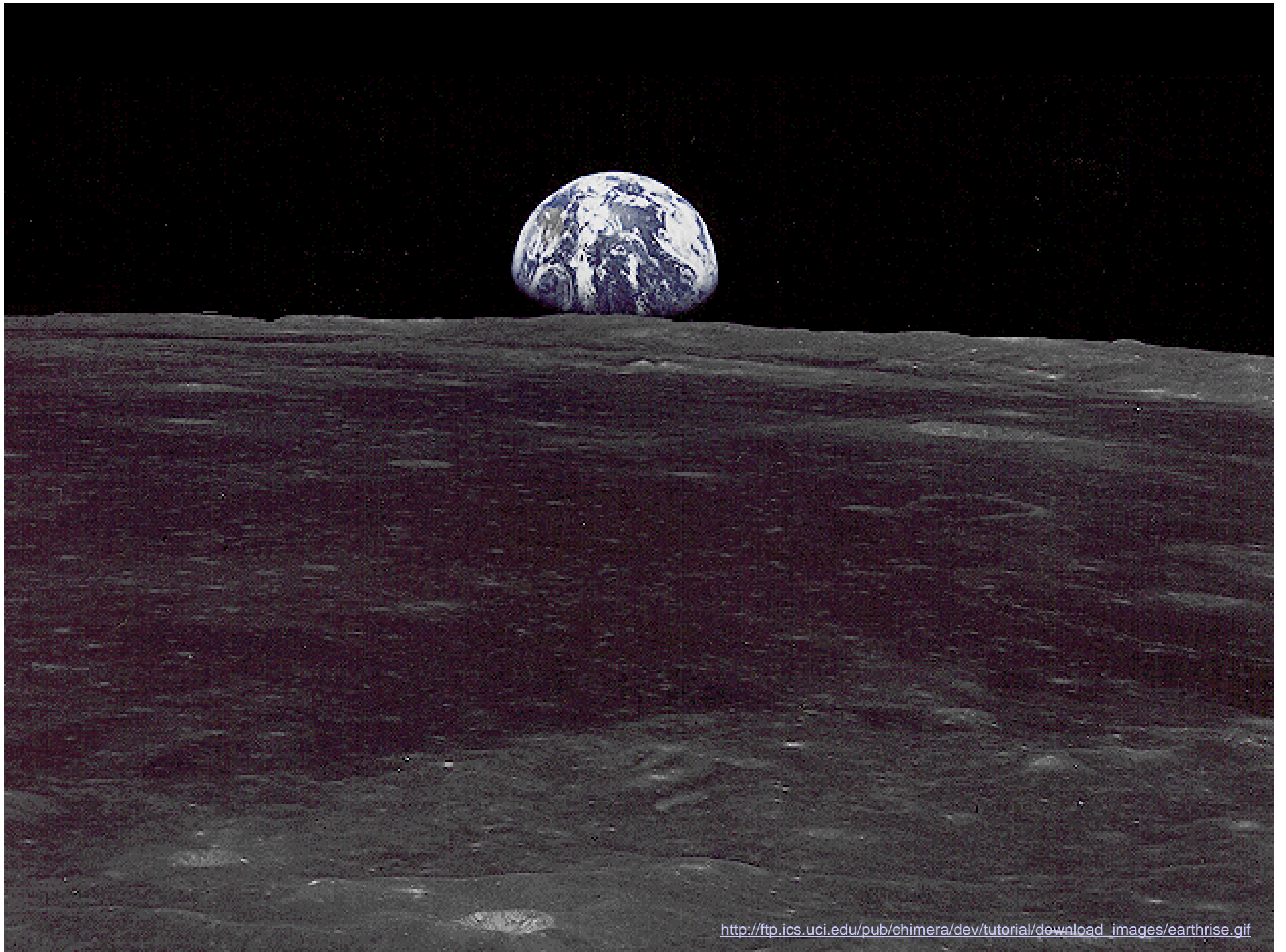


← Earth is the  
pale blue dot.

Last photo  
returned by  
Pioneer 10.

1990  
6.4 billion km





[http://ftp.ics.uci.edu/pub/chimera/dev/tutorial/download\\_images/earthrise.gif](http://ftp.ics.uci.edu/pub/chimera/dev/tutorial/download_images/earthrise.gif)



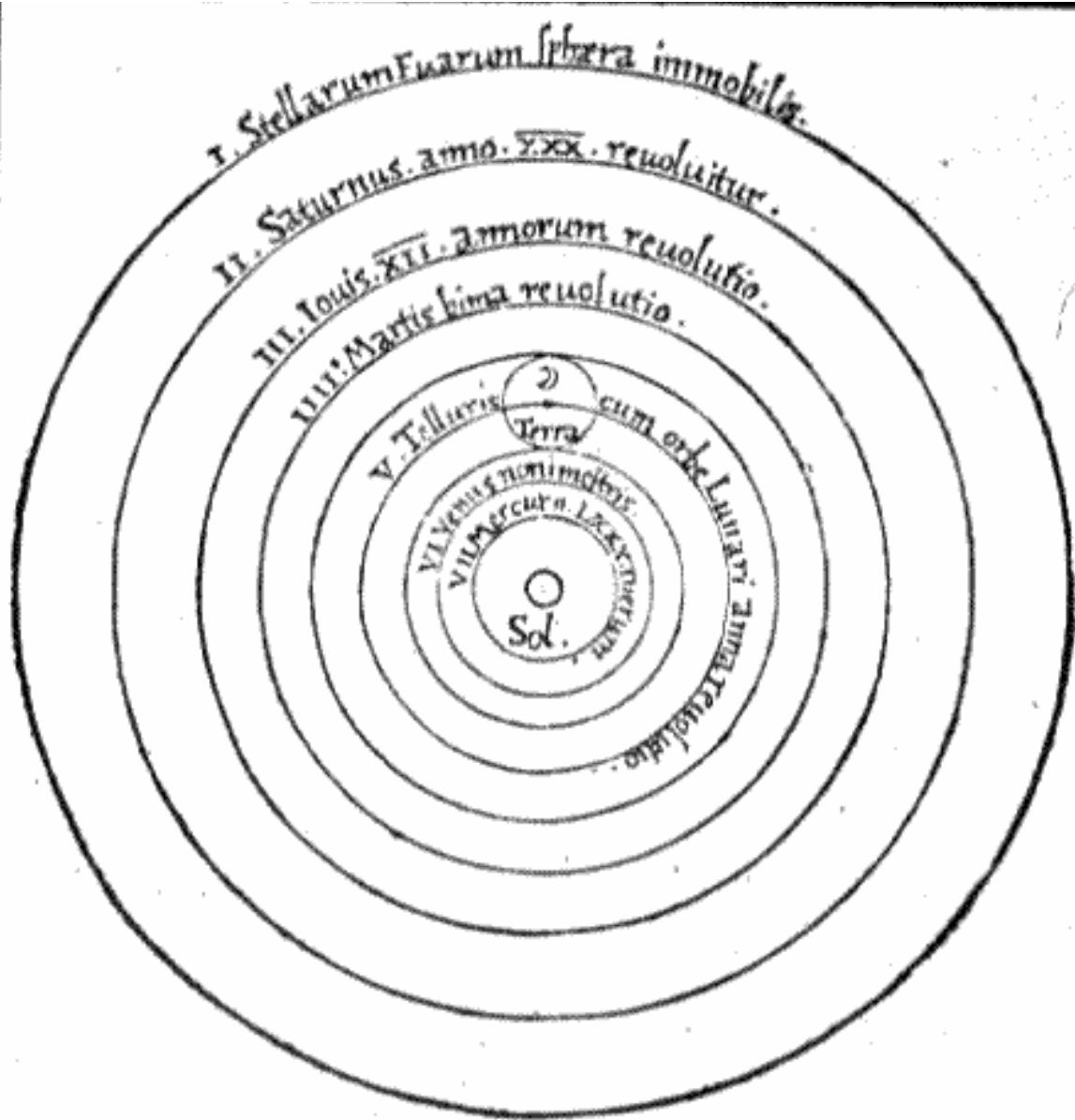
A few more moons, a few more winters, and not one of the descendants of the mighty hosts that once moved over this broad land or lived in happy homes, protected by the Great Spirit, will remain to mourn over the graves of a people once more powerful and hopeful than yours. But why should I mourn at the untimely fate of my people? Tribe follows tribe, and nation follows nation, like the waves of the sea. It is the order of nature, and regret is useless. Your time of decay may be distant, but it will surely come, for even the White Man whose God walked and talked with him as friend to friend, cannot be exempt from the common destiny. We may be brothers after all. We will see.

Chief Seattle, 1855

<http://www.halcyon.com/arbors/chiefssea.html>

# The Crown of Creation

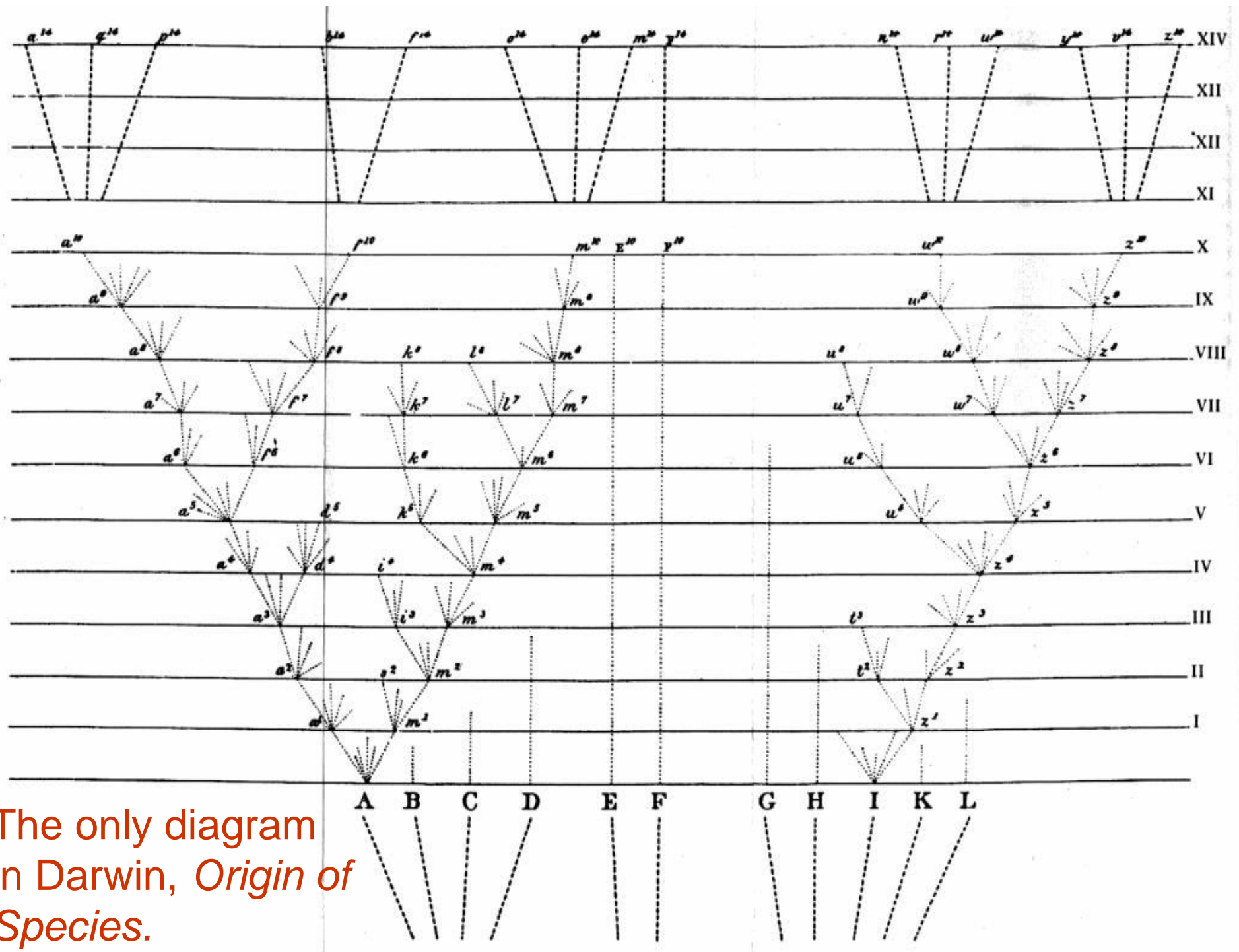
(humans and technology)



The single most important scientific diagram ever published.

- NYC Public Library

Copernicus' 1543 heliocentric model of the solar system.



The only diagram  
in Darwin, *Origin of  
Species*.

# Hubble: The Universe is not Eternal

## Edwin Powell Hubble

was born in the small town of Marshfield, Missouri, USA, on November 29th, 1889. In 1898, His family moved to Chicago, where he attended high school. Young Edwin Hubble had been fascinated by science and mysterious new worlds from an early age, having spent his childhood reading the works of Jules Verne (20,000 Leagues Under the Sea, From the Earth to the Moon), and Henry Rider Haggard (King Solomon's Mines), Edwin Hubble was a fine student and an even better athlete, having broken the Illinois State high jump record. When he attended University, Hubble continued to excel in sports such as basketball and boxing, but he also found time to study and earn an undergraduate degree in mathematics and astronomy.

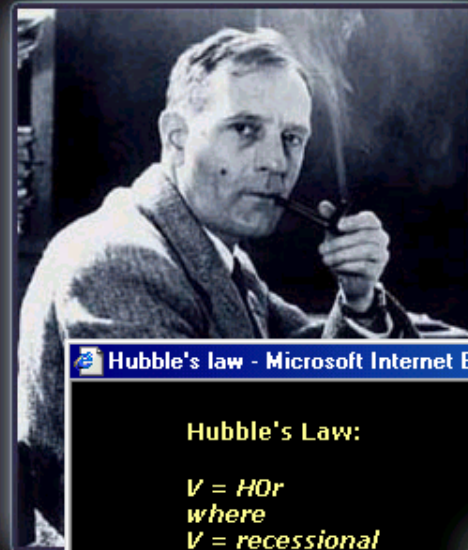
Edwin Hubble went to Oxford University on a Rhodes scholarship, where he did not continue his studies in astronomy, but instead studied law. At this point in his life, he had not yet made up his mind about pursuing a scientific career.

In 1913, Hubble returned from England and was admitted to the Louisville Kentucky; but it didn't take long for Hubble to realize his real passion was astronomy, so he studied at the Yerkes Observatory and earned his doctorate in astronomy from the University of Chicago.

Following a tour of duty in the first World War, Hubble took a job in California, where he took many photographs of Cepheid variables with a telescope, proving they were outside our galaxy, and determining the distances to other galaxies such as our own Milky Way, which had until then been thought to be the only galaxy.

Hubble had also devised a classification system for the various types of galaxies, based on their content, distance, shape, and brightness; it was then he noticed that the galaxies were moving away from each other, and the further the distance between them. From these observations, he was able to determine the rate at which the universe is expanding, helping astronomers determine the age of the universe, and providing evidence for the Big Bang theory.

It is interesting to note that in 1917, Albert Einstein had already introduced his general theory of relativity, which predicted that the universe would expand.




Hubble's law - Microsoft Internet Explorer

**Hubble's Law:**

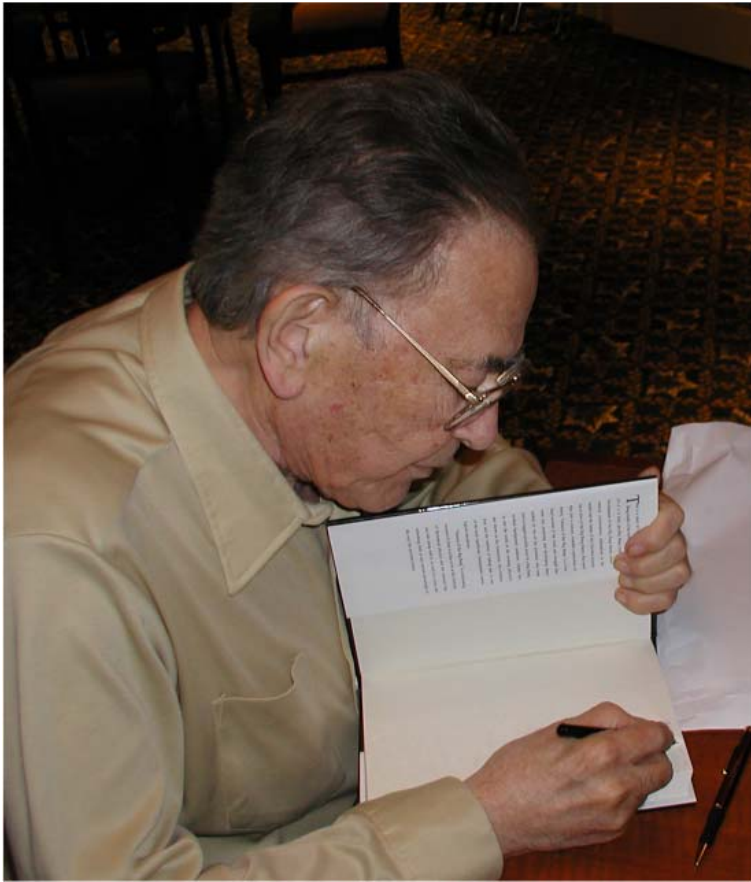
$$V = H_0 r$$

where  
 $V$  = recessional velocity  
 $H_0$  = Hubble constant  
 $r$  = distance (mpc)  
Mpc = megaparsec  
= parsec  $\times 10^6$



Here, we are assuming that the universe expands uniformly, at a constant rate, and that the recessional velocity ( $V$ ) is linearly proportional to the distance ( $r$ ). Hubble's constant ( $H_0$ ), is determined by observational data, and remains unchanged by the values of ( $V$ ) and ( $r$ ).





from Ralph Alpher to Jefferson Airplane





Christian Griepenkerl (1839-1916): Raub des Feuers. Photo © Maicar Förlag - GML

"Prometheus, you are glad that you have outwitted me and stolen fire ... but I will give men as the price for fire an evil thing in which they may all be glad of heart while they embrace their own destruction."

[Zeus to Prometheus 1. Hesiod, *Works and Days* 55]

Daedalus  
fashioned wings  
so that he and  
his son Icarus  
could escape  
from the  
Labyrinth at  
Crete.



Charles-Paul Landon, 1760-1826: Dédale et Icare. Photo © Maicar Förlag - GML.

Thomas Malthus, *An Essay on the Principle of Population*, 1789



“Population ... increases in a geometrical ratio ...

Subsistence increases only in an arithmetical ratio ...

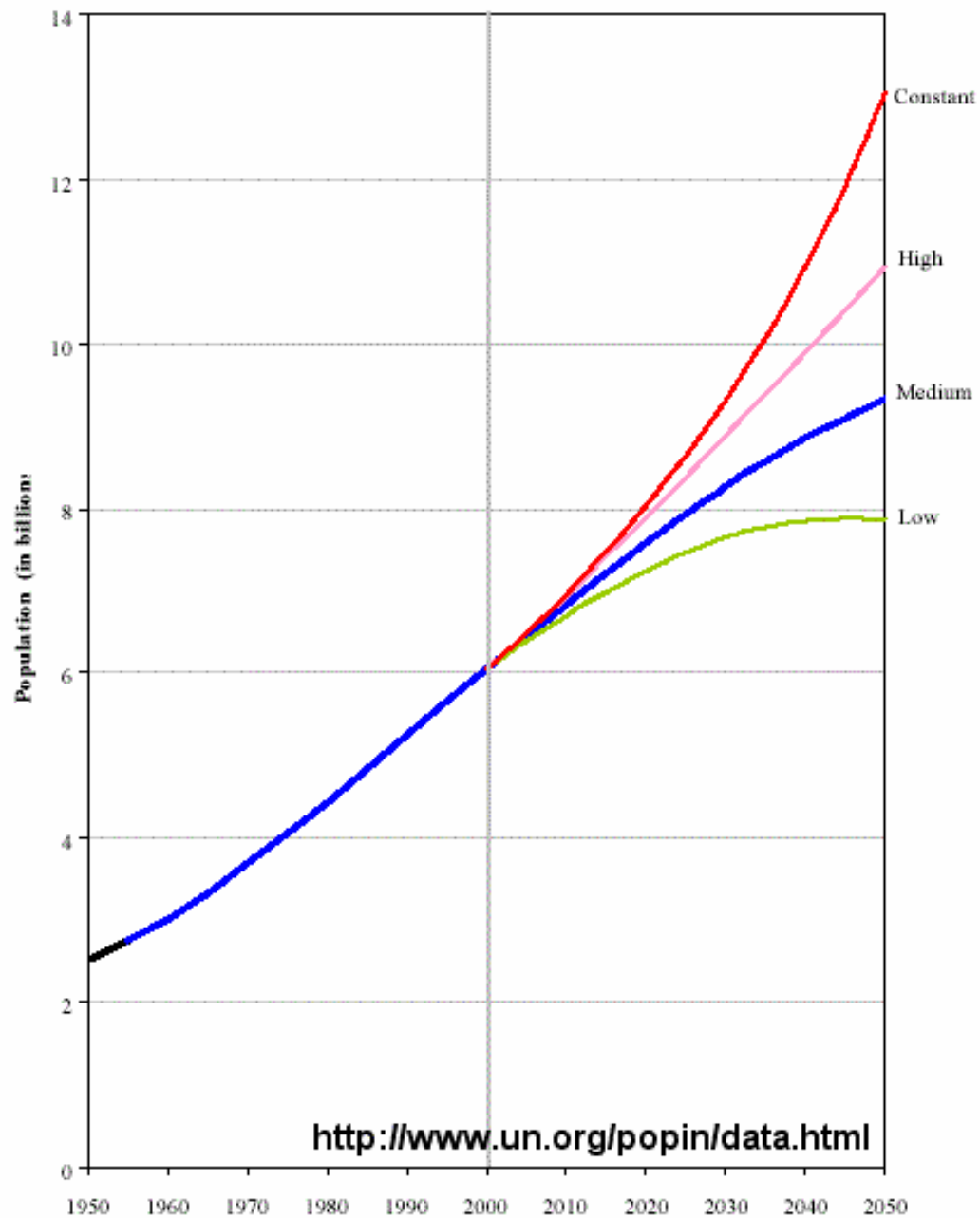
This implies a strong and constantly operating check on population from the difficulty of subsistence... .”

What has been & what will be the role of Science and Technology?

So, What of the Future?



Figure I. Estimated and projected population of the world by projection variant, 1950-2050





# JOHANNESBURG SUMMIT 2002



26 August - 4 September 2002



Welcome to the official United Nations website for the Johannesburg Summit 2002 - the World Summit on Sustainable Development.

بالعربية 中文 English Français Русский Español

[Click here for coverage from the Summit.](#)

- HOME
- BASIC INFO
- WHAT'S NEW
- CALENDAR
- PREPARATORY PROCESS
- DOCUMENTS
- MAJOR GROUPS
- MEDIA INFO
- SUSTAINABLE DEVELOPMENT IN ACTION
- LINKS
- CONTACT US

## Feature Story



Closing of the World Summit on Sustainable Development

### The Johannesburg Summit Test: What Will Change?

New York, 25 September—When the United Nations General Assembly authorized holding the World Summit on Sustainable Development, it was hardly a secret— or even a point in dispute— that progress in implementing sustainable development has been extremely disappointing since the 1992 Earth Summit, with poverty deepening and environmental degradation worsening. What the world wanted, the General Assembly said, was not a new philosophical or political debate

FAQ



Summit Logo



Virtual Exhibition



The Jo-burg Summit wrestled with these problems.

See the PBS documentary.

<http://www.pbs.org/how/science/unsummit.html>

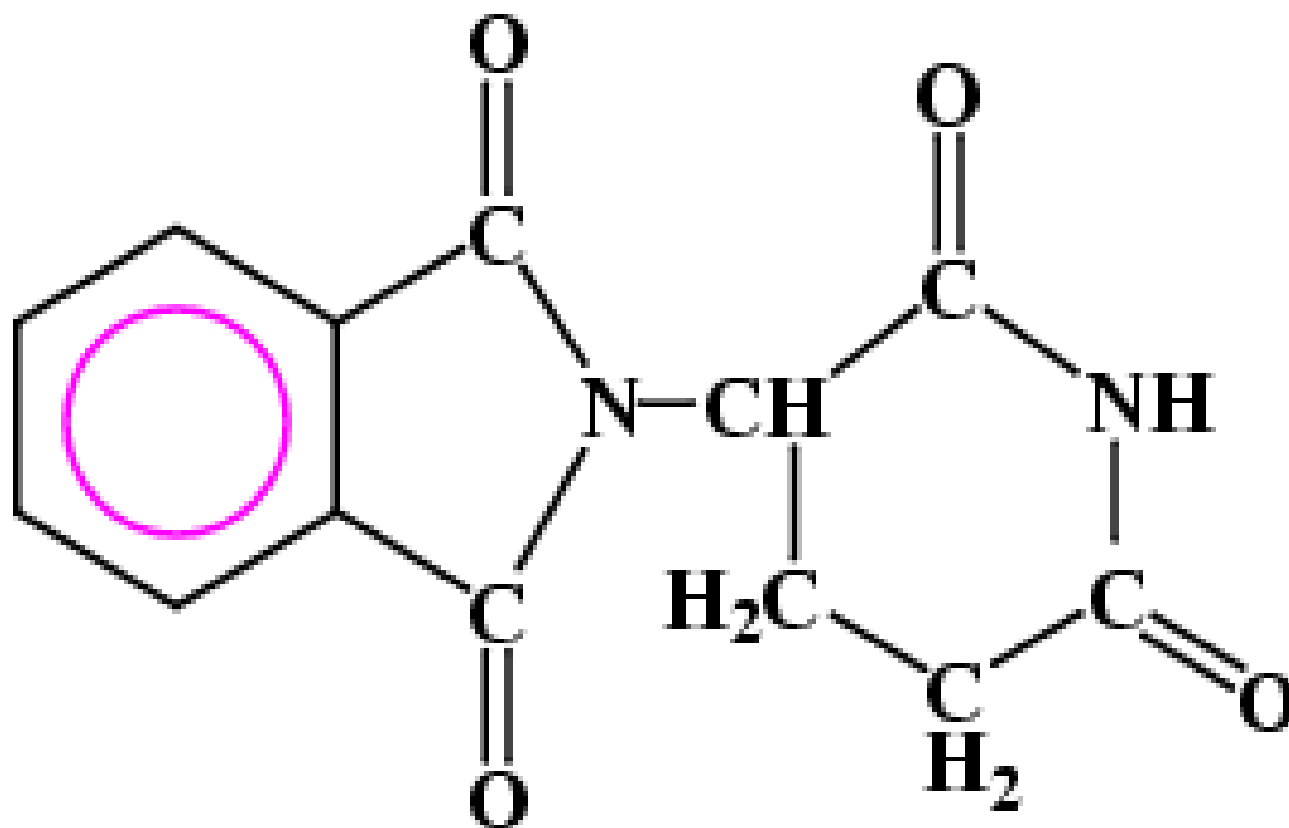


Icarus -- the man who fell to earth.

Are science & technology the  
problem or the cure?

or

Why are people skeptical?



<http://scholar.hw.ac.uk/site/chemistry/topic7.asp?outline=no>





# EDISON LIGHT

## Edison United Manufacturing Co.,

16 AND 18 BROAD STREET, NEW YORK.

ESTIMATES FURNISHED FOR ISOLATED PLANTS,

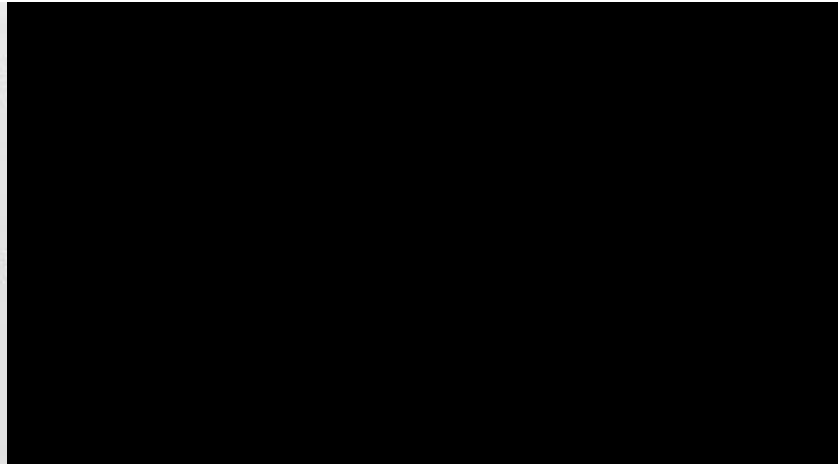
For use in Mills, Hotels, Theatres, Steamboats, etc., etc.

More than 500,000 EDISON LAMPS IN USE IN THE UNITED STATES

### A CARD

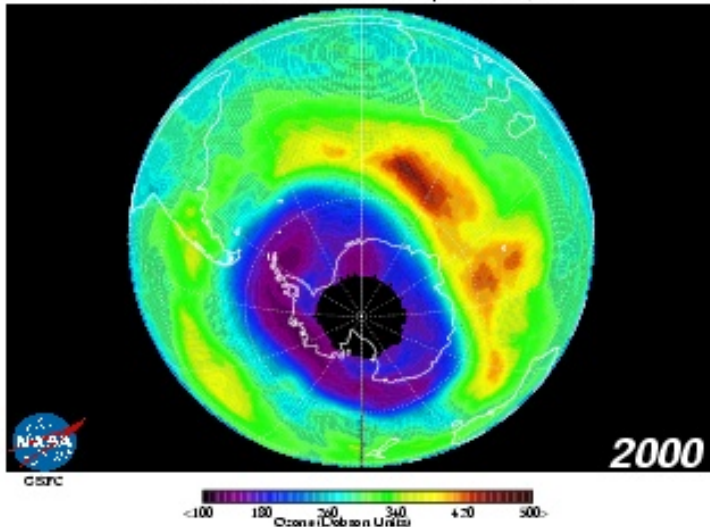
The Edison Electric Light Company has been publishing columns of the press for the courts in support of its patent of 1879 covers broadly the mitigation in the United States Patent Office has finally prevailed against all infringers nowhere anticipated; ergo, a like result facts, together with the violent effort to imitate of fraudulently posing before the public only indicate the dire extremity of those who

**EDISON**



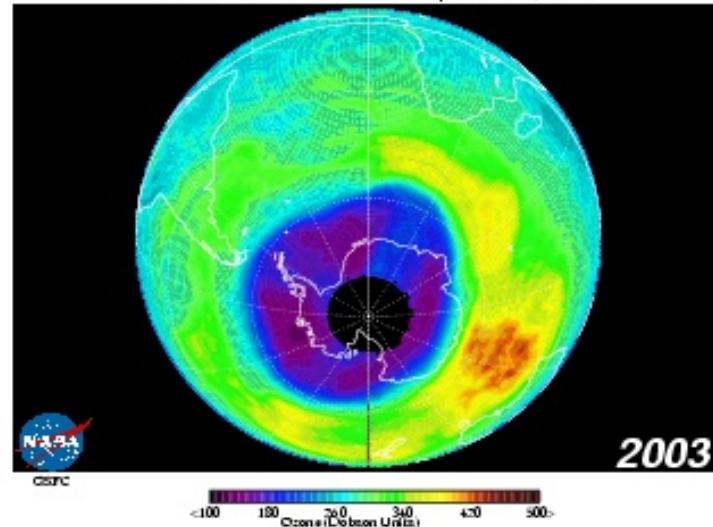
# Second Largest Ozone Hole Area

Earth Probe TOMS Total Ozone September 10, 2000



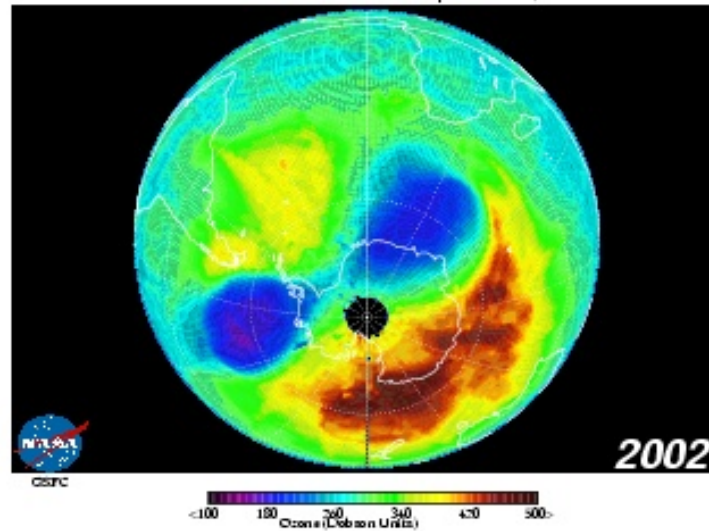
*Maximum Area = 11.5 million square miles*

Earth Probe TOMS Total Ozone September 11, 2003

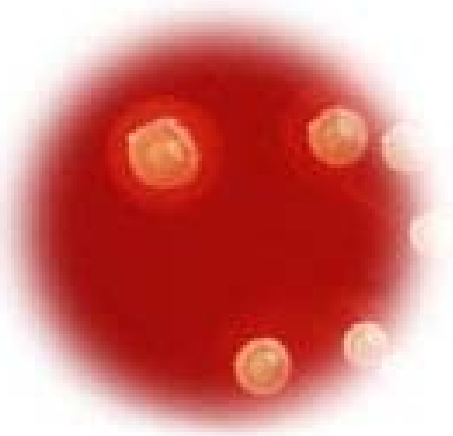


*Maximum Area = 10.9 million square miles*

Earth Probe TOMS Total Ozone September 24, 2002



*Maximum Area = 8.1 million square miles*



## **Staphylococcus aureus**

*Staphylococcus aureus*, often referred to simply as "staph," is a bacteria commonly found on the skin of healthy people. Occasionally, staph can get into the body and cause infections.

...

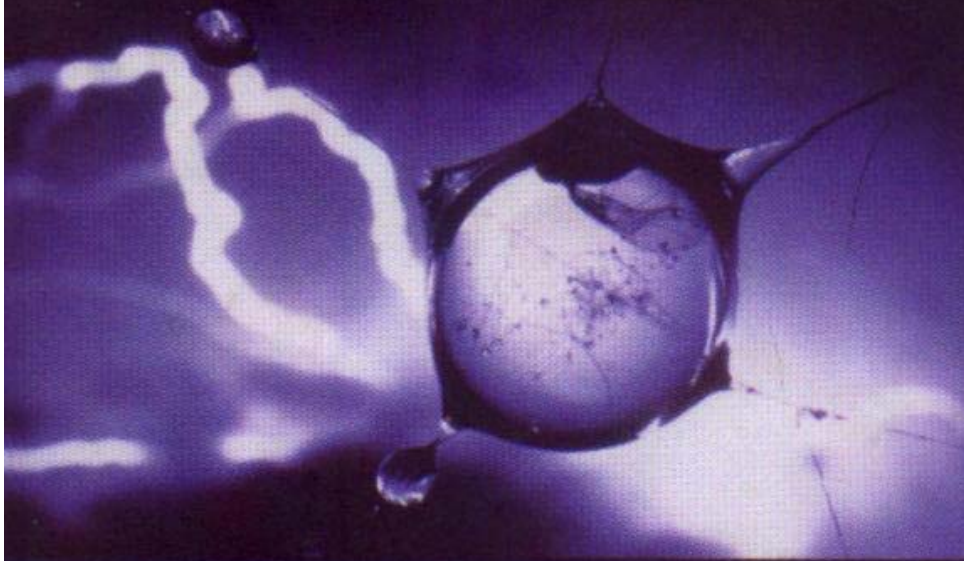
Although methicillin is very effective in treating most staph infections, some staph strains have developed resistance to methicillin and can no longer be killed by this antibiotic. These resistant bacteria are thus called methicillin-resistant *Staphylococcus aureus*, or MRSA. MRSA infection usually develops in hospital patients who are elderly or very sick or who have an open wound. Healthy people rarely get MRSA. Usually, Non-MRSA infections are treated with third generation cephalosporins, whereas for MRSA infections, vancomycin is currently the treatment of choice. The emergence of even vancomycin-resistant MRSA is one of the major challenges in hospital acquired infections.





# THE *Spirit* IN THE GENE

Humanity's Proud Illusion  
and the Laws of Nature



Reg Morrison  
foreword by Lynn Margulis

... *Homo sapiens* auto-mutated from primate hunter-gatherer to plague animal in just 10,000 years merely by applying the novel tools of culture and technology...

R. Morrison, *Spirit in the Gene* (1999), pp. 100-101



**TO BOIL A FROG ...**

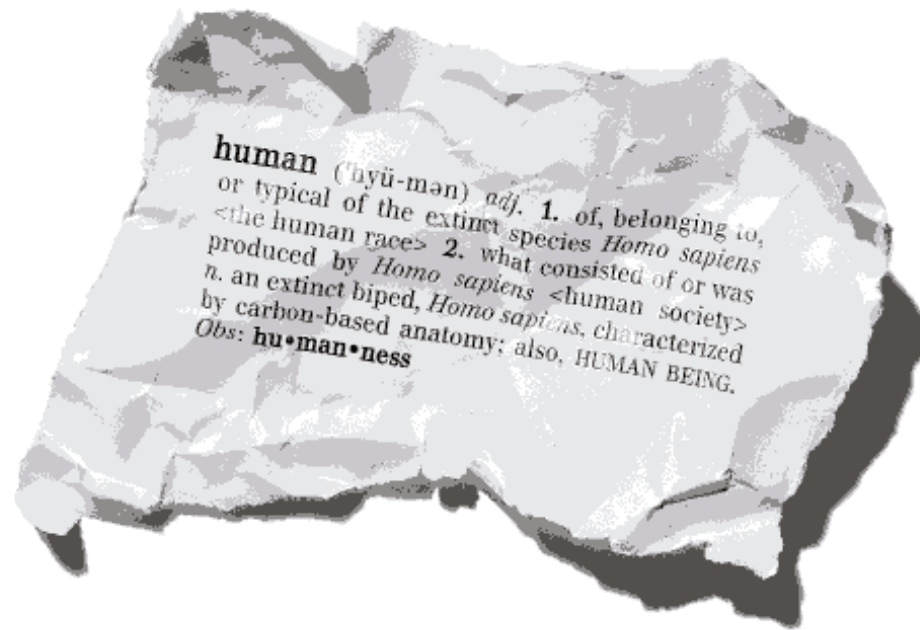


*Reg Morrison, Spirit in the Gene: Humanity's Proud Illusion and the Laws of Nature, p. 106.*

It is said that if you place an aquatic frog in a pot of water, it will sit there quite contentedly, even if you put the pot on the stove and slowly heat it. According to the story, the frog remains, acclimating for a time to the change in temperature, and just before the water boils, the frog dies. ... [T]he analogy holds true for human beings. We lit a fire under the pot 10,000 years ago by clearing the land, sowing seeds, and building communal settlements. The result was inevitable, and retreat is now unimaginable. Like the frog, we are immobile... . We cannot go back.

- Morrison, p. 106

# WIRED



**human** (hyü-män) *adj.* 1. of, belonging to, or typical of the extinct species *Homo sapiens* <the human race> 2. what consisted of or was produced by *Homo sapiens* <human society>  
*n.* an extinct biped, *Homo sapiens*, characterized by carbon-based anatomy; also, HUMAN BEING.  
*Obs:* hu•man•ness

**Why the Future  
Doesn't Need Us**

**By Bill Joy**



"But like any powerful new technology," says NSF Director Rita Colwell, "nanotech also has the potential for unintended consequences--which is precisely why we can't allow the societal implications to be an afterthought. The program has to build in a concern for those implications from the start."

Indeed, says Davis Baird, a philosopher at the University of South Carolina, "... technologies that don't do that have a way of coming to grief later on. Witness the widespread opposition to nuclear energy, and more recently, to genetically modified organisms. "So how can we go down a better path with nanotechnology?" Baird asks.

It's well known that fullerenes suck up loosely bound electrons from neighboring molecules. Inside the body, this phenomenon releases free radicals that can wreak havoc on cell chemistry.

Mitsubishi ... realized that they would need to do voluntarily what many companies won't do until forced: consider the concerns of stakeholders in academia, government, the environmental community, and the public.

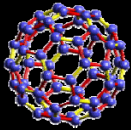
## **Mitsubishi: Out Front in Nanotech**

By Stephen Herrera  
*Technology Review*

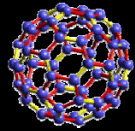
January 2005



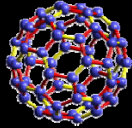
# Some observations



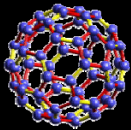
Nanotechnology is potentially powerful ...



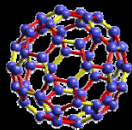
... but there are many misperceptions ...



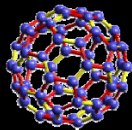
... and things we just don't know (yet).



People have enduring faith in science & technology to solve (or evade) problems ...



... in spite of evidence to the contrary (sometimes beyond the realm of science).



What are our responsibilities for using science and technology?

# ENGINES OF CREATION

**THE COMING  
ERA OF  
NANOTECHNOLOGY**

K. ERIC  
DREXLER  
FOREWORD BY  
MARVIN  
MINSKY  
WITH A NEW  
AFTERWORD BY  
THE AUTHOR

Strategies and Survival

Personal Restraint

Local or Global Suppression,  
by agreement or by force

Unilateral Advance

Balance of Power

Cooperative Development

Shields

# ENGINES OF CREATION

**THE COMING  
ERA OF  
NANOTECHNOLOGY**

K. ERIC  
DREXLER

FOREWORD BY

MARVIN  
MINSKY

WITH A NEW  
AFTERWORD BY  
THE AUTHOR

## Strategies and Survival

...nanotechnology and advanced AI will give great power to the leading force – power that can be used to destroy life, or to extend and liberate it. Since we cannot stop these technologies, it seems that we must somehow cope with the emergence of a concentration of power greater than any in history.



# ENGINES OF CREATION

**THE COMING  
ERA OF  
NANOTECHNOLOGY**

**K. ERIC  
DREXLER**

**FOREWORD BY**

**MARVIN  
MINSKY**

**WITH A NEW  
AFTERWORD BY  
THE AUTHOR**

## Strategies and Survival

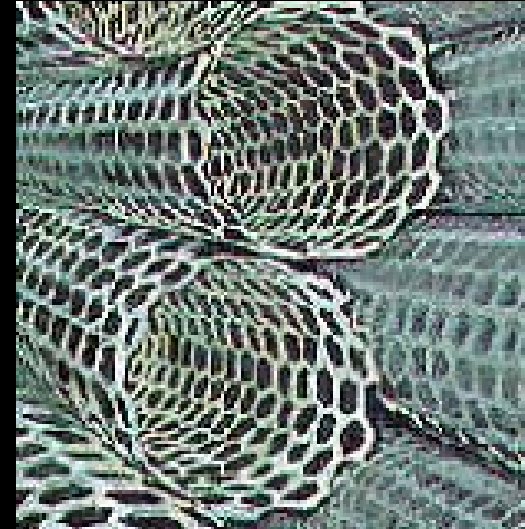
As we approach a technological crisis of unprecedented complexity, it makes sense to try to improve our institutions for judging important technical facts. How else can we guide the leading force and minimize the threat of terminal incompetence?

# Questions I would ask

- Is it safe?
- Is it reversible?
- Is it sustainable?
- Is it fair?

# Your Next Steps

- Take other courses – in other fields
- Labs – real, virtual, demonstration
- Balance breadth and depth
- Read widely
- Minor (?)
- Internship
- Summer research; here or REUs
- Senior projects (perhaps joint)
- Grad school





Ferrofluids are colloidal suspensions of magnetic nanoparticles



<http://www.mrsec.wisc.edu/edetc/nanolab/ffexp/index.html>

# Reading List

Feynman (1959), There's Plenty of Room at the Bottom

Drexler (1986), Engines of Creation

Joy (2000), Why the Future Doesn't Need Us

Drexler and Smalley (2003), Point – Counterpoint

Rees, Our Final Hour

Collection of skeptical articles on nanotechnology from the popular press (WSJ, BBC, NYT, ...)

Some Fear Ethical Restrictions on Research in Nanotechnology

Nanotech may spark fierce ethical row

Environmental group gears up to target nanotech industry

Thinktank predicts nanotechnology backlash

As uses grow, tiny materials' safety is hard to pin down

The Revolution Has Begun