

The Next Science and Technology Revolution



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Big Questions

What are the new tools?

What are the new methods

Where is the talent going?

Where is the money going?

What are interesting questions?

Key Science & Technology Assumptions

- More IT: smarter and connected everything and everyone
- More resources and talent
- More new and better tools
- Driven not by war but by sustainability challenges
 - water, food, energy, climate change, poverty
 - sustainability has human, economic and ecological dimensions

The Driving Forces of R&D

Rapid Advancements of Scientific Tools

- **Instrumentation**

- New Space Telescopes
- Large Hadron Collider and Its Successors

- **Nanotechnology**

- Carbon Nanotube Applications
- Nanoporous Biocapsules

- **Simulation and Modeling**

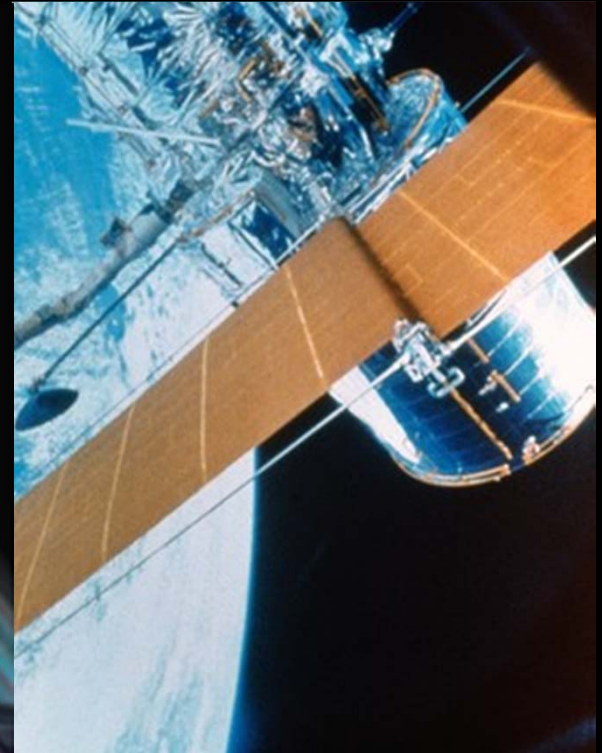
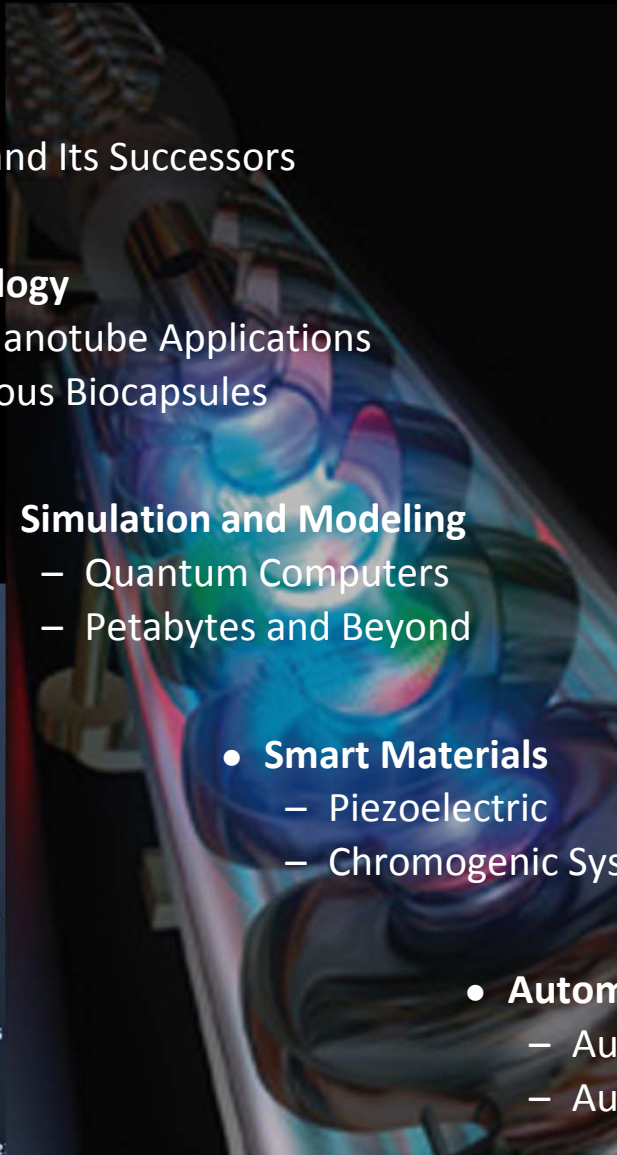
- Quantum Computers
- Petabytes and Beyond

- **Smart Materials**

- Piezoelectric
- Chromogenic Systems

- **Automation and Robotics**

- Autonomous Robotic Research System
- Autonomous Vehicles



The New Science: Four Big Ideas as to How Science is Done

- Complexity
- Big Data
- Algorithmic Discovery
- Bottoms Up Science



Human Systems: A New Domain

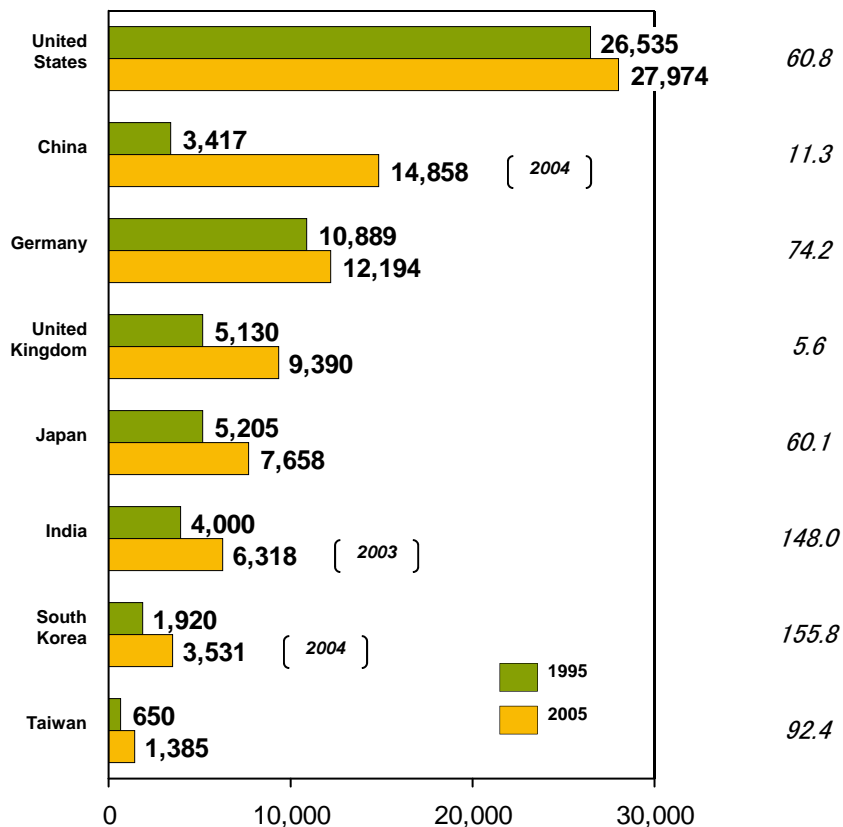
- Psychology, sociology, politics, economics, management
- Methodology was observation and theory
- New methods include neurobiology, big data, simulation, and experiments
- **Singapore** is an ideal leader in this new domain



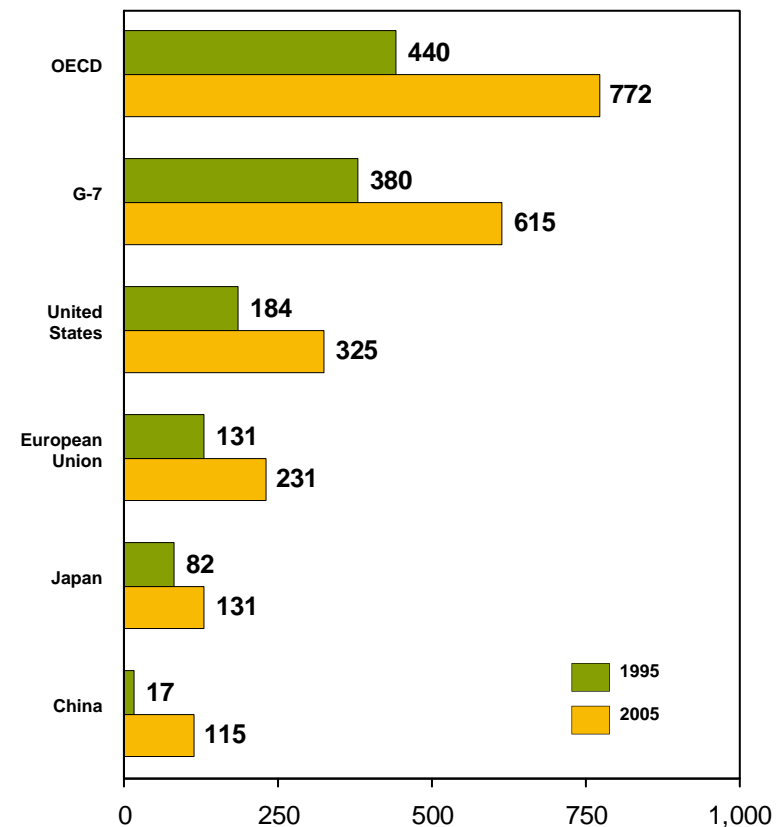
The Driving Forces of R&D: Substantial R&D Capacity Increase

**Number of Doctoral Degrees Issued
(Science and Engineering)**

*Per Million
Population
(2005)*



**Gross Domestic Expenditures on R&D
(Selected OECD Countries and China)**



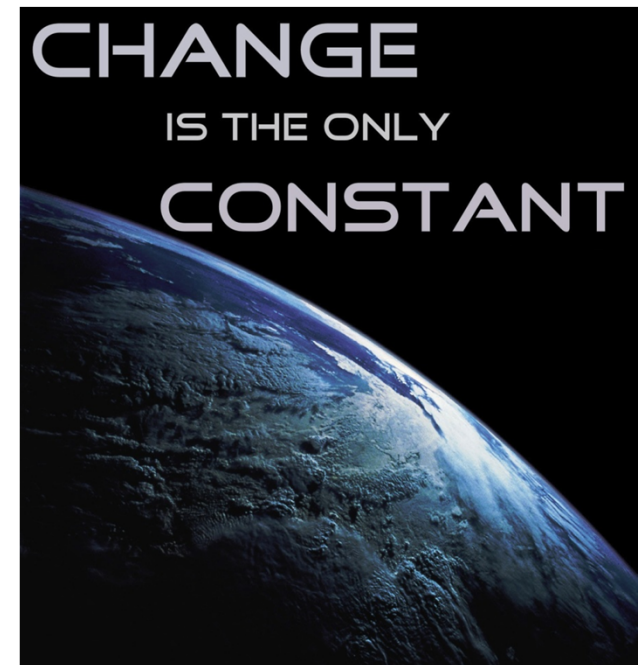
Source: Science and Engineering Indicators 2008 (NSF), World Population Statistics (UN), Main Science and Technology Indicators (OECD), Monitor Analysis

Almost inevitable in a fairly predictable future

- Much better understanding of deep molecular biology
- Much better understanding of the brain/mind
- Much smarter machines, but cybersecurity remains a challenge
- Advanced Human systems
- Many more sustainable technologies
- Discovery of life elsewhere, but not important

Big Surprises

- In the past twenty years in physics, entanglement and dark energy
- Real AI or brain downloads
- Bio molecular control, cracking the codes of biology's deep history
- Fusion power or its equivalent
- Geo-engineering
- Physics revolution:
 - very small, real nano, new model or new space like gravity
 - hyper fuels, hypersonic flight and low cost space



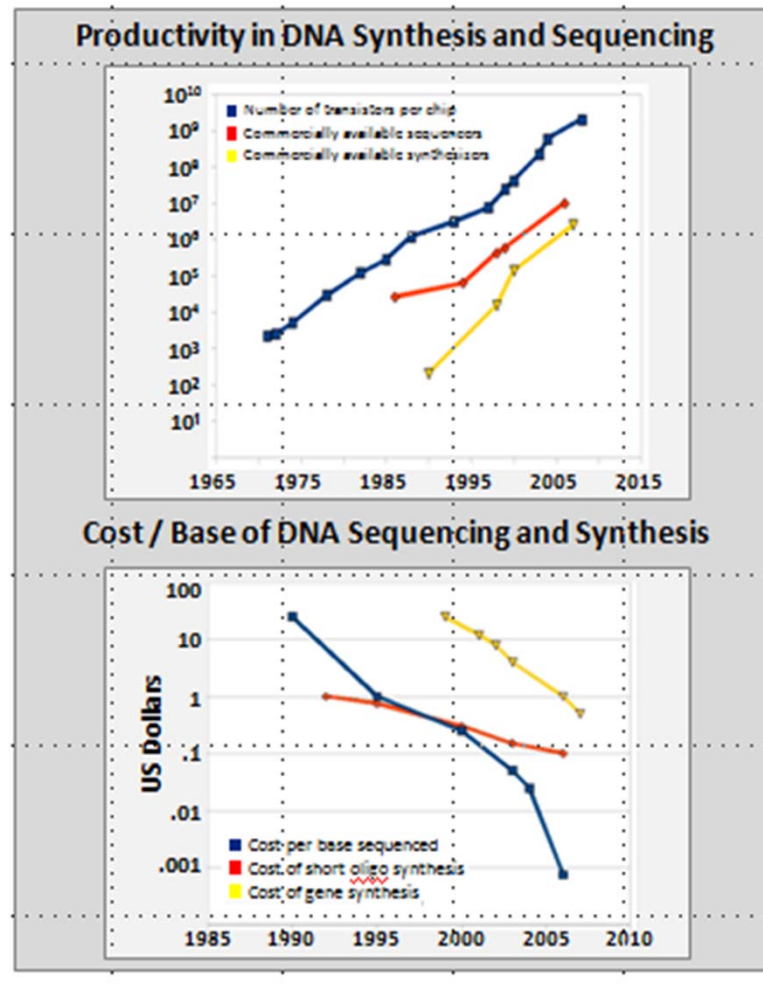


Thank You

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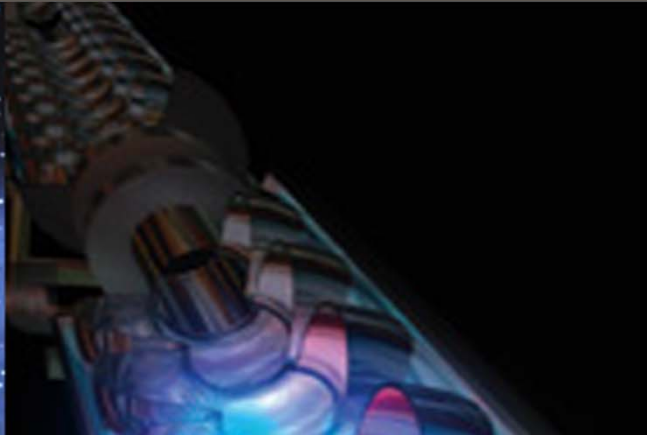
Forces and Frontiers of Science Today: Synthetic Biology



Forces and Frontiers of Science Today: The New Physics and New Chemistry



Dark Energy



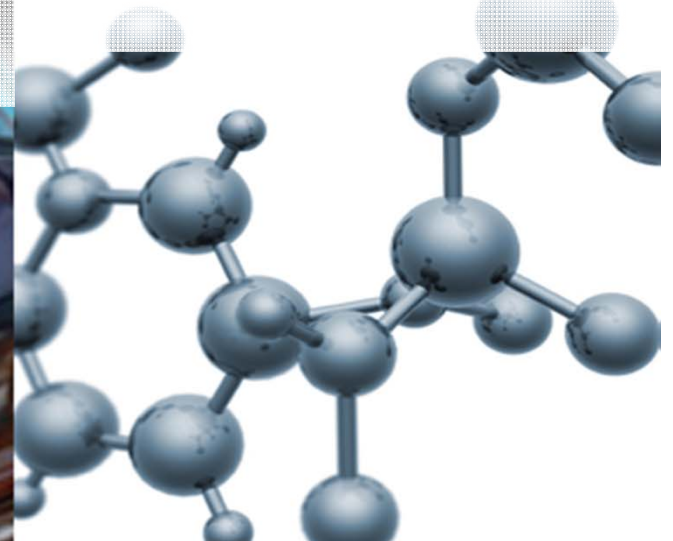
Physics of the Very Small

- World of extremes

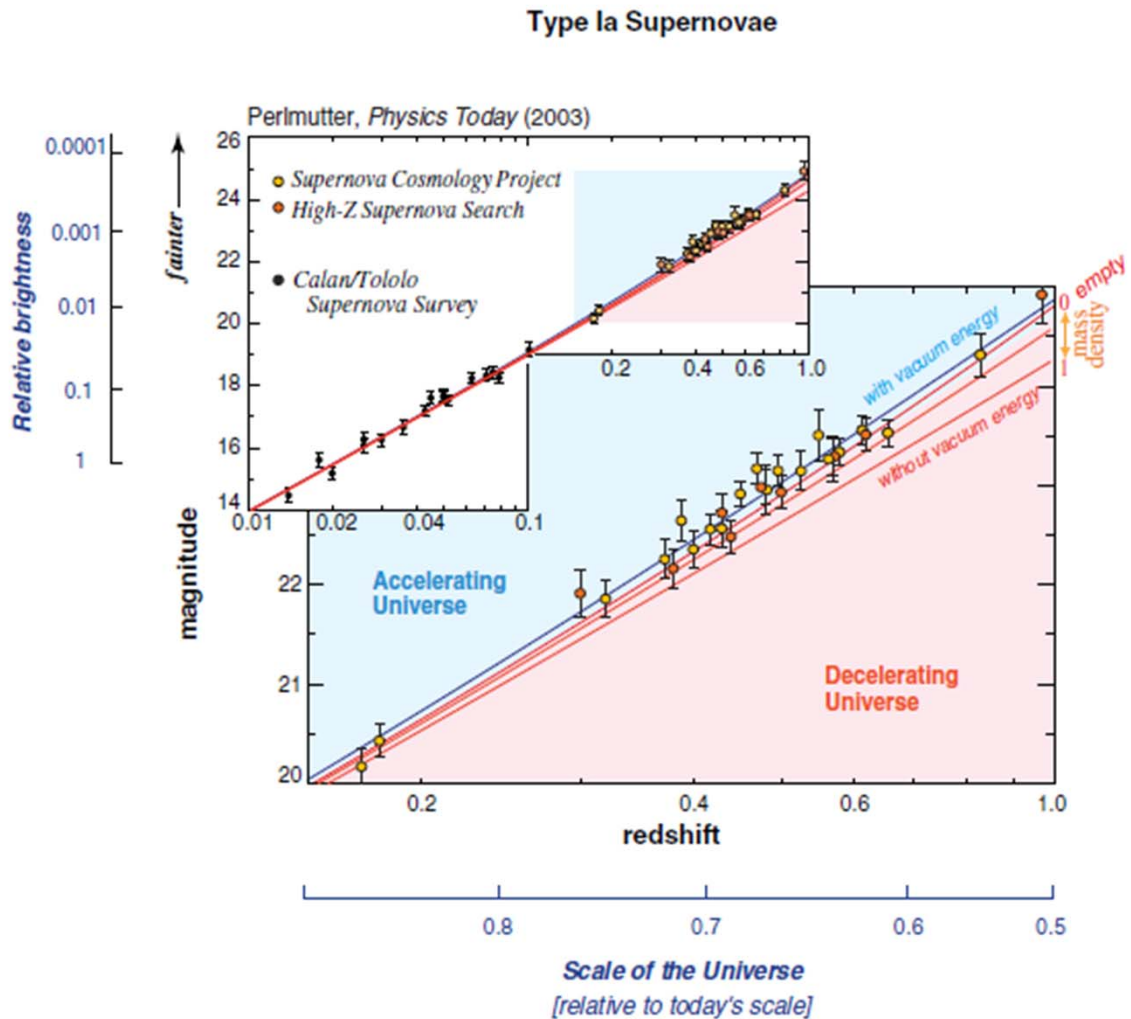
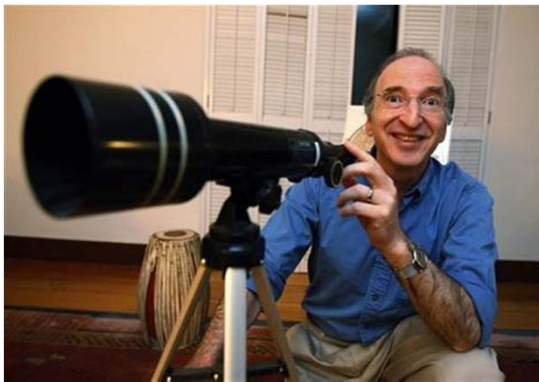


Precision Chemistry

- World of fine grained control
- New material properties
- Nanoscience
- But intersection of physics, chemistry and biology is most interesting



Forces and Frontiers of Science Today: Dark Energy



100 Year Starship Program

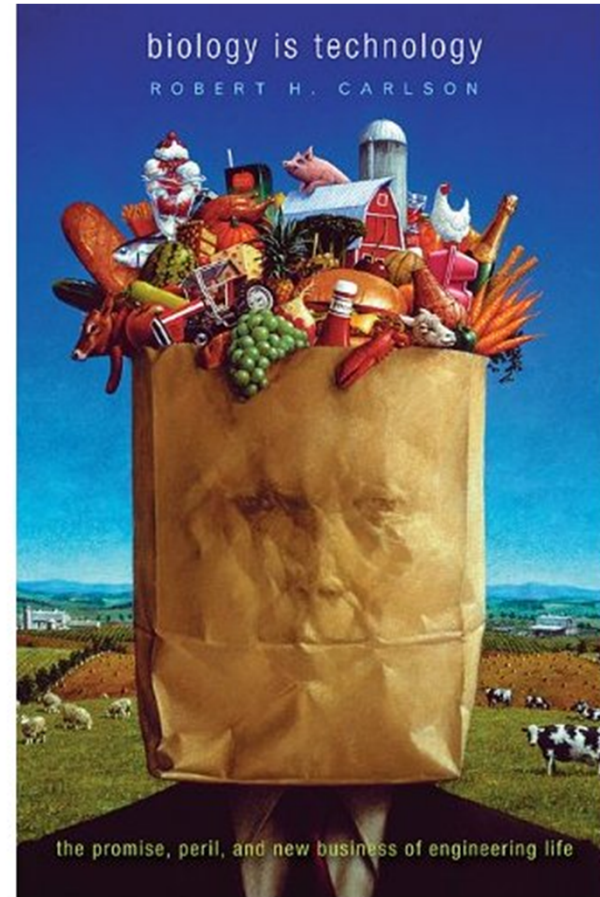


Conclusion: Revolution is coming

- Major discontinuities are coming
 - One or more of the surprises will occur
 - But no singularity
- More people will play
- Knowledge is wealth and power

World Created by Science and Technology

- Molecular Biological Engineering
- Human Performance and Emotional Enhancement



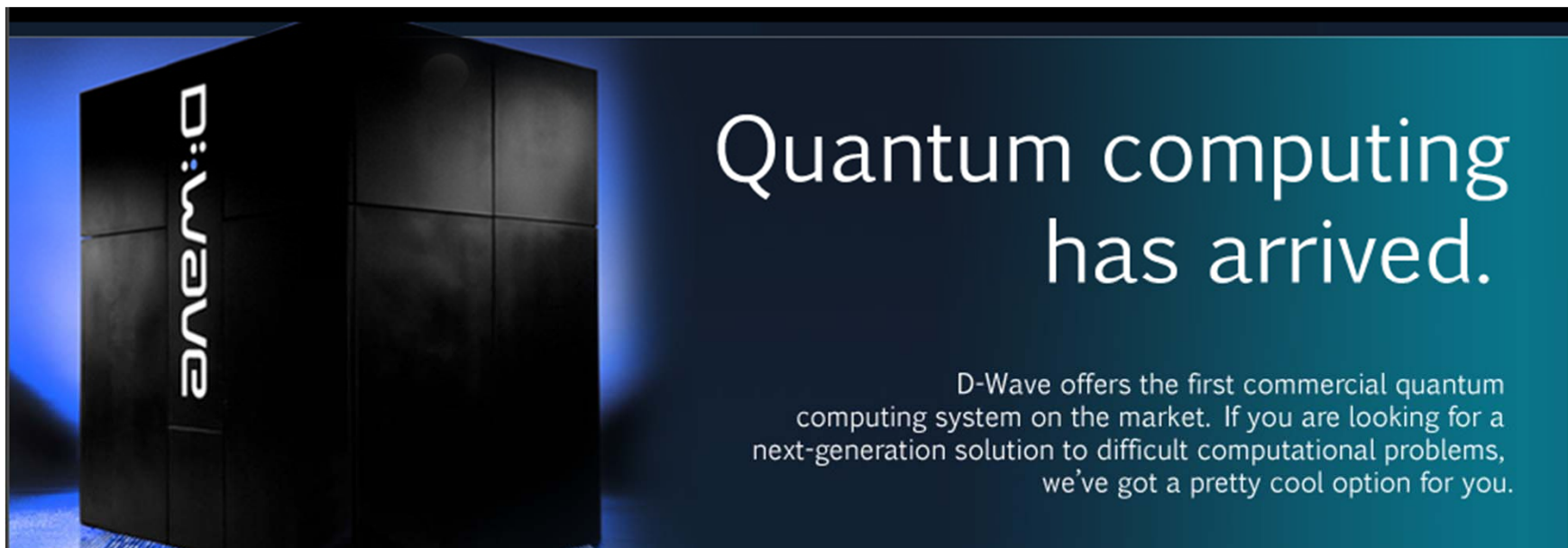
World Created by Science and Technology

- Ultra-Smart Computers
- Next-Generation Smart Robotics
- Direct Interaction with Computers and Robots



World Created by Science and Technology

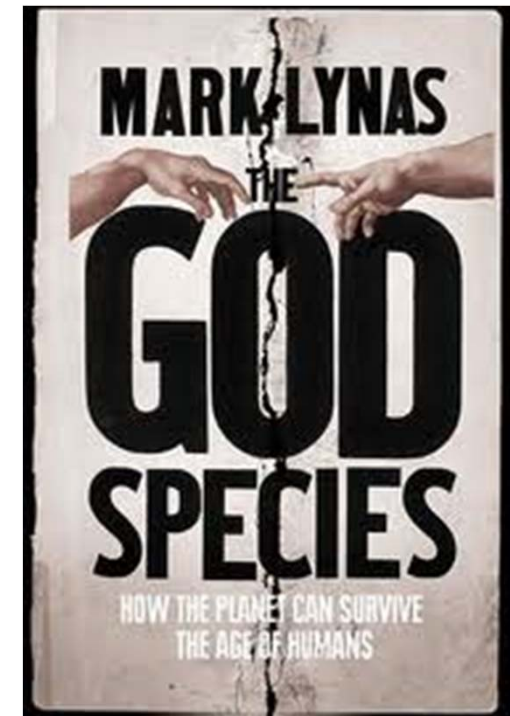
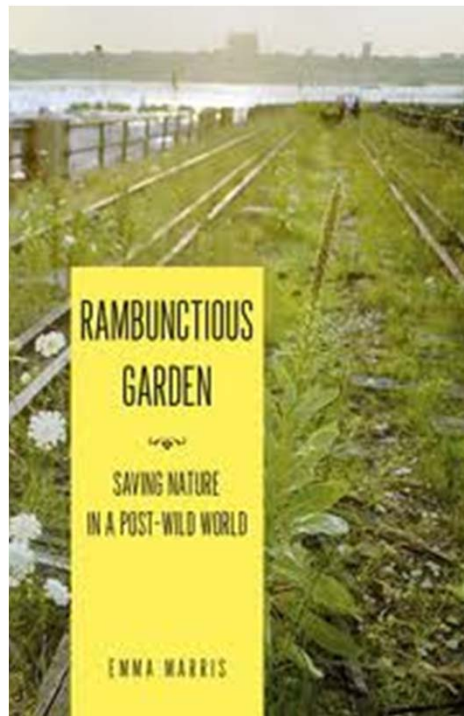
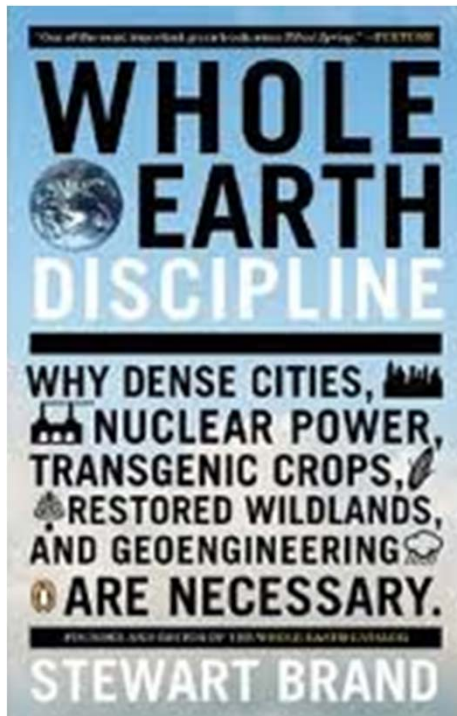
- Neural Control
- Quantum Computers



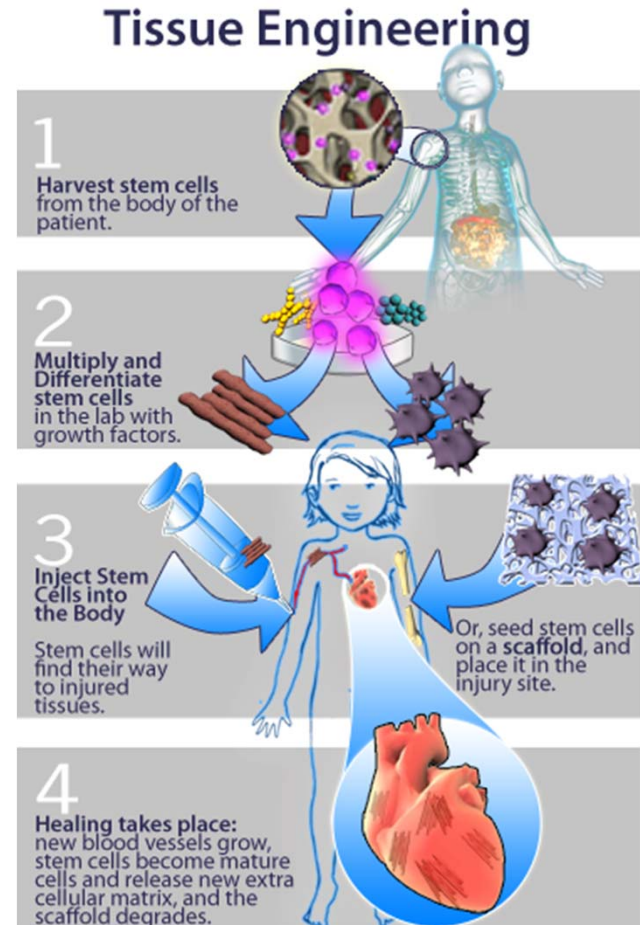
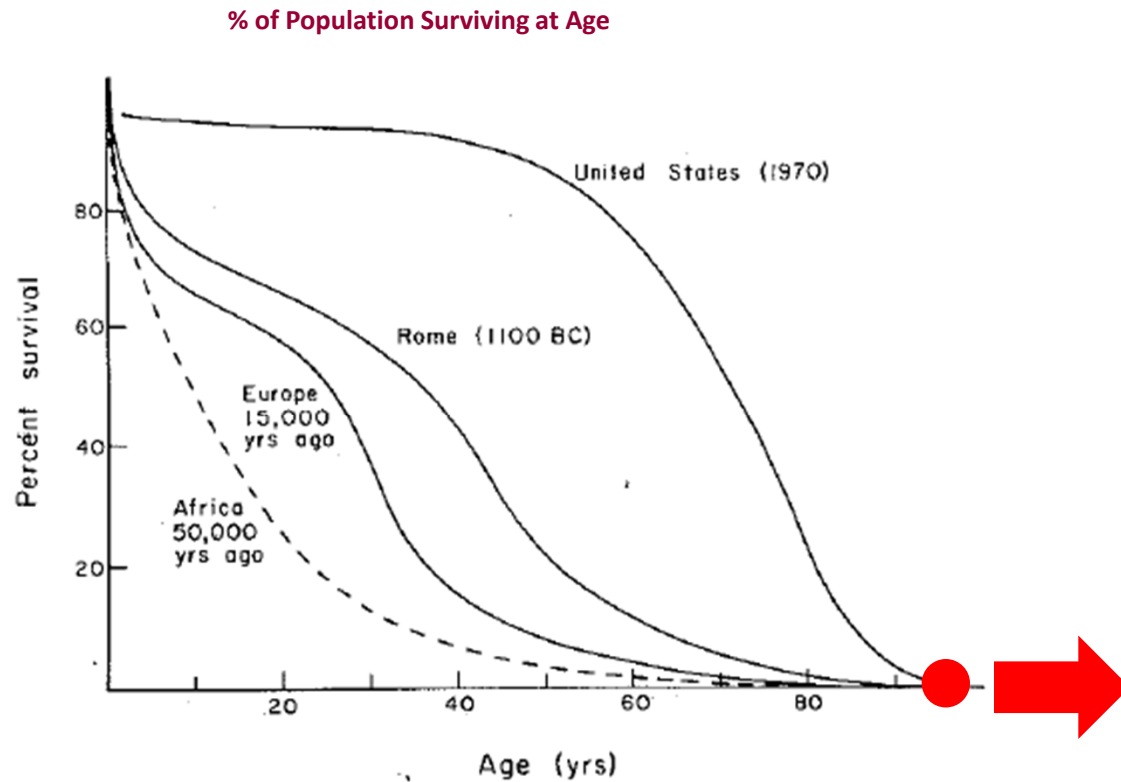
A More Prosperous, Peaceful and Sustainable World



Sustainably Gardening the Earth



Regenerative Medicine: Moving from 'more getting old' to 'getting older'?



The Driving Forces of R&D: Pursuit of Intellectual Challenges

Dark Energy

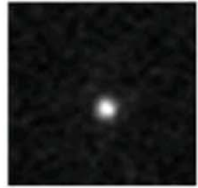
Meaning of DNA

The Brain, etc.

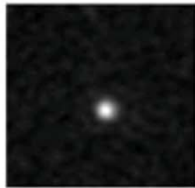
Complexity

Human Psychology and Behavior

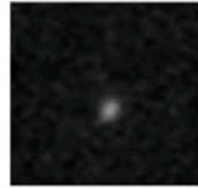
Forces and Frontiers of Science Today: Biomolecules



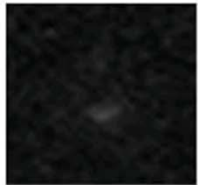
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t = 0.45s



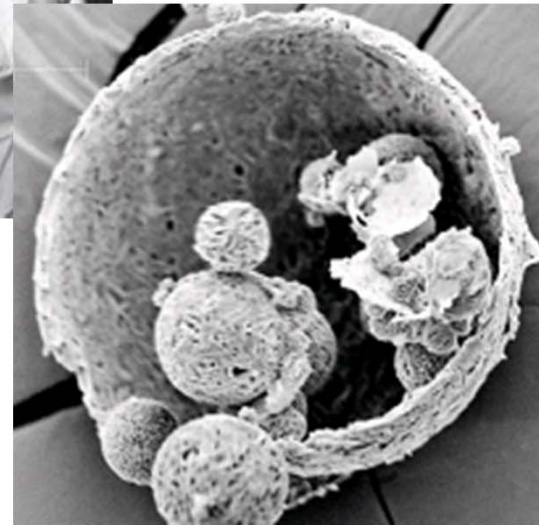
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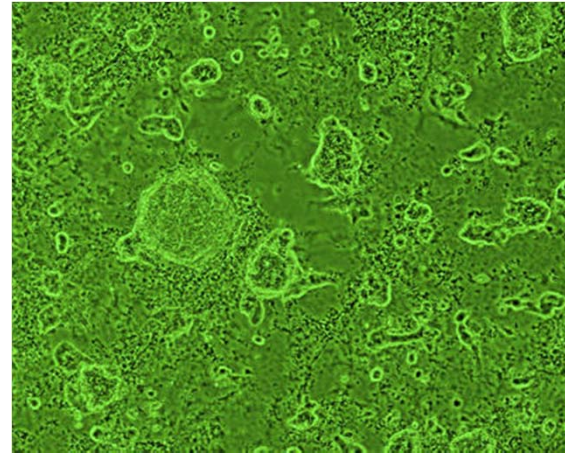
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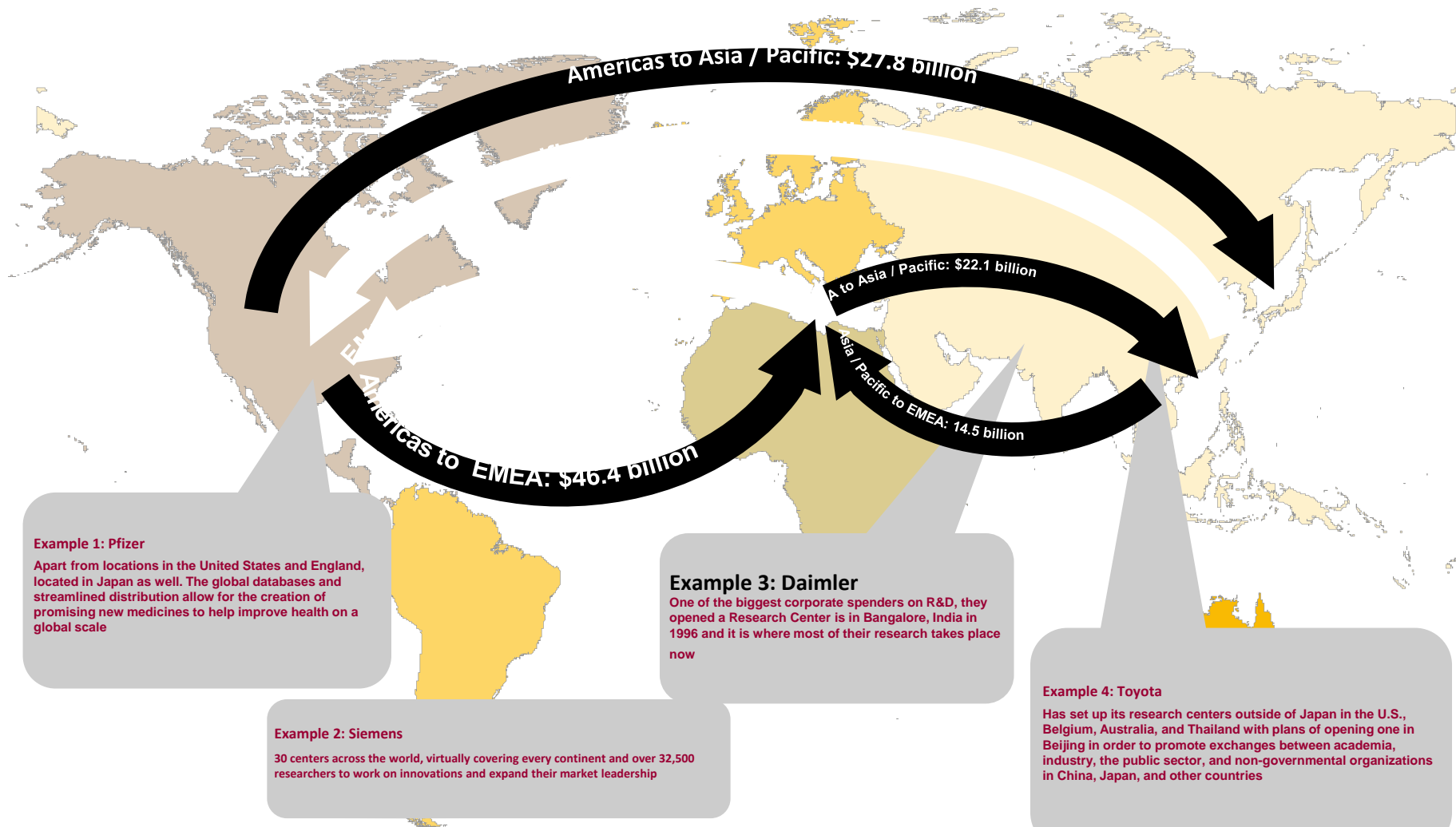
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Forces and Frontiers of Science Today: Stem Cells



Globalization of Private Sector R&D



Note: Global spending of 184 top R&D spenders which account for 71% of the Global Innovation 1,000 total
Source: R&D Magazine, Booz & Company

The Driving Forces of R&D: Research on Seven Global Issues Will Shape Next Decades

Aging



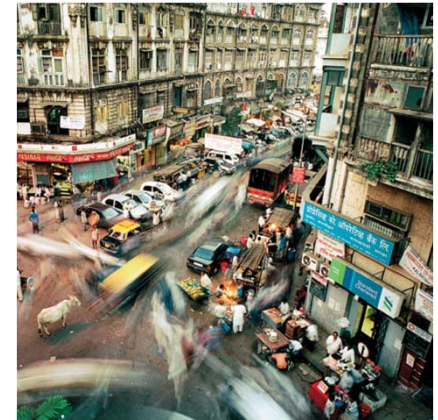
Renewable Energy



Climate Change / Sustainability



Urbanization



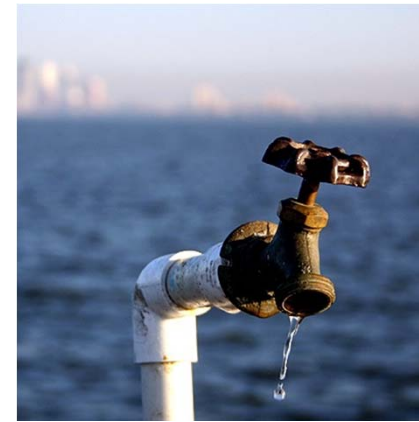
Infectious Disease



Food Security



Water Supply

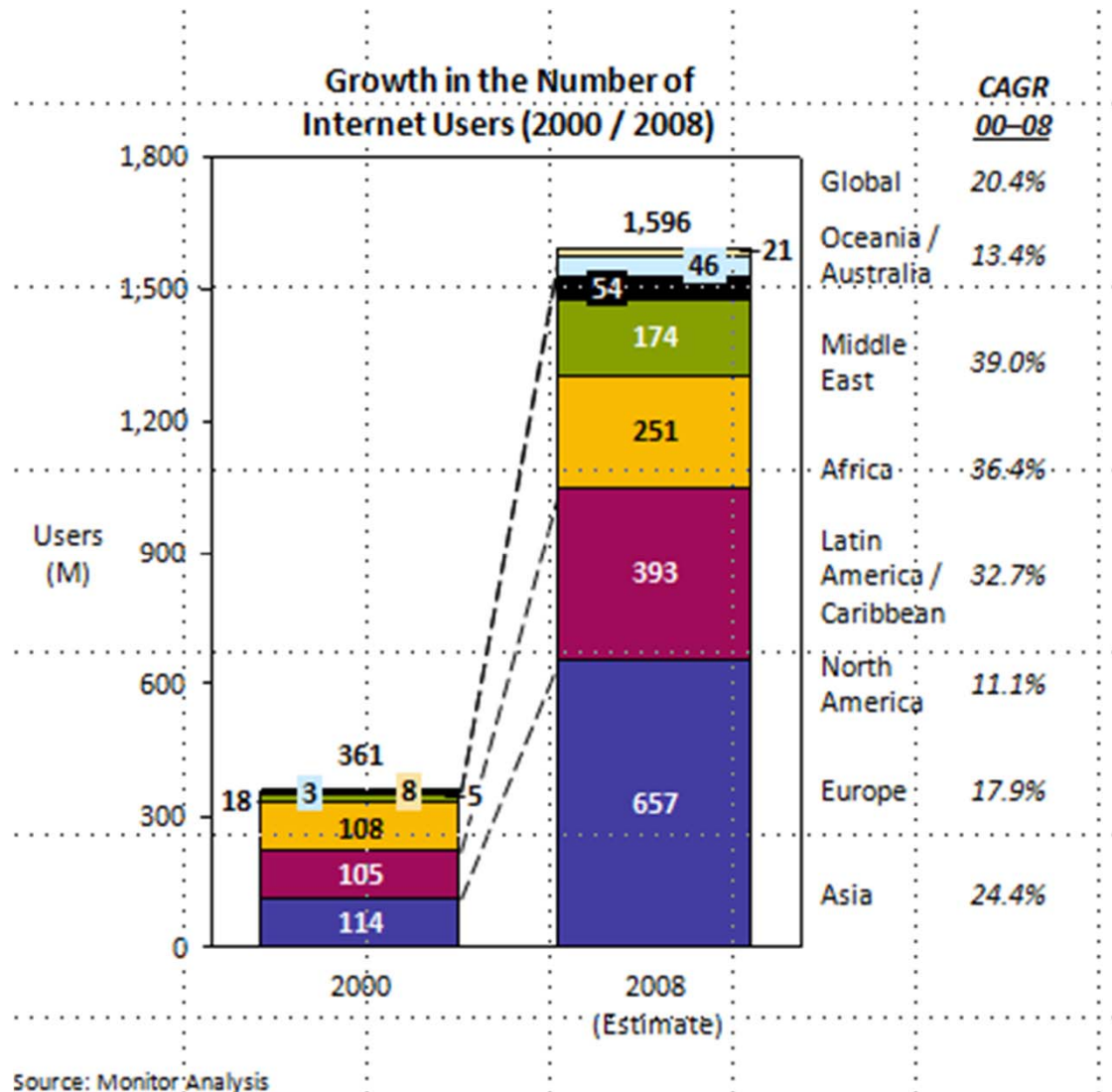


21st Century's Grand Challenges of Engineering

- Make Solar Energy Economical
- Provide Energy from Fusion
- Develop Carbon Sequestration Methods
- Manage Nitrogen Cycle
- Provide Access to Clean Water
- Restore and Improve Urban Infrastructure
- Advance Health Informatics
- Engineer Better Medicines
- Reverse-Engineer the Brain
- Prevent Nuclear Terror
- Secure Cyberspace
- Enhance Virtual Reality
- Advance Personalized Learning
- Engineer the Tools of Scientific Discovery



The Driving Forces of R&D: Ubiquity of Communication and Knowledge



Why Does This Matter?

New Industries

Demonstration of Power

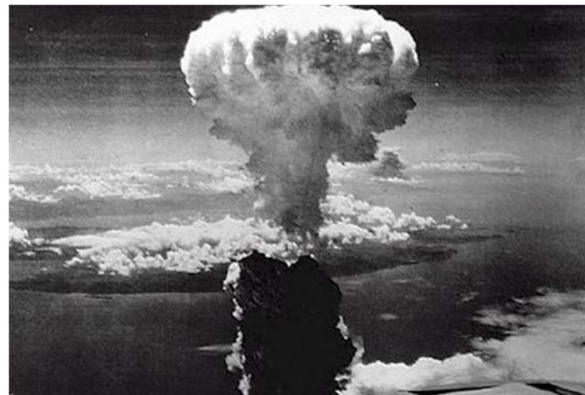
Overall Leadership
and Prosperity



Existential

Coercive

Specific Security
Impacts

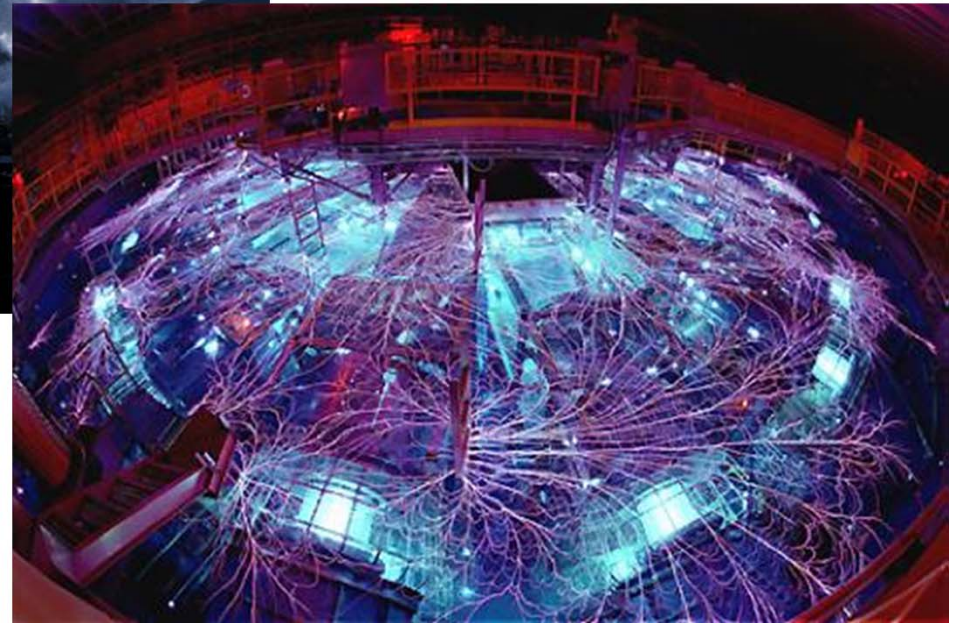


Science in 2050

Big Uncertainties Remaining

- Magnitude of climate change?
- Do we have a long-term energy solution (beyond fossils) in sight, e.g., fusion, bio, new physics?
- Will many more get wealthier?
- Runaway science?

A More Prosperous, Peaceful and Sustainable World



God is Still Alive and Kicking



What Is Distinctive About the United States?

Top Universities in the World

Rank	Institution	Country
1	Harvard University	USA
2	Stanford University	USA
3	University California - Berkeley	USA
4	University Cambridge	UK
5	Massachusetts Inst Tech (MIT)	USA
6	California Inst Tech	USA
7	Columbia University	USA
8	Princeton University	USA
9	University Chicago	USA
10	University Oxford	UK
11	Yale University	USA
12	Cornell University	USA
13	University California — Los Angeles	USA
14	University California — San Diego	USA
15	University Pennsylvania	USA
16	University Washington — Seattle	USA
17	University Wisconsin — Madison	USA
18	University California — San Francisco	USA
19	Tokyo University	Japan
20	Johns Hopkins University	USA

Key Assumptions

- Continued economic growth that funds and uses new knowledge
- NO big wars that change the direction of research
- NO new Dark Age that devalues scientific knowledge



Big Domains of Scientific Progress

1850-1950: Physics and Chemistry

- Physics getting more extreme, more expensive
- Chemistry well worked, e.g. batteries, simulation

1950-2050: IT, Biology and Globalization

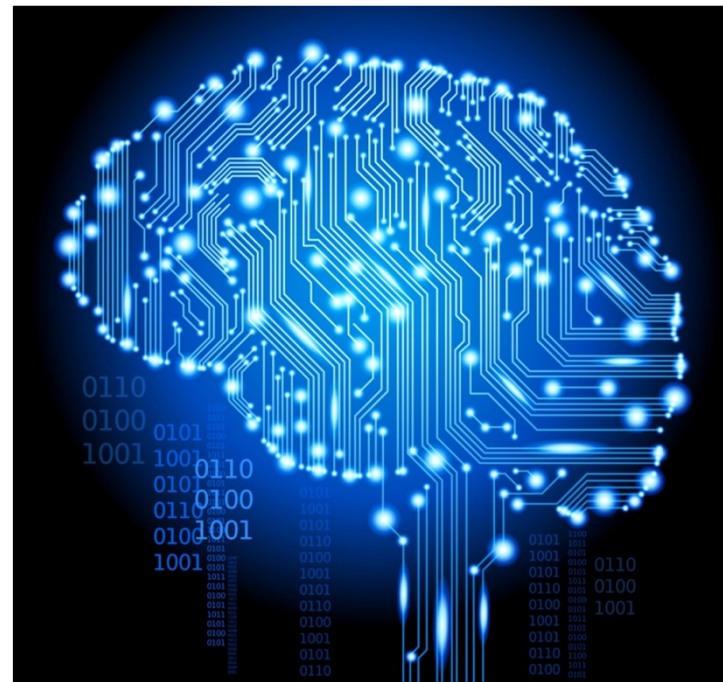
- IT only a function of human invention, no limit
- Biology harder than we thought, but not costly
- Globalization, much more talent and treasure



No end in sight to S&T progress

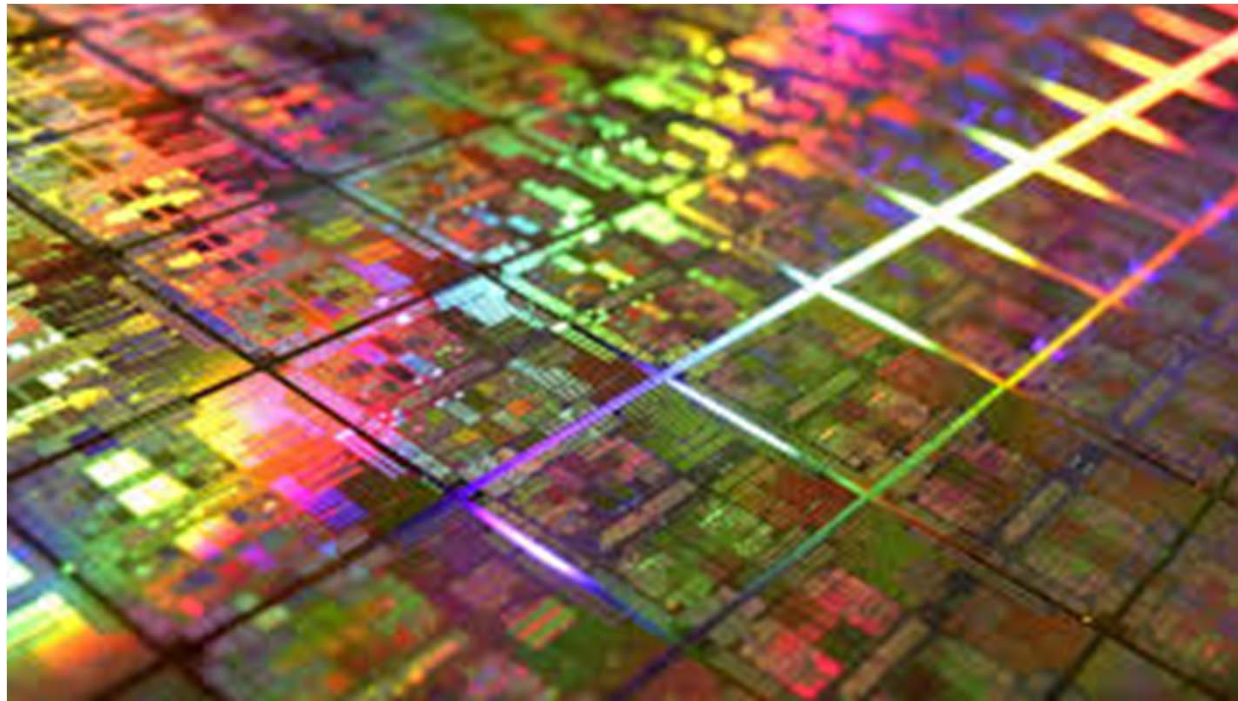
What didn't happen (yet) that we thought would?

- High speed travel
- Real space flight
- AI
- Fusion power
- Cancer cure
- Flying cars/jet packs (more fiction)



Time frame of 25-50 years

- Quantum to idea of semiconductor was 30 years
- From idea to first Intel microchip was 25 years



Forces and Frontiers of Science Today: Biology

Fundamental Shift from Empirical to Rational Science

Genetics

Neurobiology

Stem cells

Synthetic biology

Mathematical biology

Systemic science of disease

It's all Physics + Water !