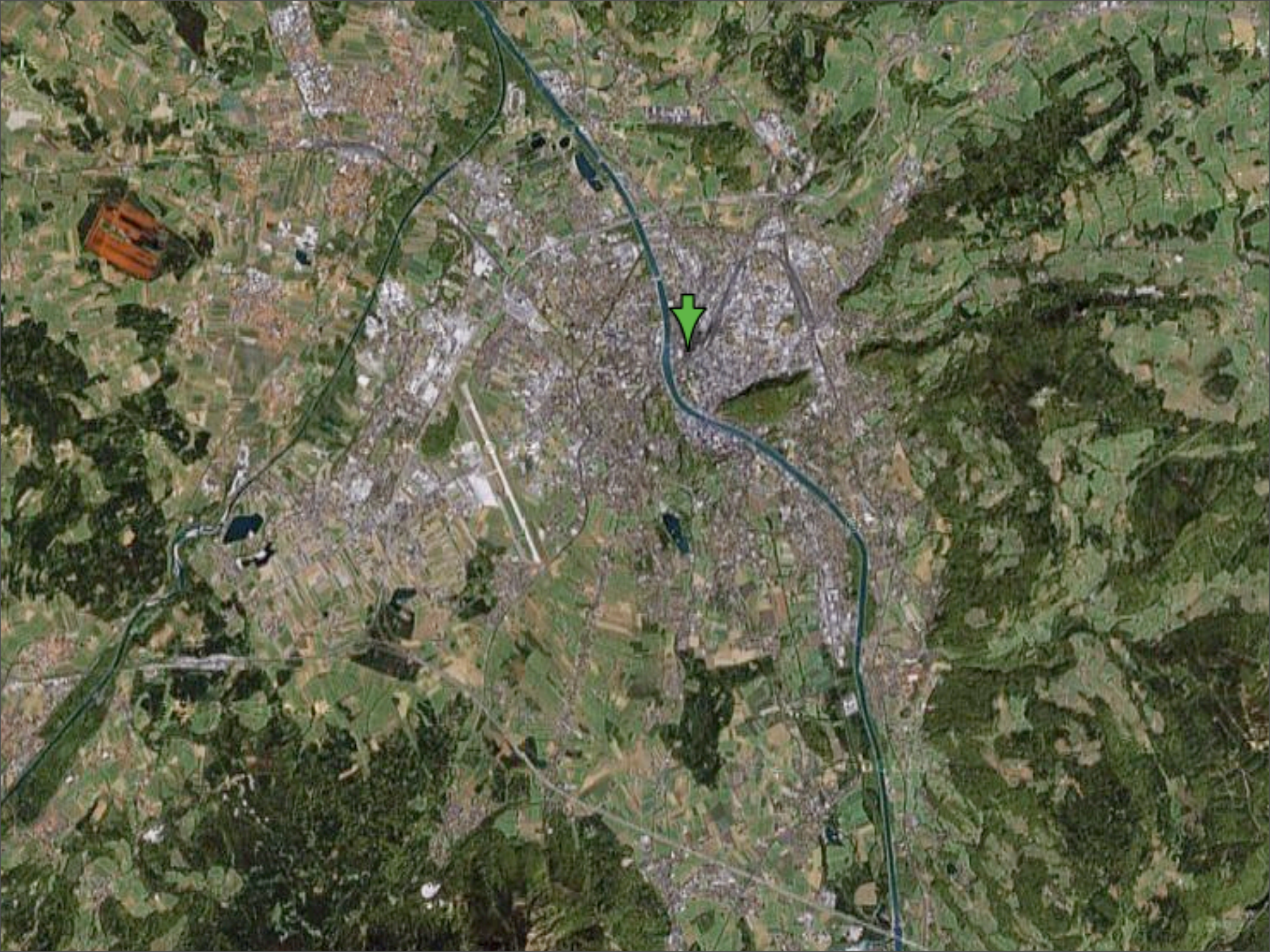
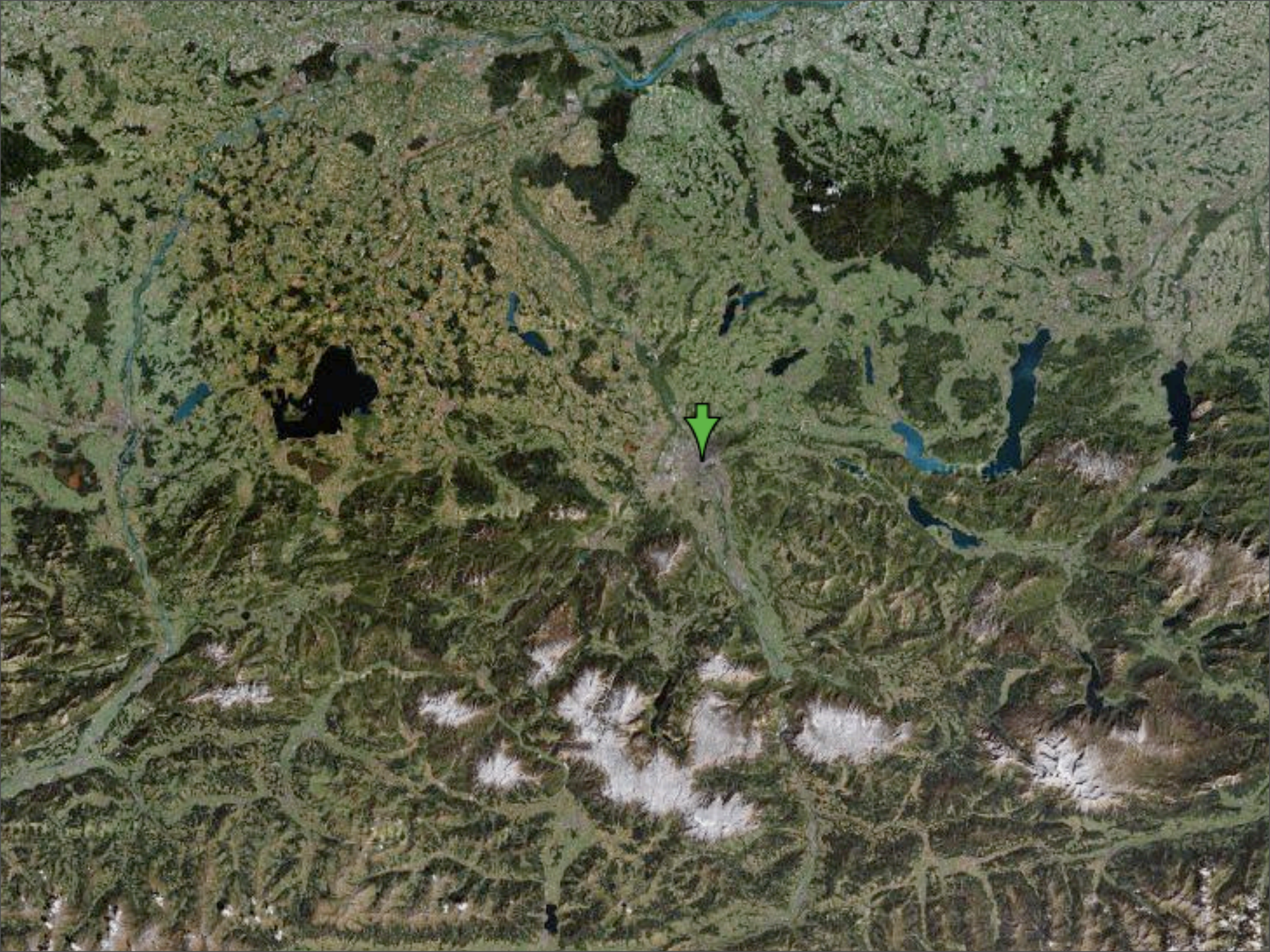
Higher Education in the 21st Century

National Imperatives…
Global Opportunities





Topic 1: The Forces of Change

- The Age of Knowledge
- Globalization
- Demographics
- Global Sustainability
- Disruptive Technologies

Topic 2: National Challenges

- Globally competitive workforces
- The need to "massify" higher education
- Resource requirements
- Political constraints
- Market forces

Topic 3: U.S. Higher Education

- Today
  - Basic characteristics
- Signs of Change
  - Spellings Commission
  - Rising Above the Gathering Storm
- Tomorrow: Paradigm Breakers (MIT OCW, Sakai, Google, Cyberinfrastructure)

Topic 4: New Paradigms

- Importance of lifelong learning
- Emergence of "universities of and in the world"
- The "meta" university
- Universal access to knowledge and learning

JJD Background

- U.S. Higher Education Policy
  - Spellings Commission (2006)
  - AGB Task Force on State of University Presidency (2006)
  - Glion Colloquium (Co-chair, 2007)
- U.S. Science Policy
  - National Academies Policy Committee (1998-2004)
  - NAS FS&T (U.S. R&D Budget, Chair, 2000-05)
  - National Science Board (1984-1996, Chair)
  - DOE Scientific Priorities Committee (2003)

JJD Background (continued)

- Information Technology
  - NSF Cyberinfrastructure Committee (chair, 2006)
  - NAS IT Forum (chair, 2000-2005)
  - Unisys (director, 1990-2006)
- Odds and Ends
  - UM Science, Technology, Public Policy (chair, 2004-06)
  - DOE Nuclear Research Committee (chair, 1996-01)
  - National Center for Atmospheric Research (2000-05)
- Technical background
  - Applied theoretical physics (nuclear systems)
  - Scientific computing and networking

Topic 1: The Forces of Change

- The Age of Knowledge
- Globalization
- Demographics
- Global Sustainability
- Disruptive Technologies

The Age of Knowledge

The Age of Knowledge

- Today we are evolving rapidly into a post-industrial, knowledge-based society, a shift in culture and technology as profound as the shift that took place a century ago when our agrarian societies evolved into industrial nations.
- Economic production is steadily shifting from material- and labor-intensive products and processes to knowledge-intensive products and services.

The Age of Knowledge

- A radically new system for creating wealth has evolved that depends upon the creation and application of new knowledge.
- In this "Age of Knowledge", the key strategic resource necessary for economic prosperity and national security has become knowledge itself–educated people and their ideas.

But…

- But unlike natural resources such as oil or iron that have driven earlier economic transformations, knowledge is inexhaustible. The more it is used, the more it multiplies and expands.
- But knowledge can be created, absorbed, and applied only by the educated mind.
- Hence the true wealth of nations in a global, knowledge-driven society has become human capital: educated people!

Demographics

Demographic Change

- Aging populations
- The global teenager
- Migration
- Ethnic diversity

Aging Populations

- Over the next decade the percentage of the population over the age of 60 will grow to over 30% to 40% in the U.S., Europe, and parts of Asia.
- Much of the world's population lives in countries where fertility rates are not sufficient to replace their current populations.
- Aging populations and shrinking work forces will have an important impact, particularly in Europe, Russia, and some Asian nations such as Japan, South Korea, and Singapore.

The Developing World

- Most population growth will occur in the developing world with high fertility rates–Africa, Latin America, Asia–where the average age is less than 20.
- In the global, knowledge economy, the key to the future of these young people is education.
- Yet it is estimated that today there are over 30 million people who are fully qualified to enter a university but there is no place available. This number is predicted to grow to over 100 million over the next decade. (Jon Daniels)

The Challenge

- Unless the world can provide this rapidly growing population with the education necessary to compete in and survive in a global economy, the resulting despair and hopelessness among the young will continue to feed the terrorism that so threatens our world today.
- “In most of the world, higher education is mired in a crisis of access, cost, and flexibility. The dominant forms of higher education in developed nations–campus based, high cost, limited use of technology–seem ill-suited to addressing global education needs of the billions of young people who will require it in the decades ahead.” (Sir Jon Daniels)

The United States

- The U.S. will be one of the few developed nations with a growing population, estimated to grow from 300 M to over 450 M by 2050 primarily because of immigration from Latin America and Asia.
- Immigration will continue to diversify the American population with respect to race, ethnicity, and nationality, posing significant social and political challenges–but also infusing great energy and hope.
- Clearly the future of the United States as "a nation of immigrants" depends on its capacity to draw strength from diversity, but political and economic barriers will continue to exist for many underrepresented populations.

Globalization

Globalization

- "We see globalization–the growing interconnectedness reflected in the expanded flows of information, technology, capital, goods, services, and people throughout the world–as an overarching mega-trend, a force so ubiquitous that it will substantially shape all the other major trends in the world of 2020."
- National Intelligence Council Project 2020

In 2020…

- China's GNP will exceed that of all individual western economic powers except for the U.S. India's GNP will be larger than European economies.
- Sheer size of China's and India's population (1.4 B and 1.3 B) along will make them powerful economies.
- The Asian mega-market–China, India, Russia, Korea, etc.–could become dominant–particularly in the availability of human capital.

The Importance of Technology

"The greatest benefits of globalization will accrue to countries and groups that can access and adopt new technologies. Indeed, a nation's level of technological achievement generally will be defined in terms of its investment in integration and applying the new, globally available technologies."

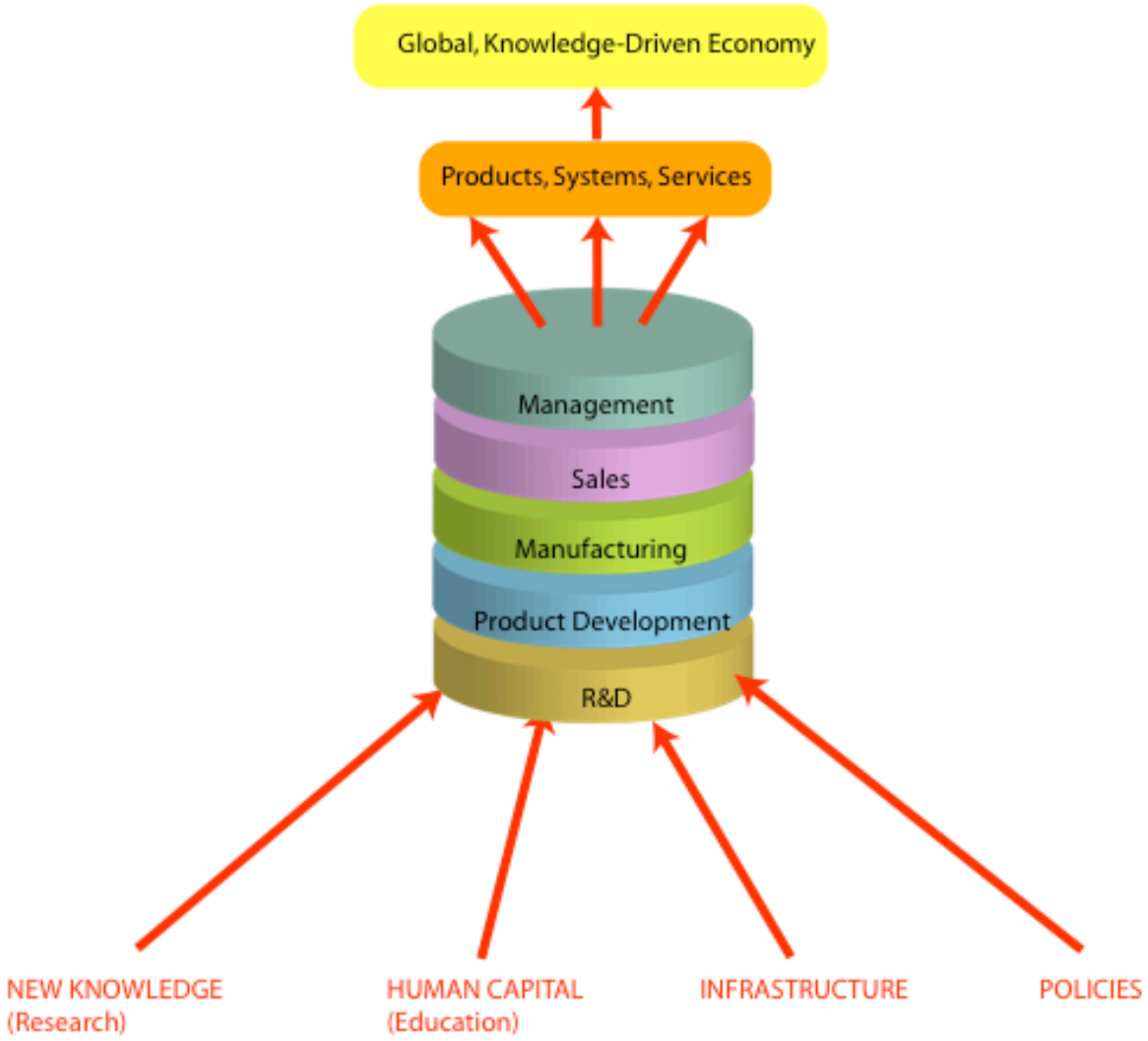
"China and India are well-positioned to become technology leaders, particularly in the next revolution of high technology involving the convergence of info-, bio-, and nano-technology." (Project 2020)

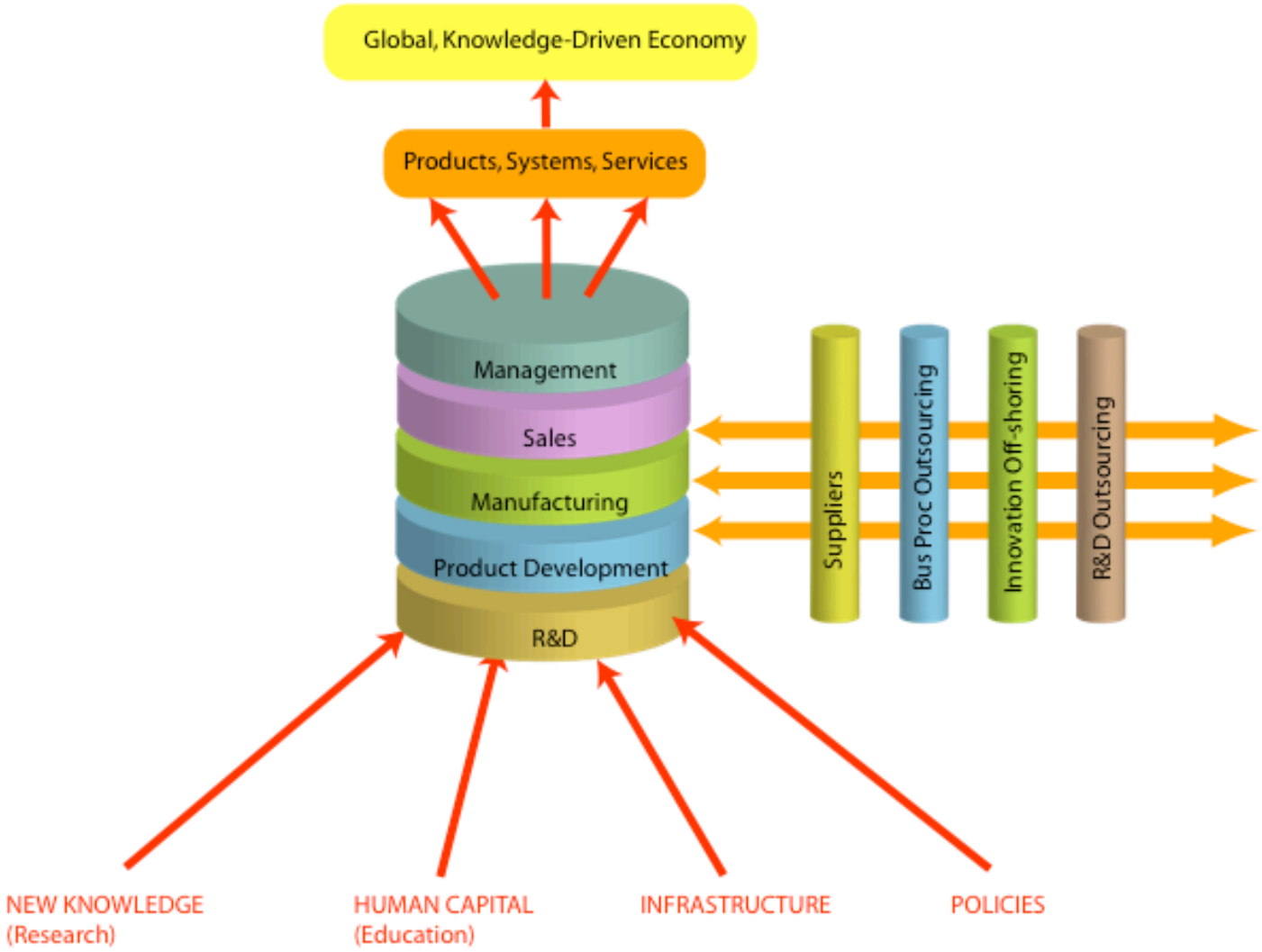
An Example: "Off-Shoring"

- The transition to a global, knowledge-driven economy will not be painless, and it will hit the middle classes of the developed world in particular, bringing more rapid job turnover and requiring professional retooling.
- Outsourcing and off-shoring on a massive scale will be disruptive.
- The convergence of the gigantic source of human capital represented by India, China, and Russia will present a serious competitive challenge to high wage nations.


Dulux
KENWOOD
HTTP://DESK.XXINFO.HA.CN

The Way the World Works Today


Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
NEW KNOWLEDGE
(Research)
HUMAN CAPITAL
(Education)
INFRASTRUCTURE
POLICIES


Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
Suppliers
Bus Proc Outsourcing
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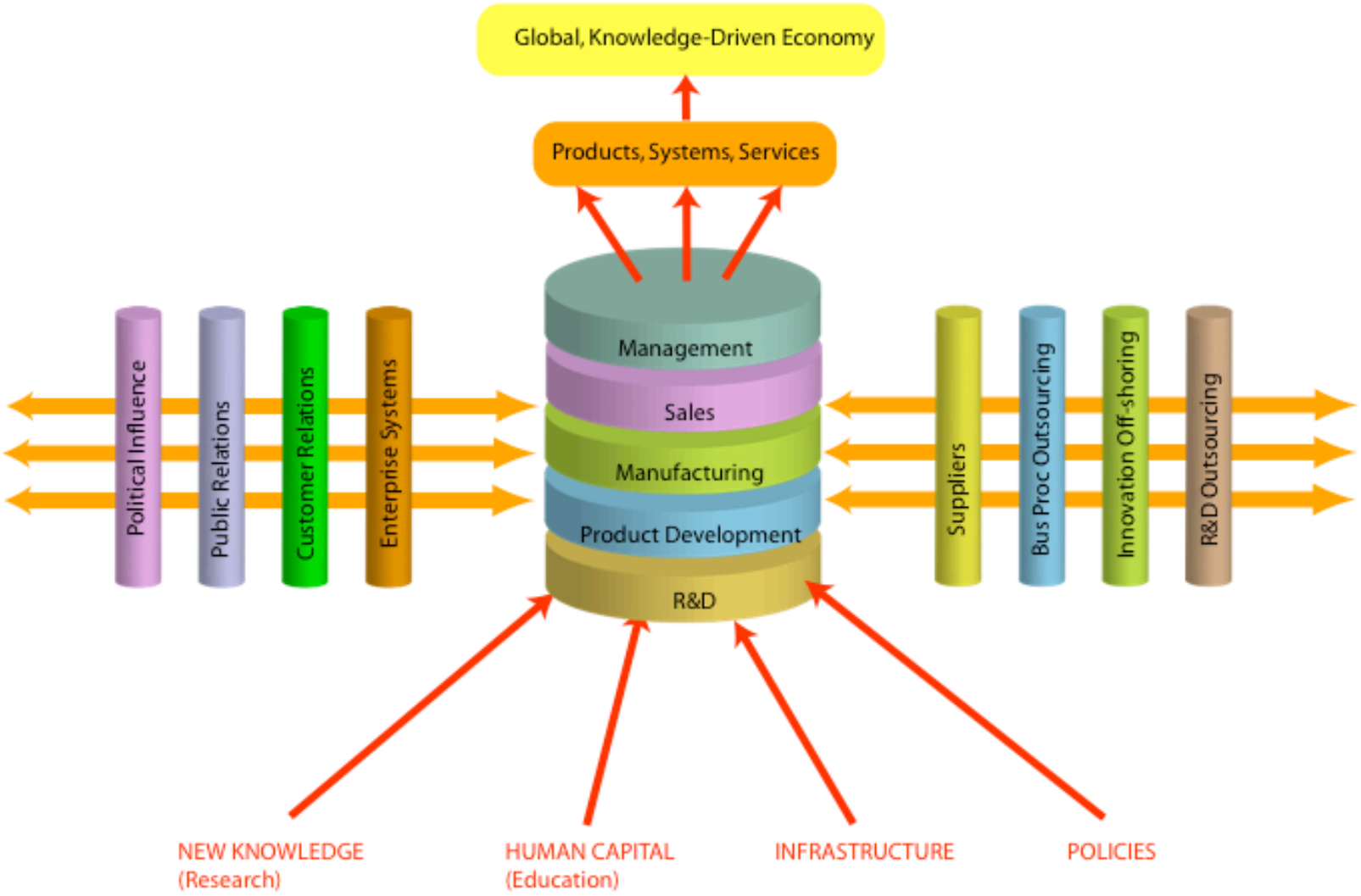
Global, Knowledge-Driven Economy
Products, Systems, Services
Management
Sales
Manufacturing
Product Development
R&D
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Suppliers
Bus Proc Outsourcing
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R&D Outsourcing
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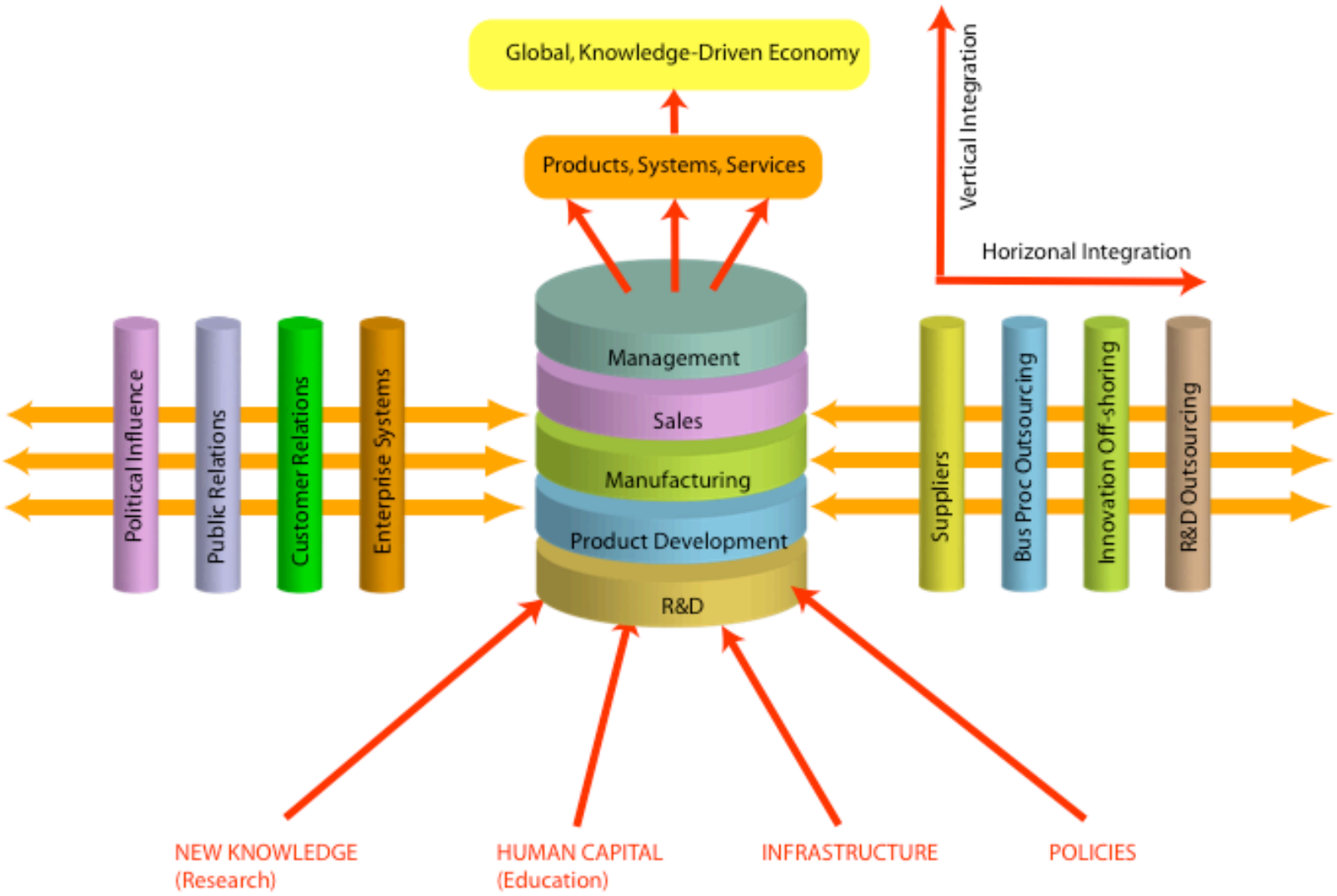
Global, Knowledge-Driven Economy
Products, Systems, Services
Vertical Integration
Horizonal Integration
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Management
Sales
Manufacturing
Product Development
R&D
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
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NEW KNOWLEDGE
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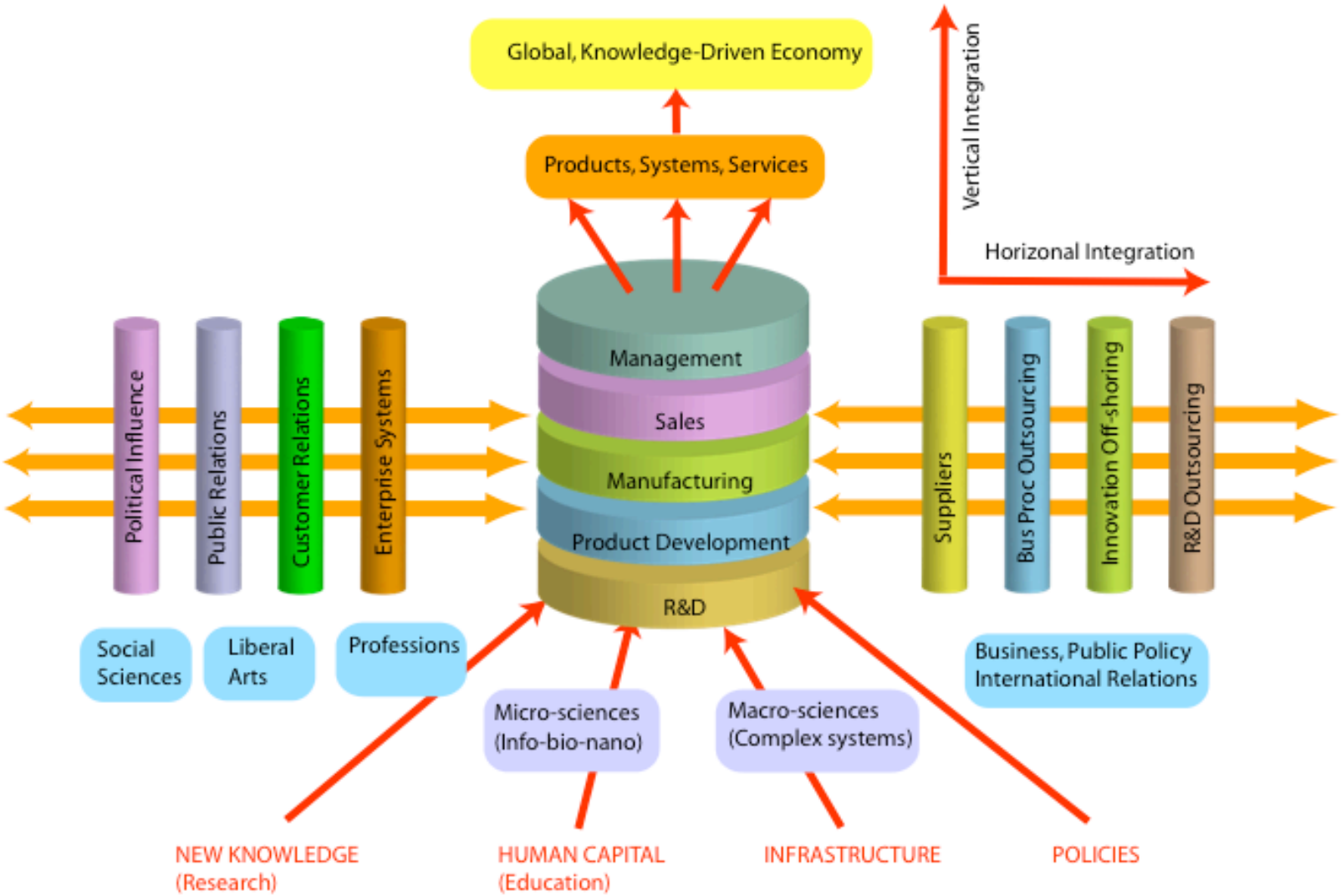

Global, Knowledge-Driven Economy
Products, Systems, Services
Vertical Integration
Horizonal Integration
Management
Sales
Manufacturing
Product Development
R&D
Political Influence
Public Relations
Customer Relations
Enterprise Systems
Suppliers
Bus Proc Outsourcing
Innovation Off-shoring
R&D Outsourcing
Social Sciences
Liberal Arts
Professions
Micro-sciences (Info-bio-nano)
Macro-sciences (Complex systems)
Business, Public Policy International Relations
NEW KNOWLEDGE (Research)
HUMAN CAPITAL (Education)
INFRASTRUCTURE
POLICIES

The World Is Flat

A BRIEF HISTORY OF THE TWENTY-FIRST CENTURY

Thomas L. Friedman

Tom Friedman

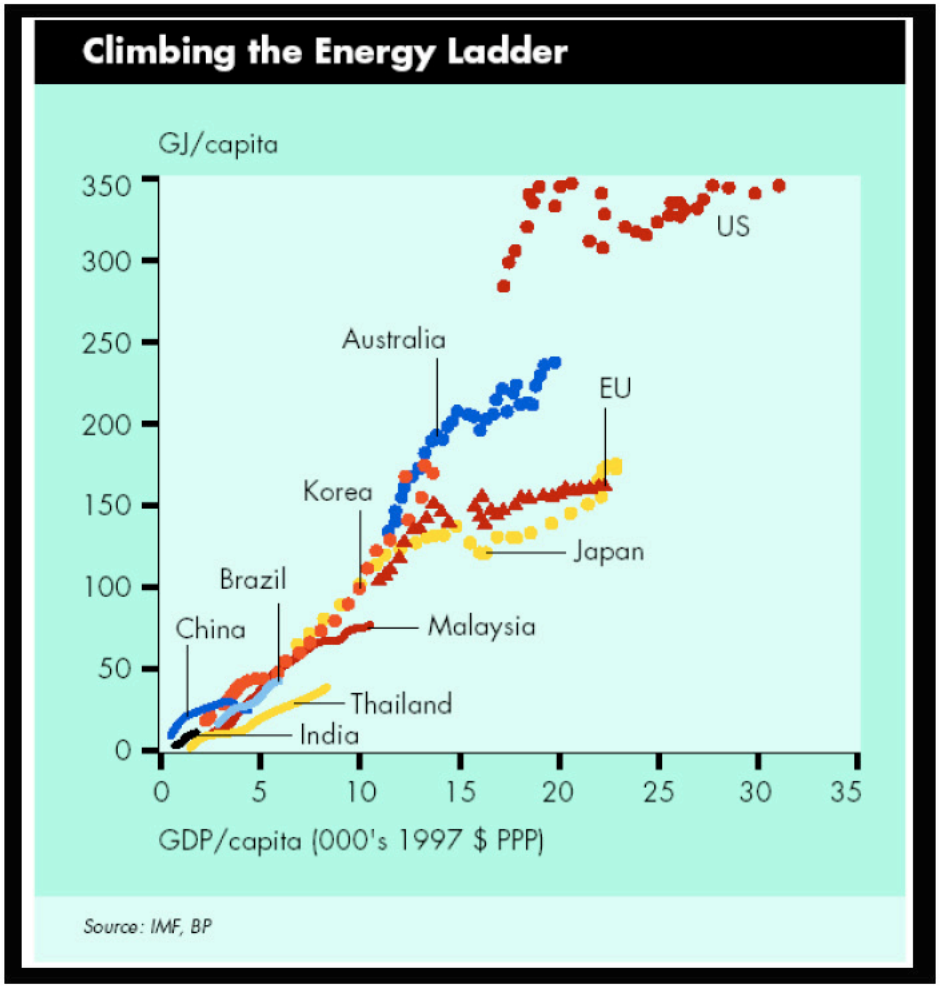
"The playing field is being leveled. Some three billion people who were out of the game have walked and often ran onto a level playing field, from China, India, Russia, and Central Europe, nations with rich educational heritages. It is this convergence of new players, on a new playing field, developing new processes for horizontal collaboration, that I believe is the most important force shaping global economics and politics in the early 21st century."

Global Sustainability

Global Sustainability

- Depletion of Resources (e.g., oil, gas, etc.)
- Water
- Deforestation
- Erosion of cultivatable land
- Extinction of biological species
- Global climate change

Economic Prosperity Requires Reliable and Affordable Energy



Source: Royal Dutch Shell, "Exploring the Future – Energy Needs, Choices and Possibilities"

Sandia National Laboratories

The End of the Age of Oil?

- Exxon-Mobil believes that "for the next 25 to 50 years, the oil available to the markets is for all intents and purposes infinite."
- But an increasing number of scientists suggest that the "Hubbert's Peak" in global petroleum production could occur in the next couple of decades.

Table II-1. Projections of the Peaking of World Oil Production

Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhitari, A.M.S.	Iranian Oil Executive[11]
2007-2009	Simmons, M.R.	Investment banker [12]
After 2007	Skrebowski, C.	Petroleum journal Editor [13]
Before 2009	Deffeyes, K.S.	Oil company geologist (ret.) [14]
Before 2010	Goodstein, D.	Vice Provost, Cal Tech [15]
Around 2010	Campbell, C.J.	Oil company geologist (ret.) [16]
After 2010	World Energy Council	World Non-Government Org.[17]
2010-2020	Laherrere, J.	Oil company geologist (ret.) [18]
2016	EIA nominal case	DOE analysis/ information[19]
After 2020	CERA	Energy consultants [20]
2025 or later	Shell	Major oil company [21]
No visible peak	Lynch, M.C.	Energy economist[22]

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The End of the Age of Oil?

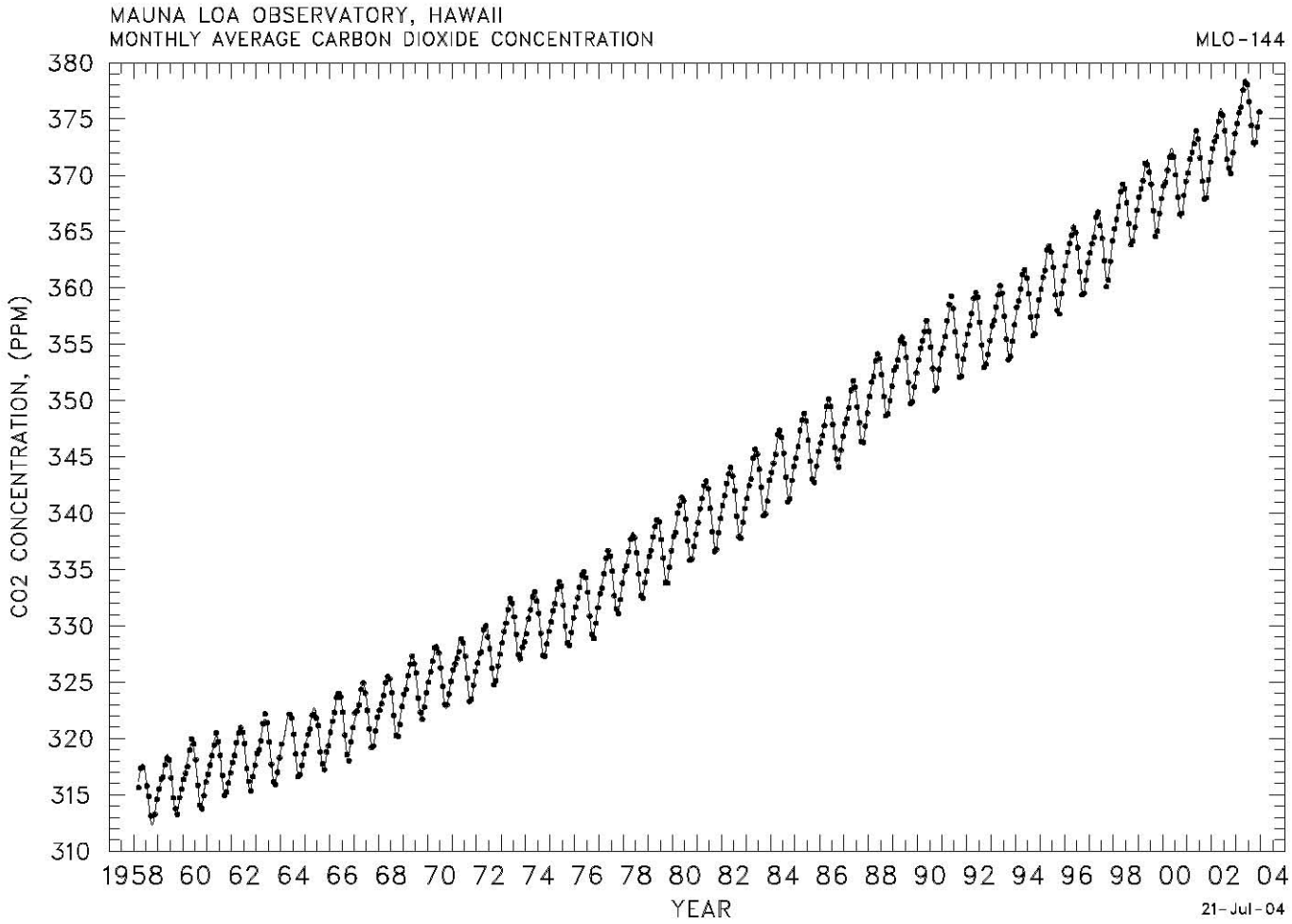
- Exxon-Mobil believes that "for the next 25 to 50 years, the oil available to the markets is for all intents and purposes infinite."
- But an increasing number of scientists suggest that the "Hubbert's Peak" in global petroleum production could occur in the next couple of decades.
- But scarcity is not the only reason why the world might move away from oil. The unnerving volatility of oil prices, together with growing concern about the environmental impact of hydrocarbons, is already spurring the search for alternatives.
- "The stone age did not end because the world ran out of stone, and the oil age will end long before the world runs out of oil!"

Global Sustainability

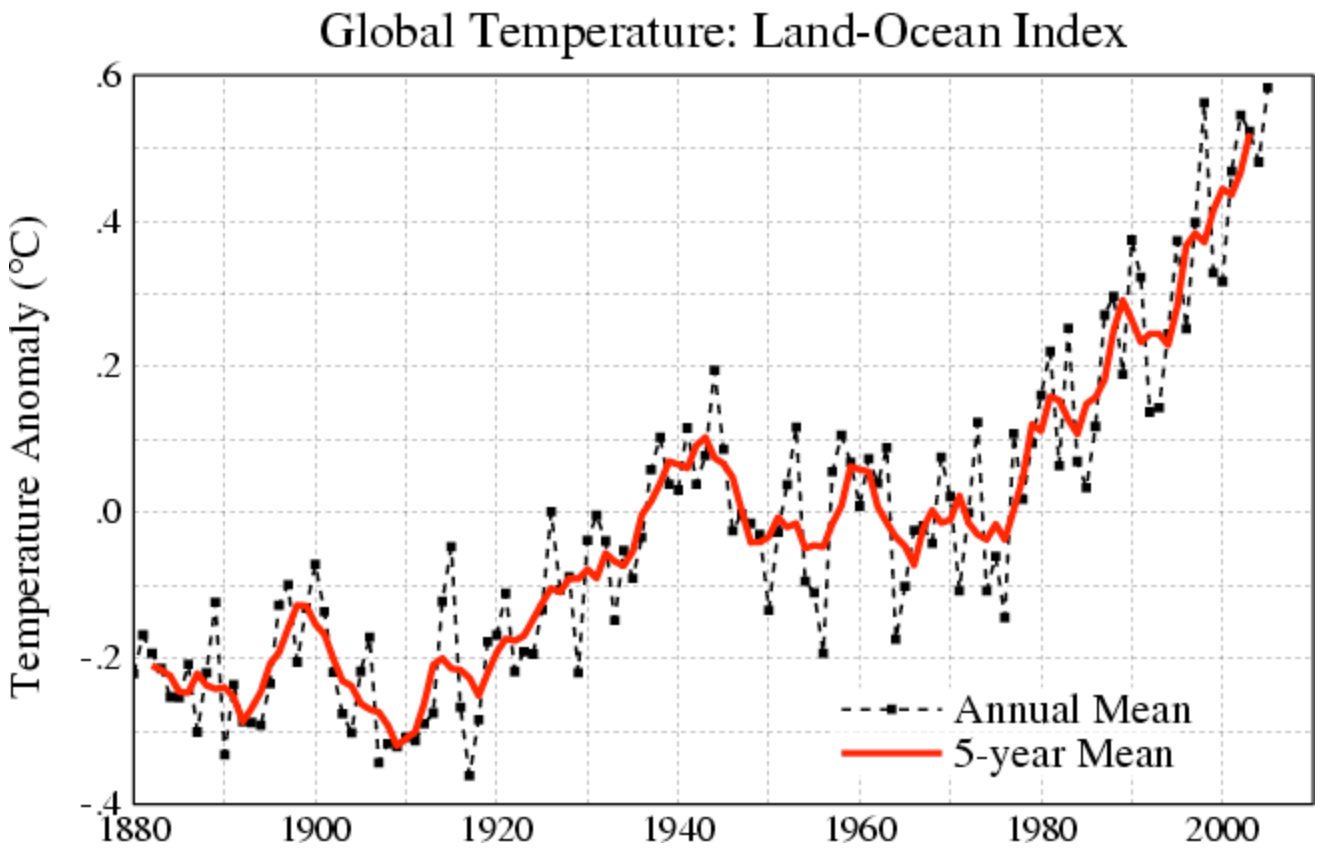
Global Climate Change

- There is compelling evidence that the growing population and invasive activities of humankind are now altering the fragile balance of our planet.
- The concerns are both multiplying in number and intensifying in severity: the destruction of forests, wetlands, and other natural habitats by human activities leading to the extinction of millions of biological species and the loss of biodiversity; the buildup of greenhouse gases such as carbon dioxide and their possible impact on global climates; the pollution of our air, water, and land.

Atmospheric CO_2 : 50-year history

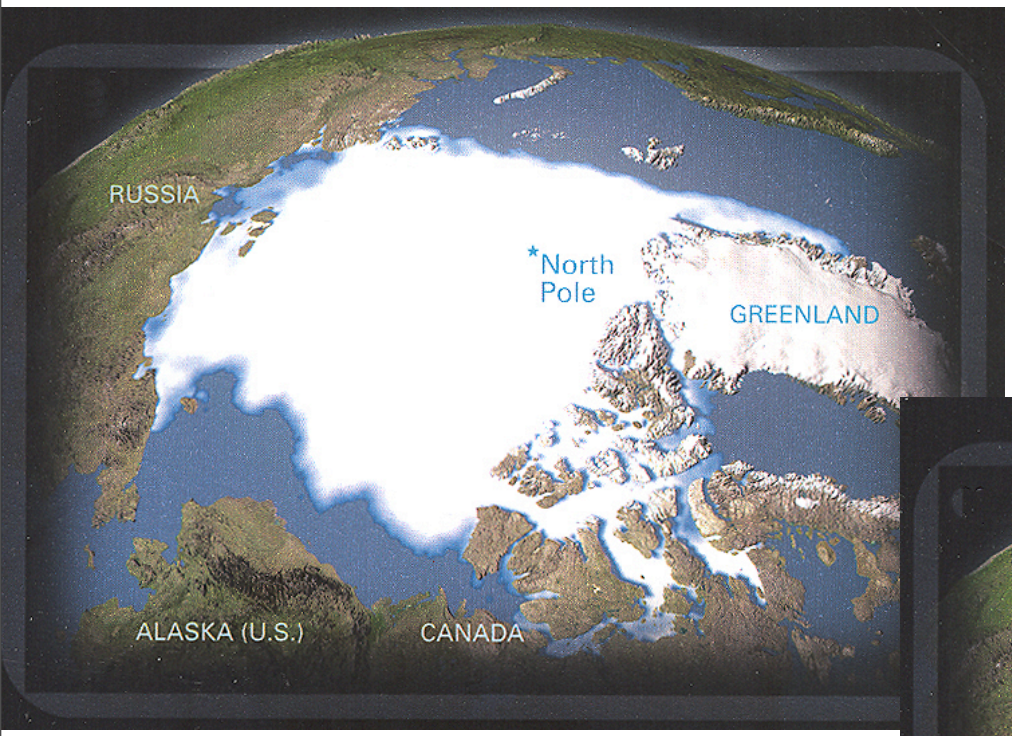


Source: Keeling and Whorf, data at cdiac.esd.ornl.gov/ndps/ndp001.html



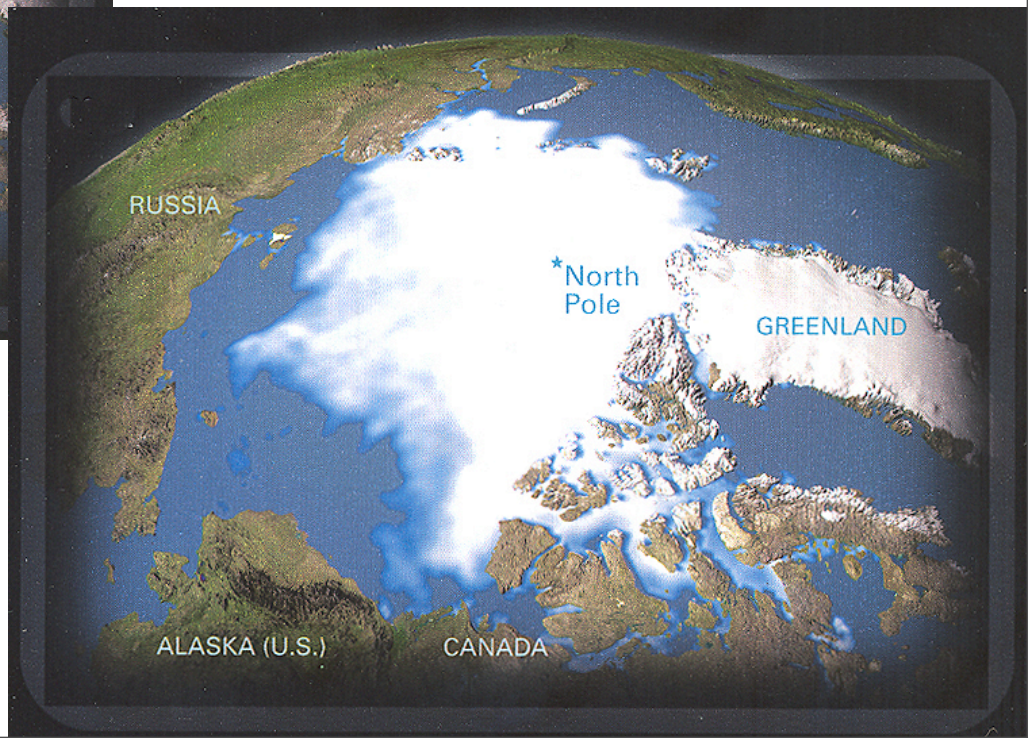
Source: NASA GISS, at data.giss.nasa.gov/gistemp/graphs/

Arctic Ice Cap Change



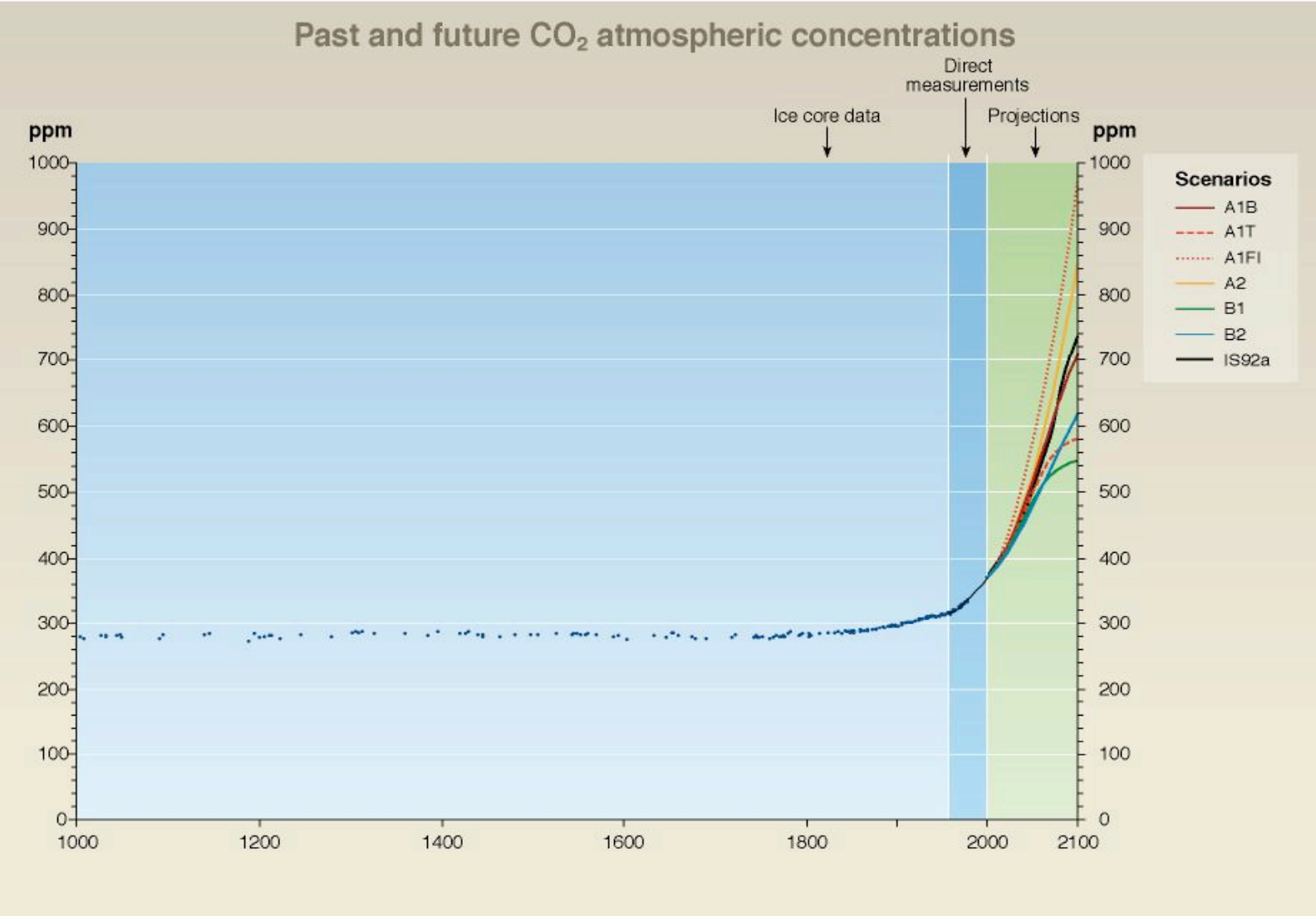
1979

2003



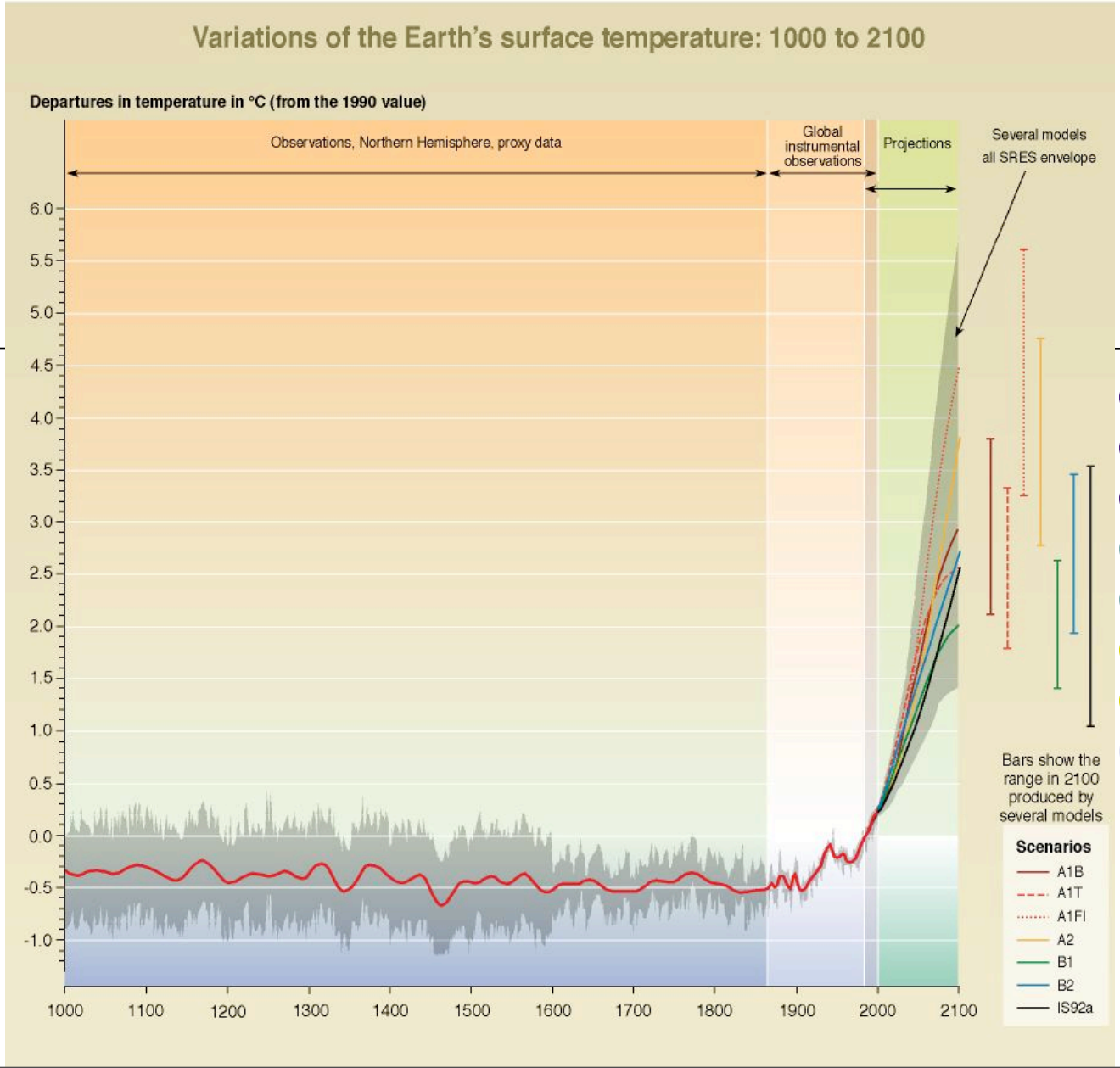
Atmospheric CO_2: 1,000-year history, 100-year projections

SPM - 10a



Projected Warming in the Context of 1,000 years of History

SPM - 10b



What to do?

- It could well be that coming to grips with the impact of our species on our planet, learning to live in a sustainable fashion on Spaceship Earth, will become the greatest challenge of all to our generation. We must find new ways to provide for a human society that presently has outstripped the limits of global sustainability.

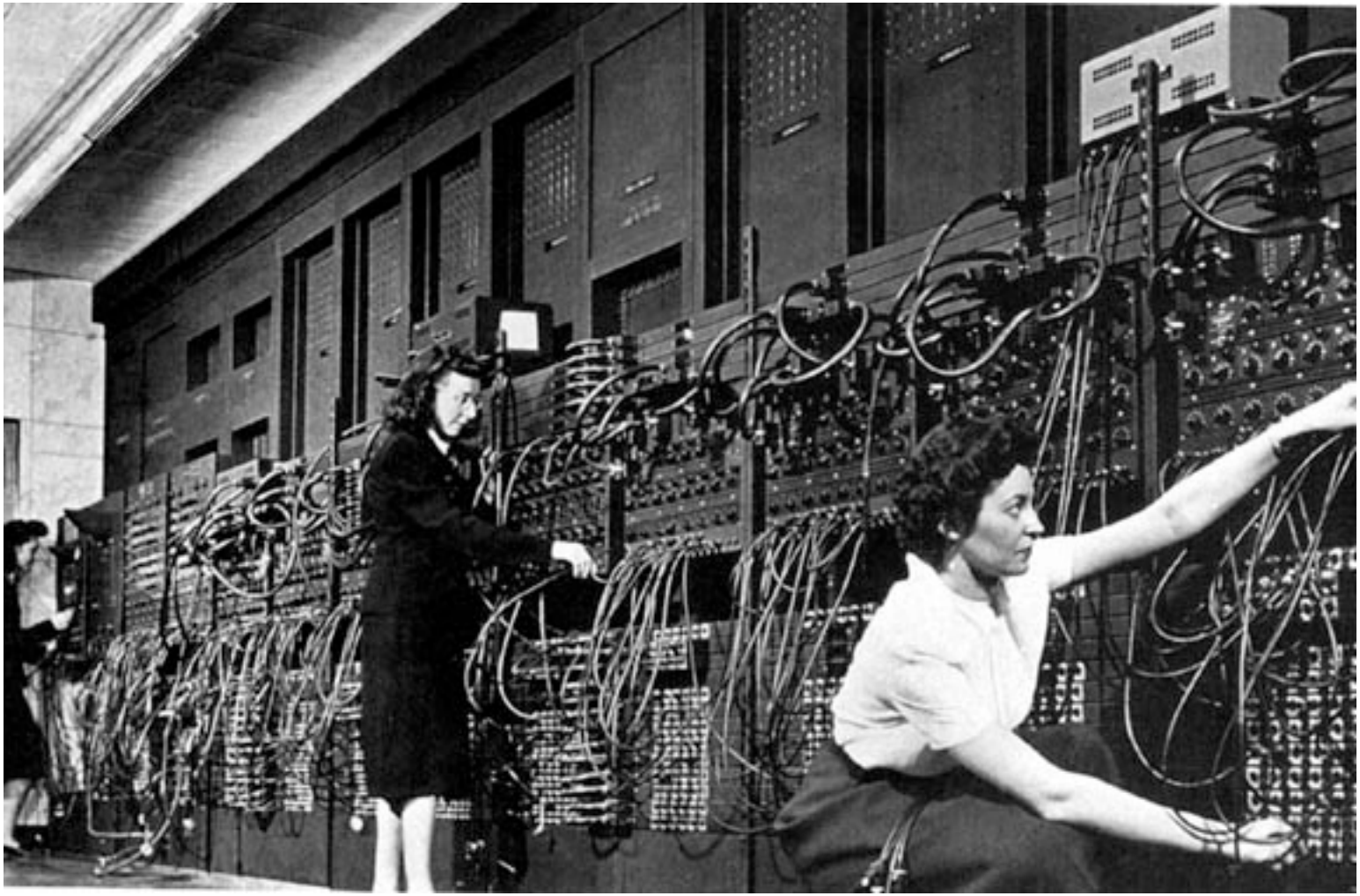
Disruptive Technologies

Exponential Growth

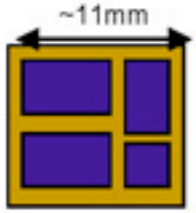
- The technologies driving such profound changes in our world, technologies such as information technology, biotechnology, and soon nanotechnology, are all characterized by exponential growth.
- When applied to computers, this remarkable property, known as Moore's Law, suggests that every 18 months computing power for a given price doubles. Other aspects such as memory, bandwidth, and miniaturization, are evolving even more rapidly, 100 or a 1,000 fold every decade.
- In fact, scientists and engineers today believe that the exponential evolution of these microscopic technologies is not only likely to continue for the foreseeable future, but the pace may be accelerating.

Information Technology

From Eniac

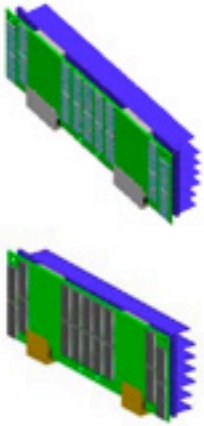


Building BlueGene/L



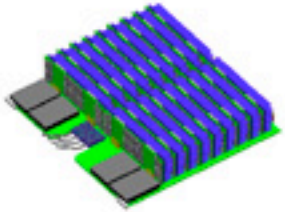
Compute Chip

2 processors
2.8/5.6 GF/s
4 MiB* eDRAM



Compute Card
I/O Card

FRU (field replacable unit)
25mmx32mm
2 nodes (4 CPUs)
(2x1x1)
2.8/5.6 GF/s
256/512 MiB* DDR
15 W



Node Card

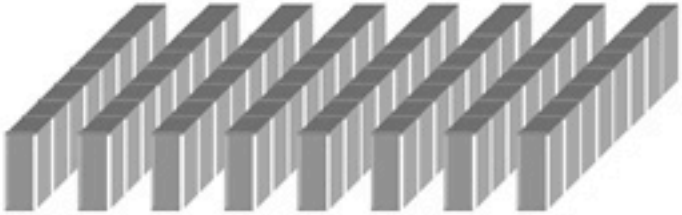
16 compute cards
0-2 I/O cards
32 nodes
(64 CPUs)
(4x4x2)
90/180 GF/s
8 GiB* DDR

Midplane

SU (scalable unit)
16 node boards
512 nodes
(1,024 CPUs)
(8x8x8)
1.4/2.9 TF/s
128 GiB* DDR
7-10 kW

Cabinet

2 midplanes
1024 nodes
(2,048 CPUs)
(8x8x16)
2.9/5.7 TF/s
256 GiB* DDR
15-20 kW



System

64 cabinets
65,536 nodes
(131,072 CPUs)
(32x32x64)
180/360 TF/s
16 TiB*
1.2 MW
2500 sq.ft.

(compare this with a 1988 Cray YMP/8 at 2.7 GF/s)

* http://physics.nist.gov/cuu/Units/binary.html

Curve 3

IBM Blue Gene L (2005):

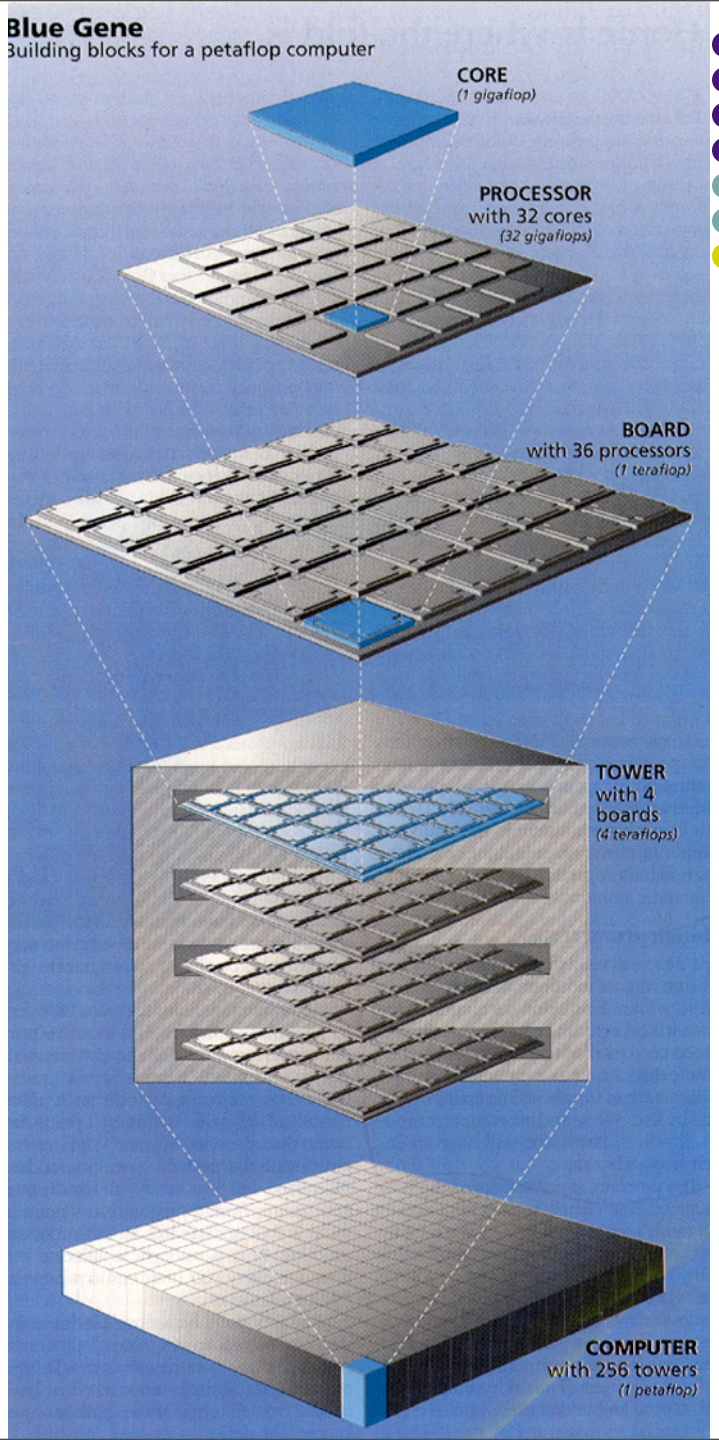
360 TeraFlops

IBM Blue Gene P (2007):

“Several” PetaFlops

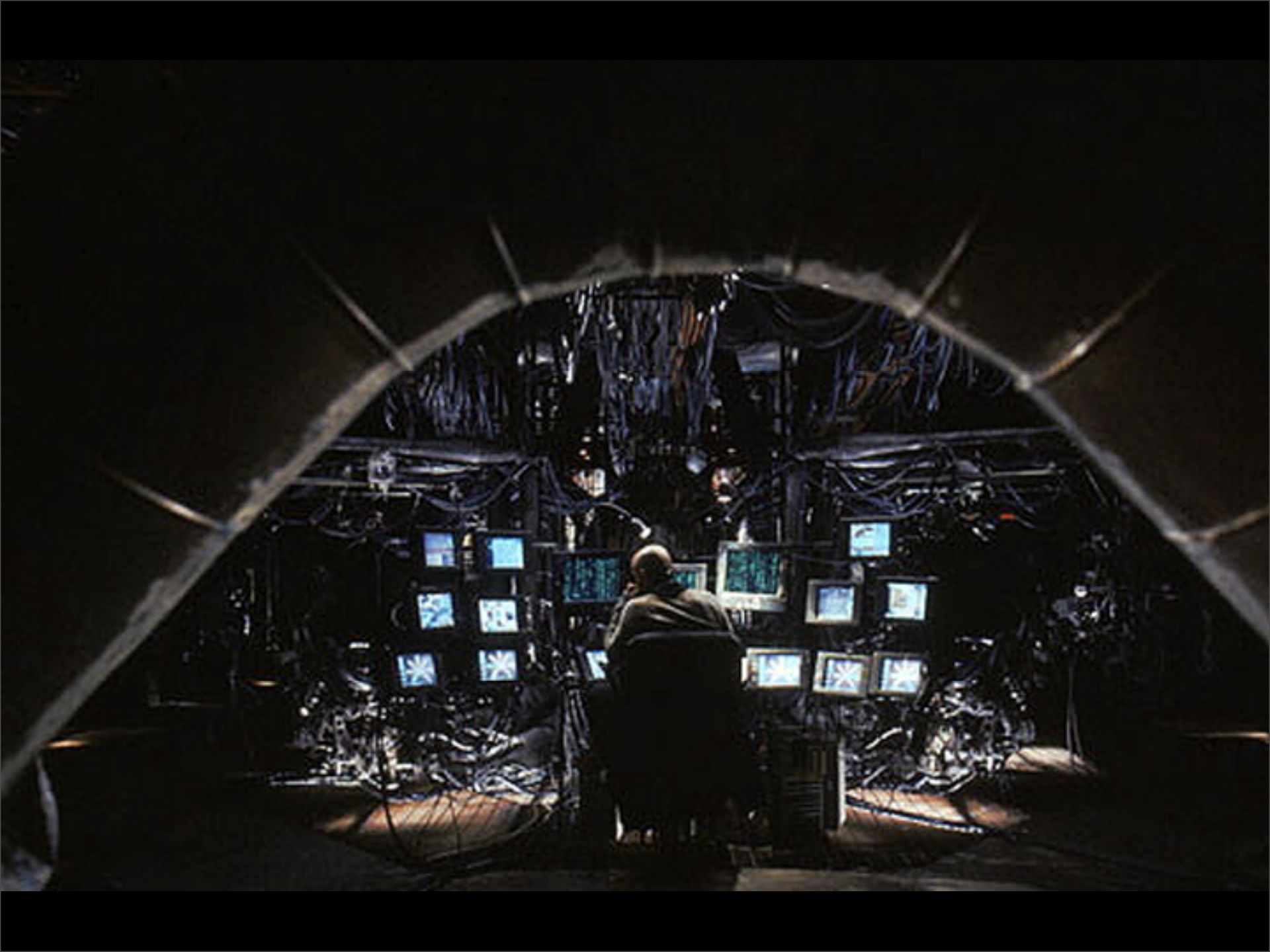
ExaFlops (2020)?

Note: One Petaflop is roughly the processing speed of the human brain. An exaflop is 1,000 times faster…

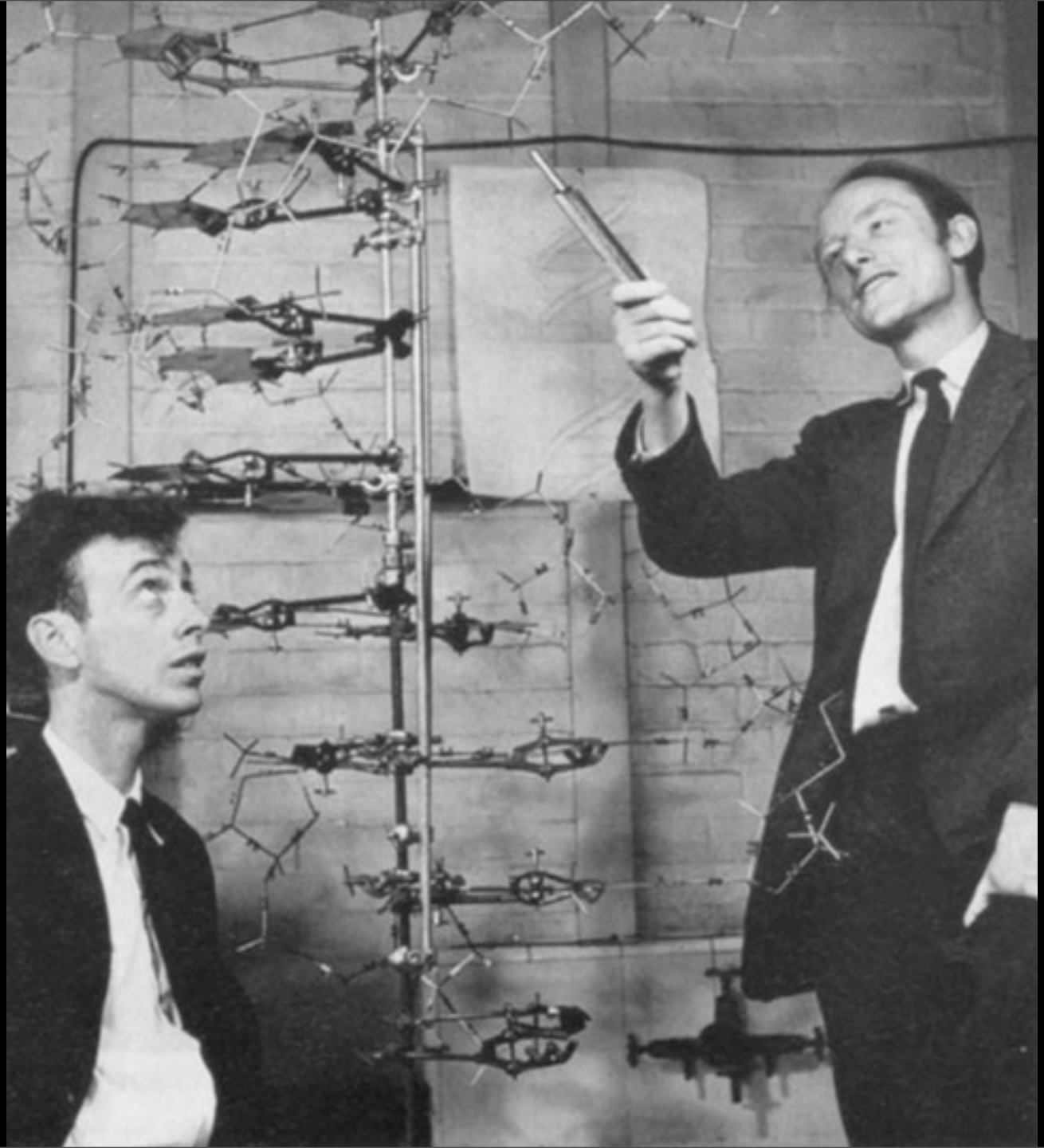


Evolution of the Net

- Already beyond human comprehension
- Incorporates ideas and mediates interactions among billions of people
- Basis of all economic and communication activity
- Soon to be coupled with a 21st C "library of Alexandra"



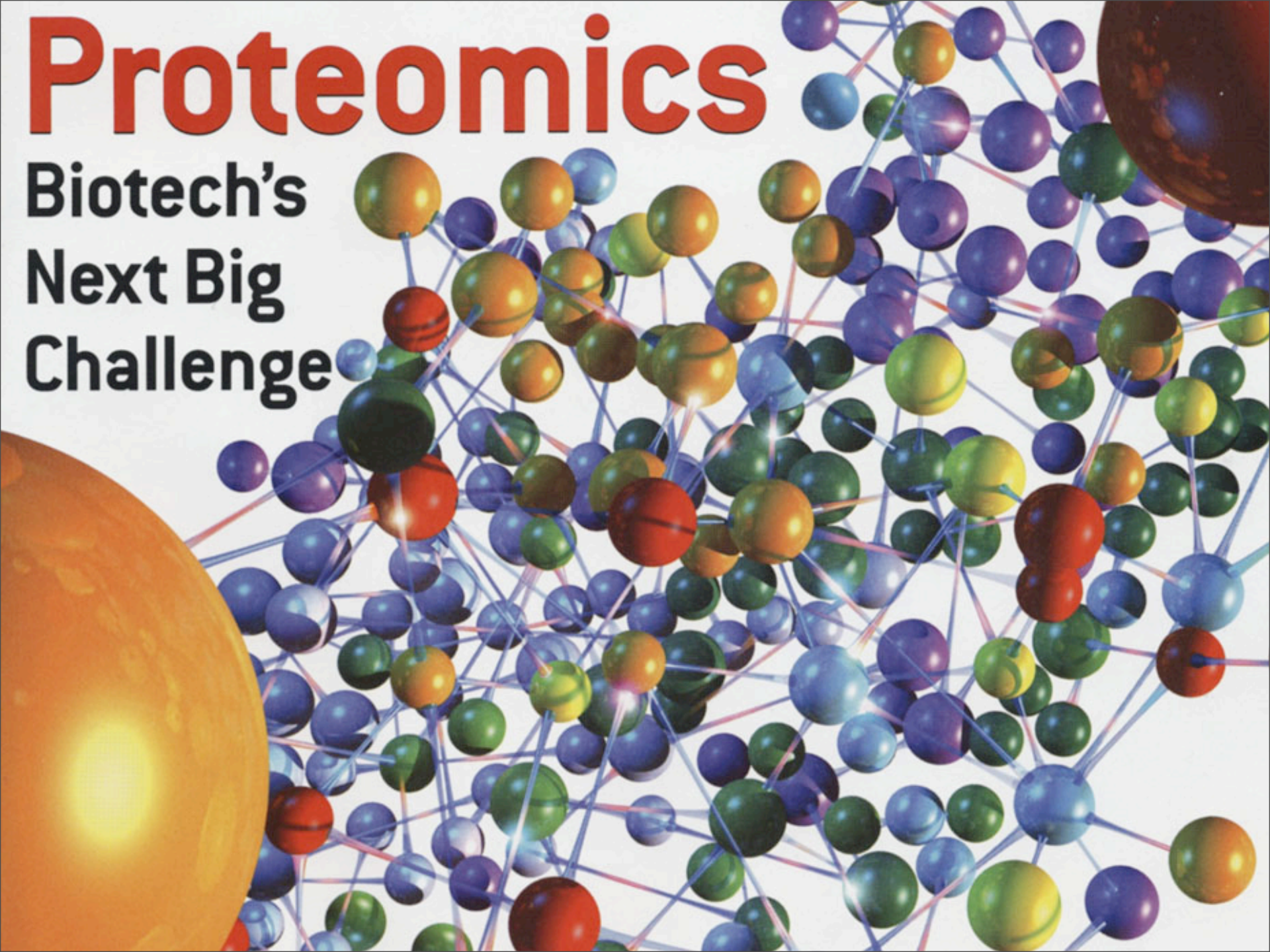
Biotechnology




ACGTAGCAGAGT
CAGATGCTGGAGCCTATTT
TATAGAGTGATTAGCCACATT
ACAAATGGCCACTCCAGACC
TTACAGAGCTTGACCACAAA
AGAGTACCCAACAAGCCGACC
GACAGTGATAGCCGAGTTCC
TTCCAGTGACCTTGTGGA
GAAACCGAGGTCCA
TTGAGCCAAGGAACCC
CCGATATCGCGCTAC
ATGCGATAGATCGAT

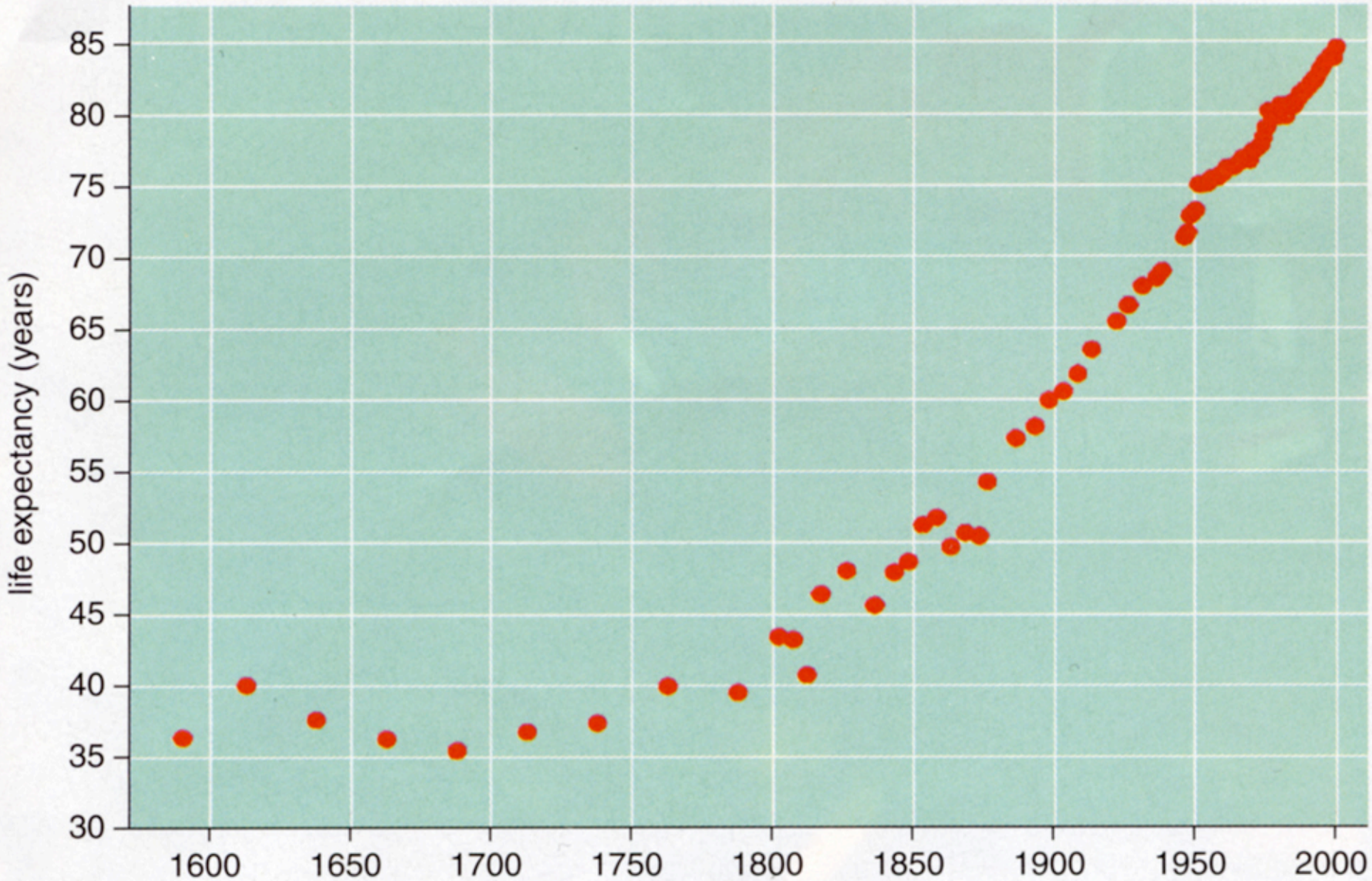
Proteomics

Biotech's Next Big Challenge



Over the next two decades

- Medicine will evolve from:
  - “reactive” medicine (curing disease)
  - “predictive” medicine (using genetic information to predict susceptibility to particular diseases and adjusting lifestyles accordingly)
  - “preventive” medicine (using human gene therapy to correct genes)
- But what about aging? Survival beyond child-bearing and rearing age was not favored by natural selection…


life expectancy (years)
85
80
75
70
65
60
55
50
45
40
35
30
1600
1650
1700
1750
1800
1850
1900
1950
2000

Changing the aging process

- Some experts believe that within 20 years, the life span will have increased by 10 years or more.
- Eventually, nanotechnology will allow us to repair at the microscopic level cell structure.
- Indeed, some believe that biotechnology will soon be adding more than a year to human life expectancy every year.

One More Concern

Last year the United Nation's projected the Earth's population in the year 2050 as 9.1 billion, 50% larger than today.

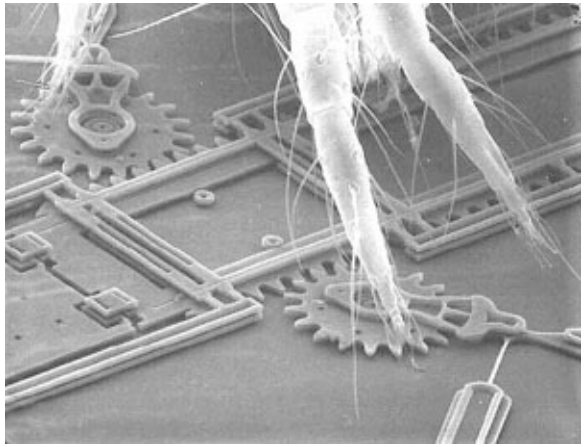
Can we sustain a population of that magnitude on Spaceship Earth?

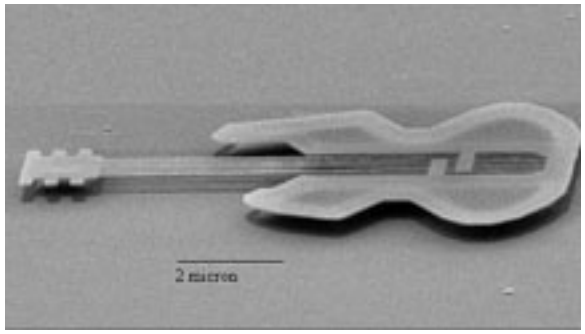
Nanotechnology

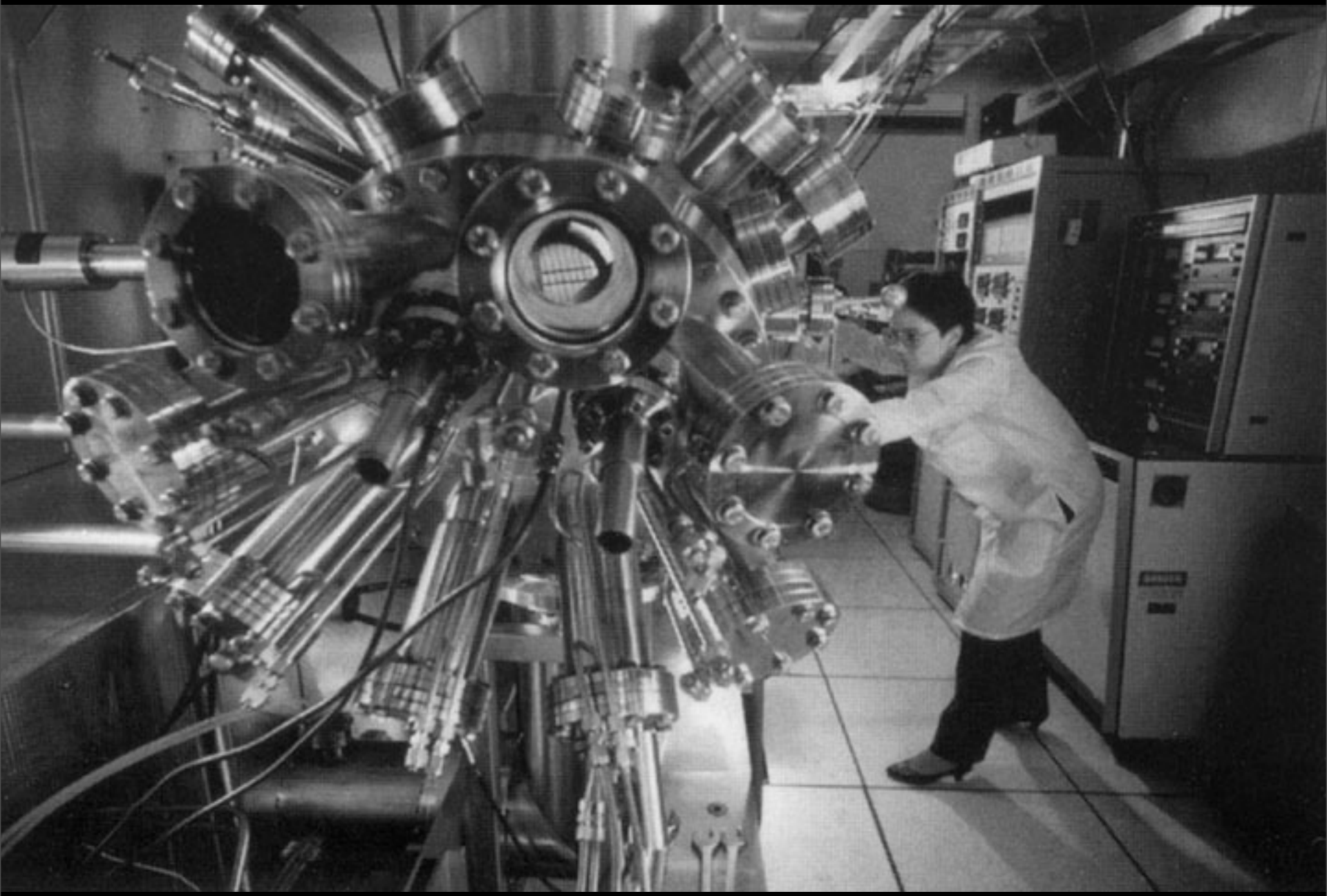
MEMS

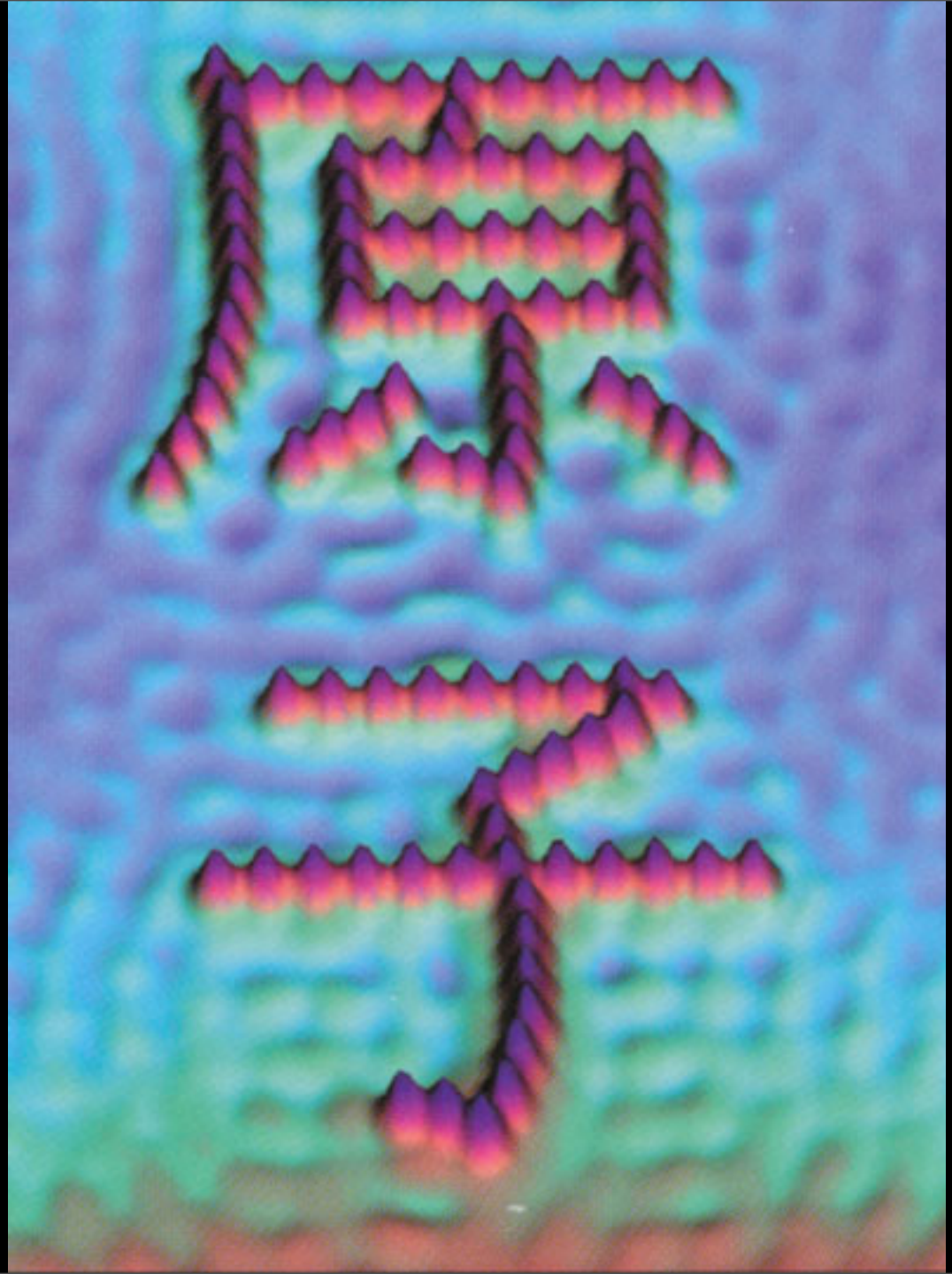
MEMS: Micro electromechanical machines

Engineers have developed the capacity to fabricate microscopic gears, machines, and motors out of silicon, much as they do electronic circuits. These are typically of submicron size.

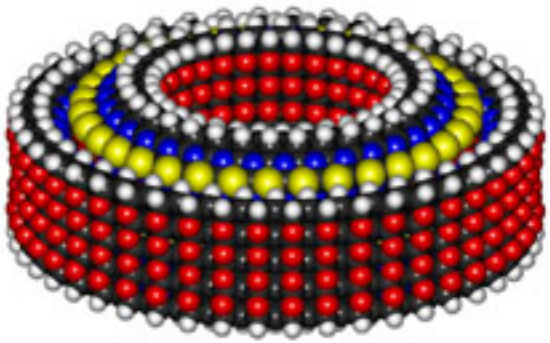




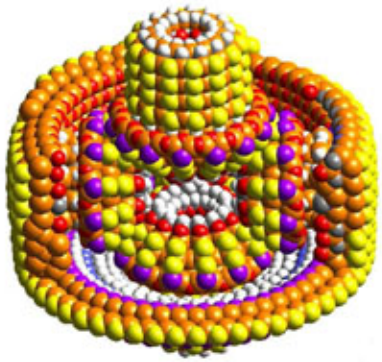




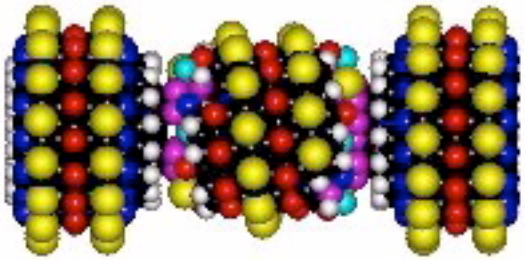
Molecular Nanomachines



Bearing



A differential gear



Pum
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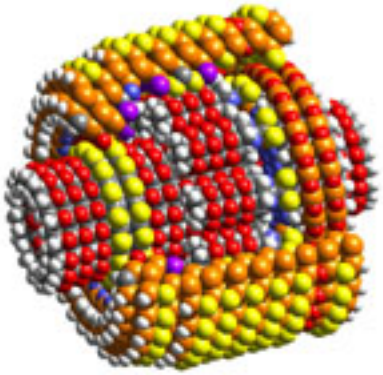
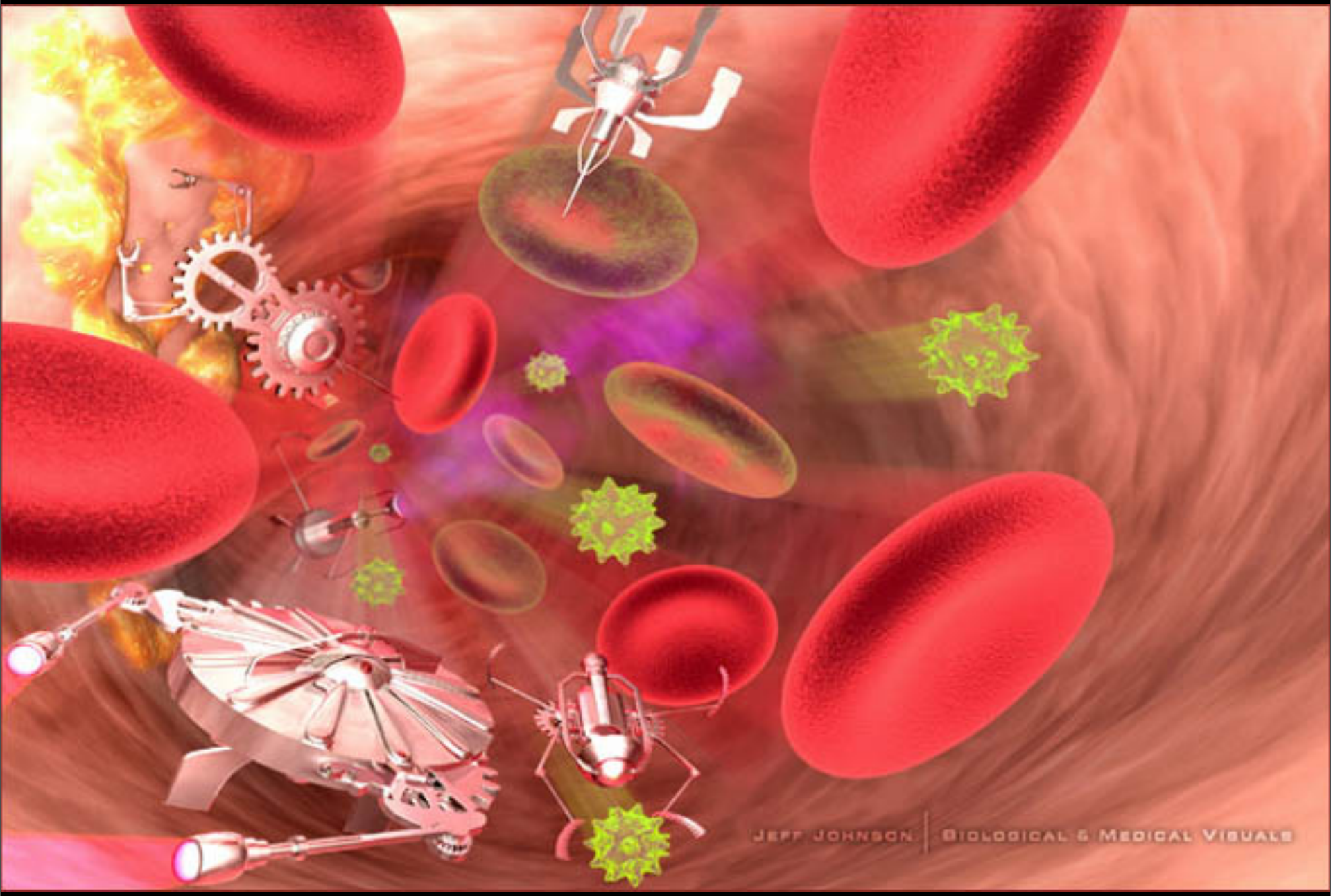
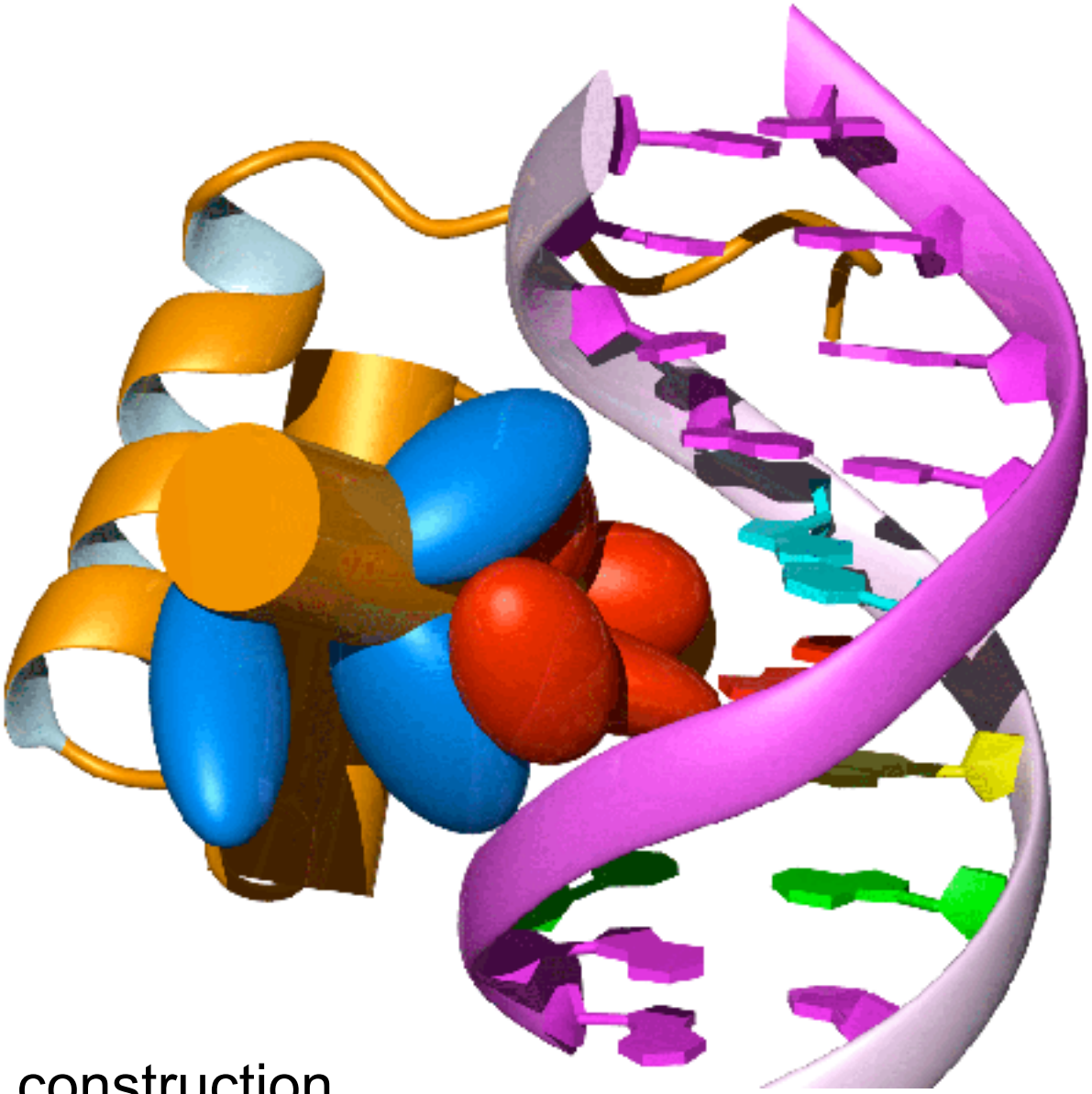


A planetary gear


Jeff Johnson | Biological & Medical Visuals



DNA construction

Disruptive Technologies

- Beyond this fact, there is another important characteristic of such technologies: they are disruptive! Their impact on social institutions such as corporations, governments, and learning institutions is profound, rapid, and quite unpredictable.
- As Clayton Christensen explains in *The Innovator's Dilemma*, while many of these new technologies are at first inadequate to displace today's technology in existing applications, they later explosively displace the application as they enable a new way of satisfying the underlying need. If change is gradual, there will be time to adapt gracefully, but that is not the history of disruptive technologies.

Topic 1: The Forces of Change

- The Age of Knowledge
- Globalization
- Demographics
- Global Sustainability
- Disruptive Technologies

Topic 2: National Challenges

- Globally competitive workforces
- Need to "massify" higher education
- Resource requirements
- Political constraints (e.g., demands of aging populations vs. educational needs of the young)

Human capital trumps all!

- In a hypercompetitive, global knowledge-driven economy, the key strategic resource necessary for economic prosperity and national security has become knowledge itself–educated people and their ideas.
- Hence education, at all levels and for all citizens, becomes the most important investment a society can make in its future!

Financial Imperatives

- Increasing societal demand for university services (education, research, services)
- Increasing costs of higher education
- Declining priority for public support (particularly in aging societies)
- Public resistance to increasing prices (tuition, fees)
- Inability to re-engineer cost structures (i.e., productivity)
- Concern: The current paradigms for conducting, distributing, and financing higher education may no longer be sufficient to adapt to the demands and realities of the knowledge economy.

So, what to do?

- How can education systems designed in earlier times for the education of the elite be extended to a substantial fraction of the population (> 50%)?
- Can such massification be supported entirely from public sources, e.g., taxation? Or will it require a more blended public-private approach (e.g., through student fees or tax incentives for philanthropy)?
- Or will it require entirely quite different paradigms? Open universities? For-profit universities? Cyberspace universities? Or something entirely new? (More on this later…)

Challenge of the Baby Boomers

- A growing population of aging voters will increasingly focus national priorities on the concerns of the elderly (e.g., health care, tax relief) rather than the needs of the young (e.g., education).
- In the United States we are increasingly concerned that for the first time in our history the next generation will not have the educational opportunities–nor the skills–of their parents!

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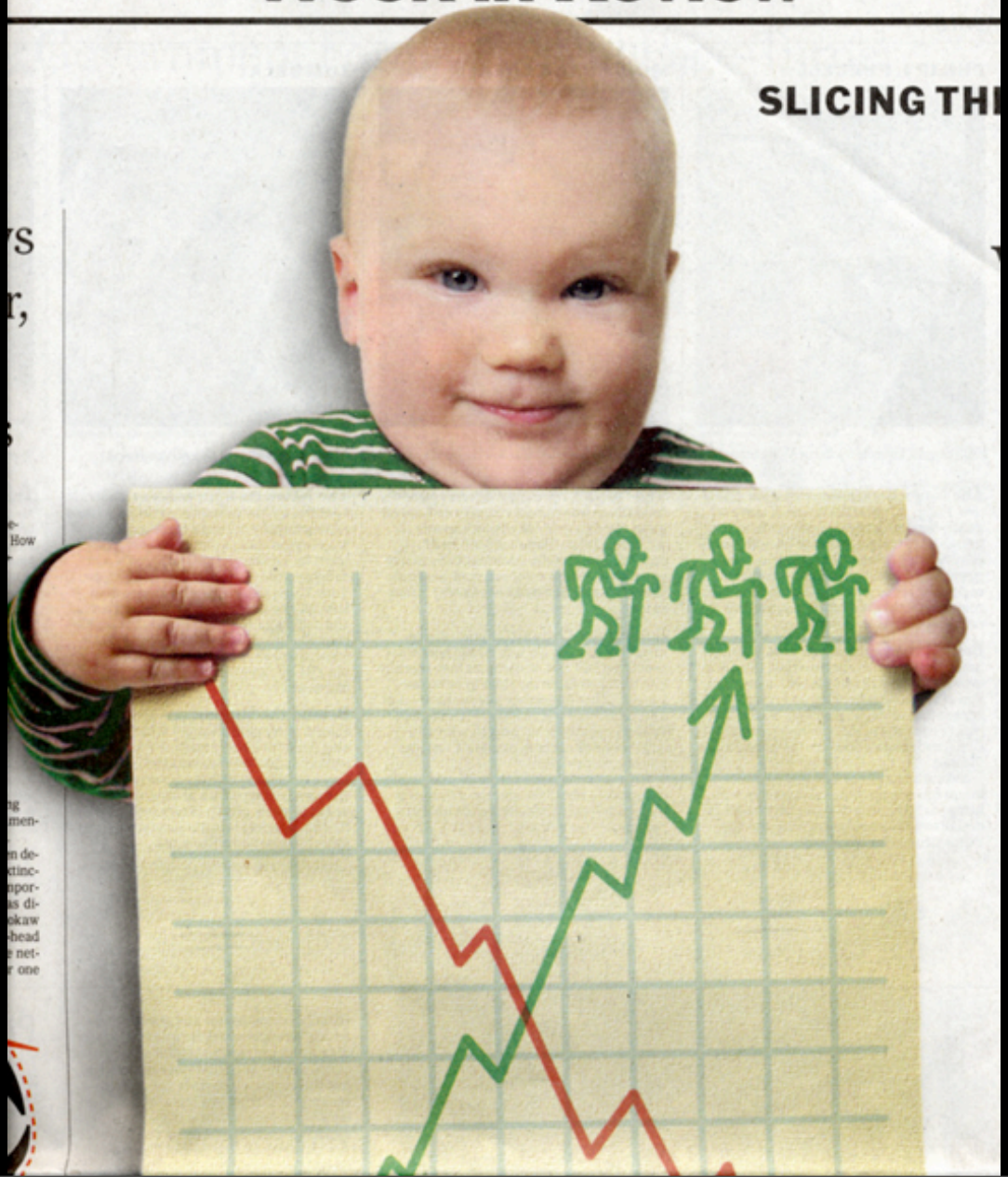

Market Forces

- Changing societal needs, economic realities, and rapidly evolving technology are creating powerful market forces in the higher education enterprise. The traditional monopolies of the university, sustained in the past by geography and certification, are breaking apart.
- We may be seeing the early signs of a **restructuring** of the higher education enterprise into a global knowledge and learning industry.
- Concern: The current faculty-centered, monopoly-sustained university paradigm is ill suited to the intensely competitive, technology-driven, global marketplace.

A Restructured Industry?

- There are signs that higher education may be in the early stages of a major restructuring like other economic sectors such as energy, banking, and transportation that underwent restructuring following deregulation.
- The same forces of changing social needs, financial pressures, and rapidly evolving technology that are driving market forces in higher education are also driving a convergence of education with other knowledge-intensive industries such as information technology, telecommunications, information services, and entertainment into what might be regarded as "a global knowledge and learning industry".

A Brave New World?

- Unbundling
- A commodity marketplace
- Mergers, acquisitions, hostile takeovers
- New learning “lifeforms”
- An intellectual wasteland???

A Key Policy Question

How do we balance the roles of market forces and public purpose in determining the future of higher education. Can we control market forces through public policy and public investment so that the most valuable traditions and values of the university are preserved?

Or will the competitive and commercial pressures of the marketplace sweep over our institutions, leaving behind a higher education enterprise characterized by mediocrity?

Topic 3: U.S. Higher Education

- Today
  - Basic characteristics
- Signs of Change
  - Spellings Commission
  - Rising Above the Gathering Storm
- Tomorrow: Paradigm Breakers (MIT OCW, Sakai, Google, Cyberinfrastructure)