# I. Introduction: Some Definitions and Basic Phenomena; Innovation Management

# What is a Technological Innovation?



- Science: creating knowledge (answers the question: why?)
- Technology: Applying knowledge (answers the question: how?)
- Difference between technology and scientific technology
- Science understands nature, scientific technology manipulates nature.
- Technological innovation is the **utilization** of technical inventions or technological know-how for **economic purposes**.
- A technological innovation is
  - a new or considerably improved product/service or
  - a new or considerably improved production process.
- The process of innovation includes all activities leading to the innovation: Starting with the perception of an unsolved need, the generation of an idea, R&D to solve the problem, through setting up new production capacities and ending with the introduction and widespread diffusion in the market.

# Historically Important Innovations



| Innovation | Function | Date |
|---|---|---|
| Tools | Technology | Pre-history |
| Pottery | Materials | Stone Age |
| Bronze | Materials | 2500s BC |
| Writing | Literacy | 2500s BC |
| Iron | Materials | 1500s BC |
| Gun | Weapons | 1300s AD |
| Printing | Literacy | 1400s |
| Telescope | Optics | 1500s |
| Microscope | Science | 1700s |
| Steam Engine | Power | 1700s |
| Powered Machinery | Production | 1700s |
| Railroads | Transportation | 1830s |
| Telegraph | Communications | 1850s |
| Chemicals | Materials | 1850s |
| Steam Ships | Transportation | 1860s |
| Cameras | Images | 1860s |
| Telephone | Communications | 1880s |
| Electric Lighting | Illumination | 1880s |
| Electrical Power | Power | 1880s |
| Bicycles | Transportation | 1880s |
| Automobiles | Transportation | 1890s |
| Airplanes | Transportation | 1900s |
| Plastics | Materials | 1900s |
| Movies | Communications | 1910s |
| Electron Tubes | Electronics | 1910s |
| Radio | Communications | 1920s |
| Radar | Sensing | 1930s |
| Space Rockets | Transportation | 1930s |
| Nuclear Fission | Weapons | 1930s |
| Television | Communications | 1930s |
| Computers | Computation | 1940s |
| Transistors | Electronics | 1940s |
| Satellites | Transportation | 1950s |
| Integrated Circuits | Electronics | 1950s |
| Computer Networks | Communications | 1970s |

Really called *innovation*?

# Case Studies

- Best and worst practice stories that support the theory
- They themselves do not develop or validate a theory
- Ex: Concurrent engineering design of Ford Taurus (1981)
  - Examined 400 best features of top-class cars
  - Saved Ford in 1980, sold well, cancelled in 2008
  - Couldn't it save Ford from bankrupcy in late 00's?
  - Failure of proper innovation strategy
  - Bought Volvo and Jaguar
  - What happened to Ford?

# Innovation

- Formerly: Business side
  - Focus on technological progress to
    - Design
    - Produce
    - Market new services, products, processes
- Technical side
  - Required engineering management (EM)
  - Technical personnal reqirement grew esp. in IT:
    - Programmers
    - Mathematicians
    - Computer scientists
- Now: Management of engineering and technology (MOT)
  - Empirical: describes historical patterns of change in science, technology and economy
  - Theoretical:develops useful concepts, techniques and tools for managing future change in science, technology and economy

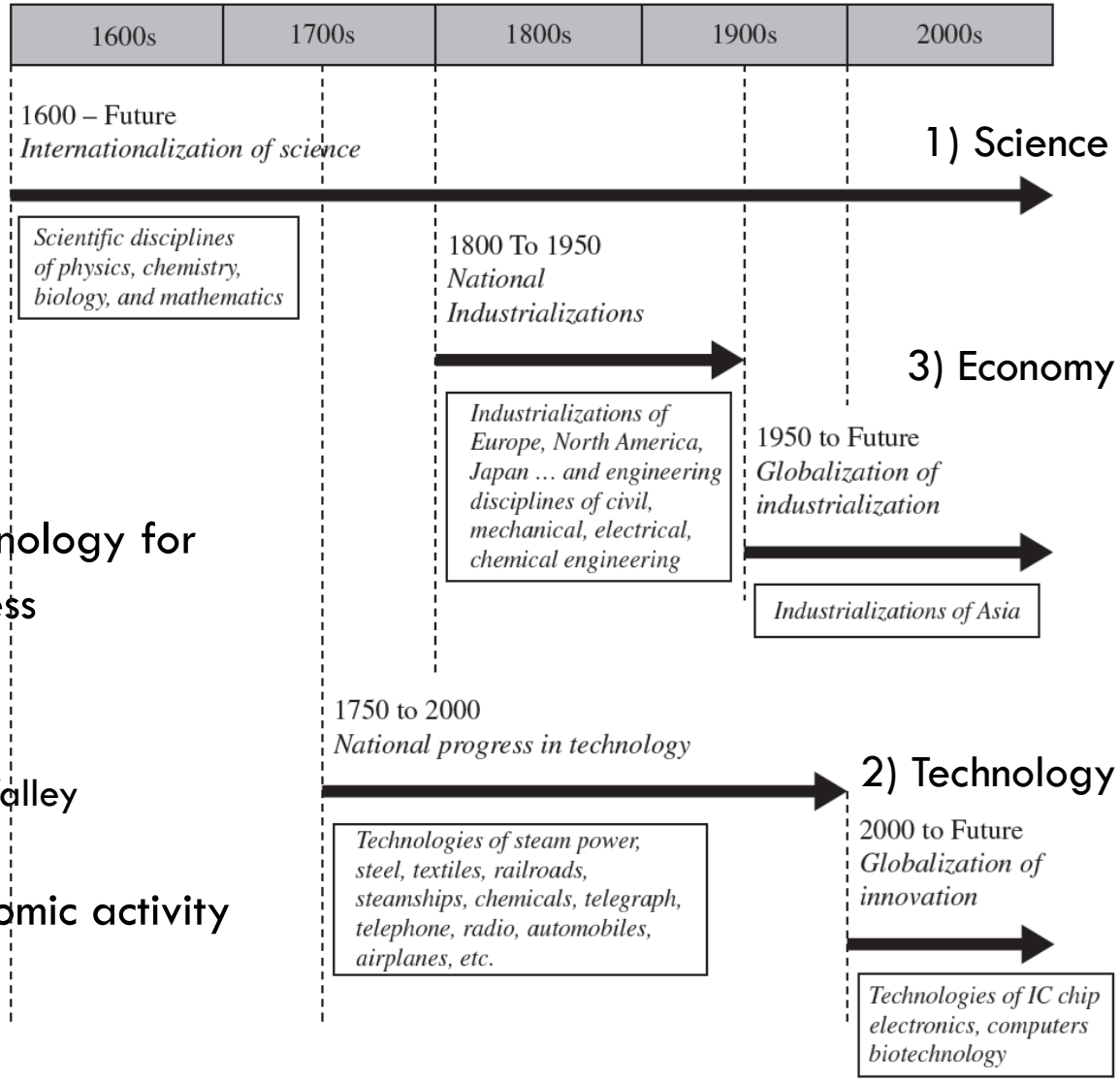
# Questions to be answered

- How is innovation organized as a process?
- What is technology?
- What kind of technologies are there?
- Why is progress in any technology eventually finite?
- How does technological progress impact a nation?
- How can innovation strategy be formulated for a nation?
- How does technological progress impact a business?
- How can a manager identify technologies relevant to the future of a business?
- How should high-tech research and development projects be managed?
- How should innovation strategy be formulated in a business?
- How does the innovation differ in hardware, software and sciences?
- What is the ethical context of technology?

# Timeline of events



- Gunpowder + printing press
- Invented in China
- Innovated in Europe
- Newton: physics+math
- Industrialization trends
  - (1765 – 1865) — Europe
  - (1865 – 1965) — North America
  - (1965 – 2065) — Asia
- Appreciation of science and technology for international economic competitiveness
- Strategic collaboration between academia and high-tech companies
  - Stanford and UCBerkeley: Silicon Valley
  - Singapore, Taiwan, South Korea…
- Global trade = 26% of all economic activity



# Always keep in mind: Key factors in globally effective industrialization

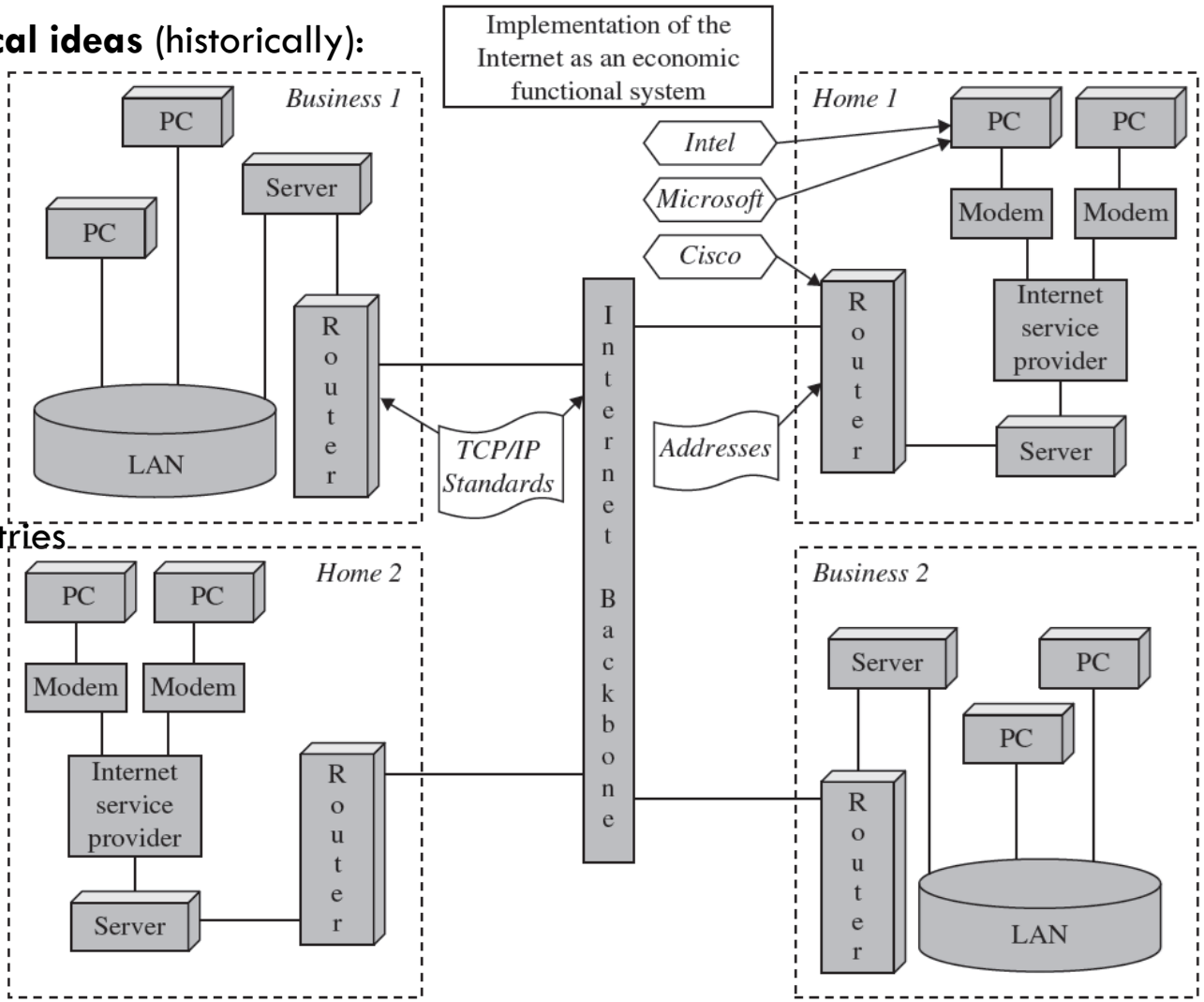


- political forms
- national and industrial infrastructures
  - police and judicial systems
  - public health and medical systems
  - energy systems
  - transportation systems
  - communication systems
- domestic markets
- firm strategies

# Case Study: (Macro-)Innovation of the Internet (~1960s-today)



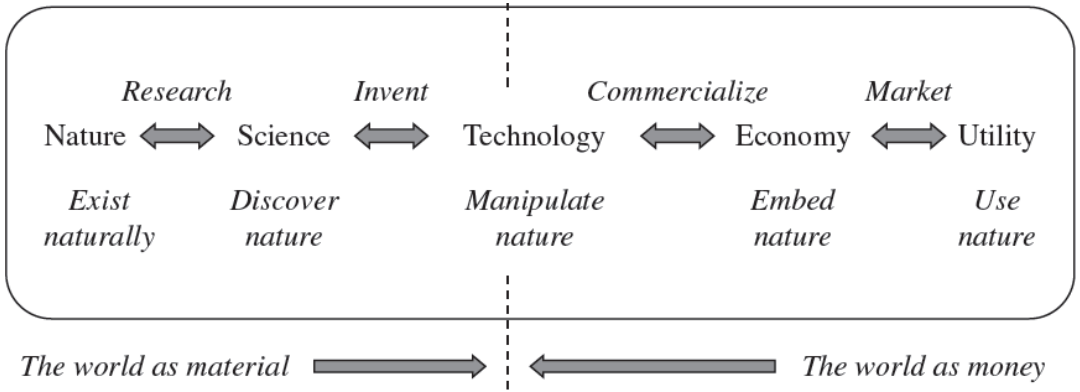
- Two important components for an innovation
- Required invention of **technical ideas** (historically):
  - PC-PC comm.
  - Packet-switching
  - Standards, protocols
  - Routing
  - HTML
  - WWW
  - Browser
  - Search Engine
  - Web page publication
- Growth of **commercial** industries
  - PC's
  - Microproc.
  - OS
  - Modems
  - ISPs
  - Server+router
  - LAN, WAN
  - Backbones
  - Search services, etc.



# Innovation Process - Overview



- **Nature**: Totality of the essential qualities of the observable phenomena of the universe. (Material, social, biological, etc.)
- **Science**: Discovery and explanation of nature
  - Knowledge about nature – what it is (discovery) and how it operates (expl.) - is gained by ***research***
- **Technology**: Knowledge of the manipulation of nature for human purpose
  - Scientific knowledge is used to create new technologies through the act of ***invention***
- **Economy**: Social process of the human use of nature as utility
  - Technical knowledge is embedded within a product through design. ***Commercialization*** is the act of embodying technology into the products/services/processes.



# Characteristics of Innovations



- Innovations are new products, processes or services aimed to be **commercialized**.
- Innovations can be **offered in the market** (products or services) or applied **within a firm** (mainly as processes).
- Innovations result in a **considerable benefit** or **increase of efficiency** (leap in progress); this distinguishes them from improvements.
- Innovations generate substantial **benefits for the users**.
- Within innovations we differentiate between **incremental** and **radical** innovations. Radical innovations are breakthroughs with a major impact on production and application patterns. (i.e. drive by wire, biodegradable packages)
- Innovations include **high risks**.
- Innovations need **long time** to ripe and enter the market.
- The emergence of innovations is in most cases a **complex process**.

# Case Study: (Micro-)Innovation of Google Inc.



- The company used the **macro-level technology** of the Internet to begin a new business in the **micro-level technology** of a search engine.
- Founded in 1998 by Sergey Brin and Larry Page (PhD students in Stanford Uni.)
- Idea: The importance of the page is measured by the number of links pointing to it.
- Licensing at the university
- Spin-off company
- Funded by Sun Microsystems ($100,000)
- How to earn money?
- By 2005, advertising revenues: $6 bln. (98.8% of all)
- It started by licensing its «software», but later became an advertising company.
- Compared to Yahoo! (first search engine), accuracy, speed, ease of use, and objectivity was superior.
- It also charged the advertisers not on view but only on click-throughs.
- Business model: Provide values: (1) search value to its users (market base), (2) sales value to its advertisers (Google's customers)
- Always in search of new services -> Improved brand name

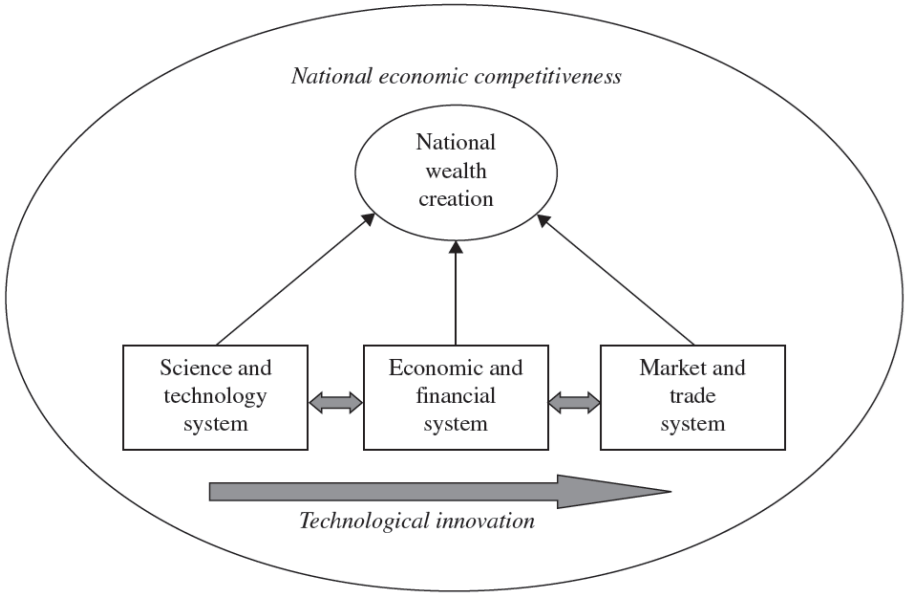
# Technology and Wealth



- Technological innovation is commercialized in economic systems to add value to markets and to international trade.
- Technological innovation provides a competitive advantage for exports and for the businesses in a nation, thus contributing to wealth creation.
- To create wealth, two stages are necessary in innovation:

(1) inventing new technology and

(2) commercializing new technology in high - tech products or services.



# Innovations within Systems or System Products



Three types of innovations:

- *Radical innovation* — a basic technological innovation that establishes a new functionality (e.g., Internet, steam engine, or steamboat)
- *Incremental innovation* — a change in an existing technology system that does not alter functionality but incrementally improves performance or lowers cost (e.g., regulator on a steam engine)
- *Next-generation technology innovation* — a change in an existing technology system that does not alter functionality but dramatically improves performance, features, safety, or quality, or lowers cost — to open new applications (e.g., substitution of jet propulsion for propellers on airplanes, transistors for electron vacuum tube)
- Discuss the innovation on computers throughly 1950-201X.

# Economic Scale of Innovations

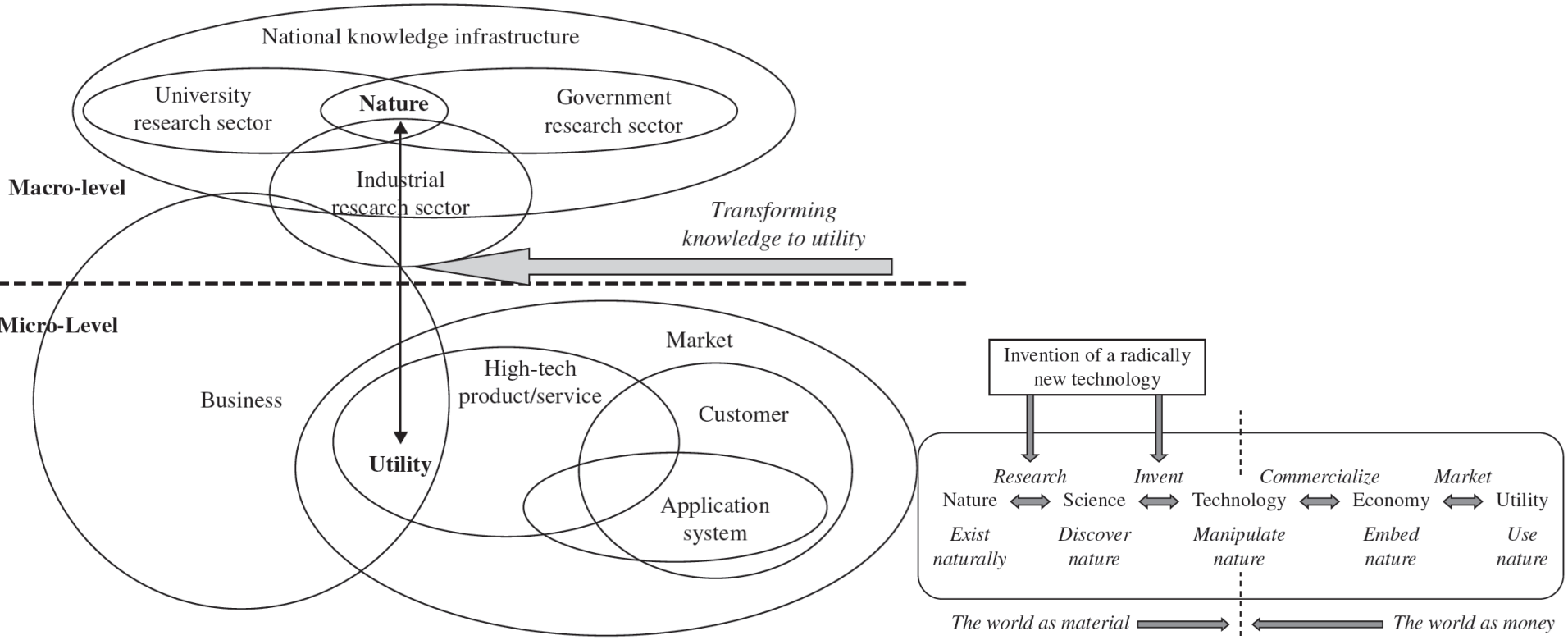


- Radical innovations occur as (1) basic new technologies or (2) next – generation technology innovations.
- Incremental innovations occur as small but significant improvements in an existing technology.
- Discontinuous technological innovation provides the competitive conditions for displacing older businesses — by beginning new businesses and growing a new industry.
- Continuous (incremental) technological innovation enables an existing firm to defend against competitors and to grow its markets.

# Transforming knowledge to utility



- The process of radical innovation consists of many interactions between (1) national research sectors of university and government and industry and between (2) high - tech firms and markets of customers.



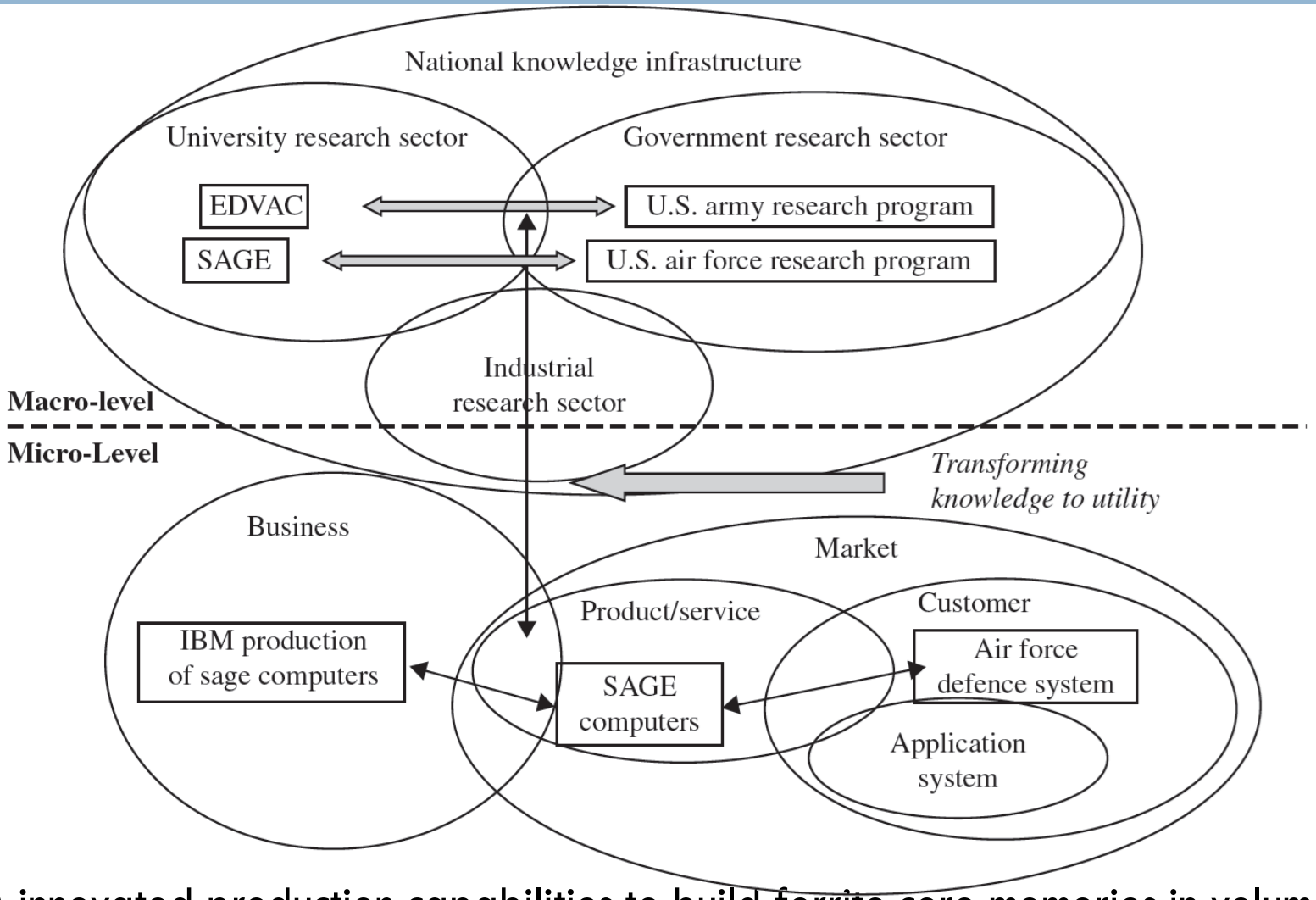
# 3 highlights from the national innovation system



- The technological sophistication of a high-tech business is bounded by the *research capability* of the industrial, university, and governmental R & D infrastructure.
- The research and technological capability of a business is known to a customer only through the business's products. In a high-tech business, research and technical capability that do not directly contribute to product performance, quality, or price are not valuable to the business because they are not seen by a customer.
- Since the satisfaction of a customer with a product depends on its performance in an application (and since a business does not directly experience the application), it is the *application* that is the greatest source of uncertainty about commercial success in the design of a product.

# Case Study: Radical Innovation of Computer





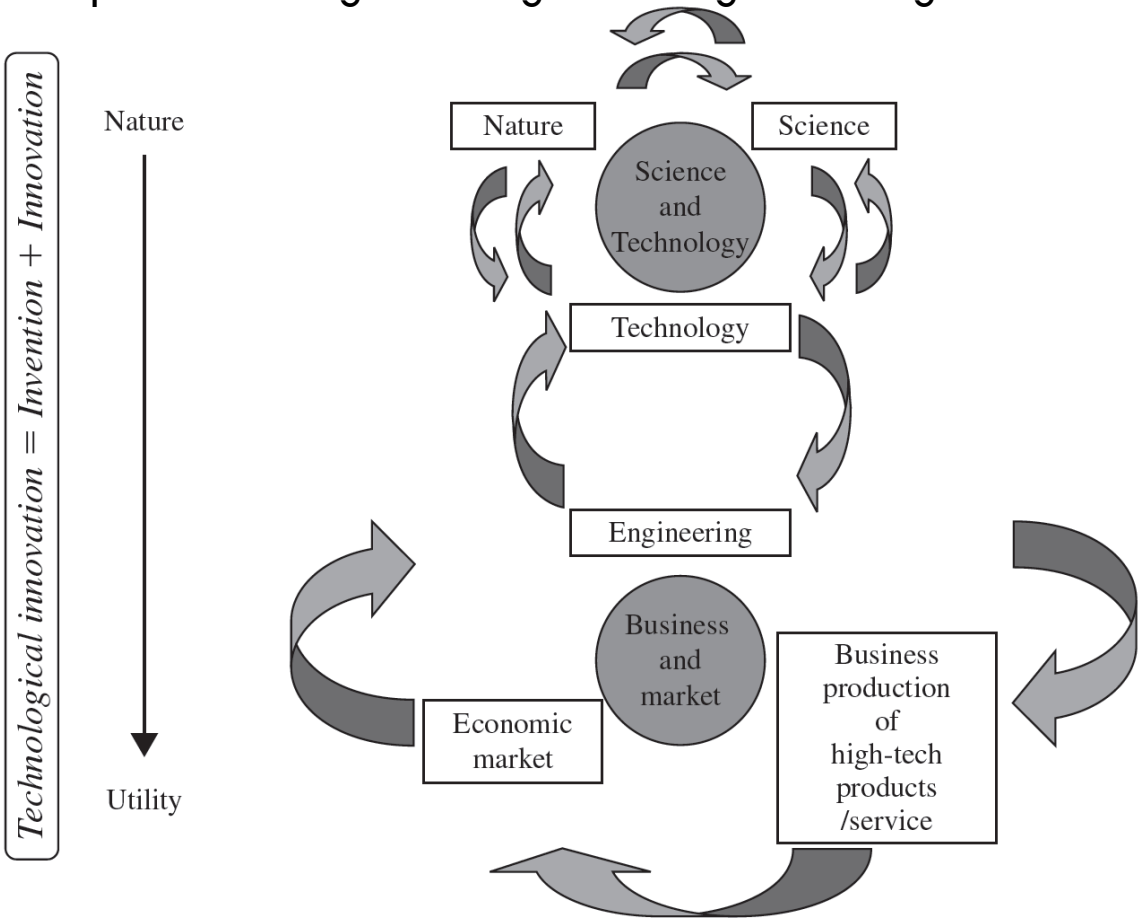

- IBM innovated production capabilities to build ferrite core memories in volume

# Circular Interactions in an Innovation System



The flow of knowledge in the process of radical technological innovation is *linear*, in that knowledge does ultimately flow from nature into utility.

Yet the infrastructure processes of generating and using knowledge are interactive and *circular*



# Performance of National Innovation Systems



- A national innovation system should have **strong research capabilities** in its **industrial sectors.**
- A national innovation system should have a **high - quality research – oriented university** sector.
- A national innovation system should have **at least one strong internationally competitive industrial or service sector.**
- A national innovation system should have a **culture of valuing high quality of performance.**
- A national innovation system should be **supported by government** policies that strongly fund appropriate R & D activities in universities and selected mission areas.
- A way to identify **cutting-edge science** (which can help surpass current technology) should be a national science and technology policy priority.
- Science and technology policy must support research for technology improvement in current industries, and research **to establish new internationally competitive industries** in new technologies.

# Case Study: Innovation of Xerography



- Good example for the importance of commercialization and management challenges
- The inventor of xerography was a technical person, Chester F. Carlson, and the commercialization of xerography was accomplished by a businessperson, Joseph Wilson.
- Carlson had backgrounds in physics and chemistry of carbon and understood the market need for copying.
- Like all new inventions, it was not commercially efficient, cost-effective, or easily usable.
- The development of a new technology usually costs a great deal of money, takes time, and requires skilled resources.
- From 1939 to 1944, he was turned down by twenty major companies.
- Wilson was looking for new technology for his company for new products. At the time, Wilson' s main customer was Kodak, which could at any time eliminate his small business if it chose.
- Finally, all the innovative pieces for Carlson had fallen in place

— inventions, patents, R & D, commercialization. Wilson subsequently changed the name of his company to Xerox

- Take-home message: For technological innovation, two roles are always required: (1) an inventor (invention) and (2) an entrepreneur (commercialization).

# Innovation Management



- What made Carlson an outstanding inventor was that he had **two kinds of skills**
  - an understanding of a technical need
  - scientific background to invent a process to accomplish the technical goal
- What made Wilson an outstanding business leader was that he had two kinds of skills
  - Technical savviness
  - Business savviness
- A technically savvy manager needs to know how to manage the business process of innovation — planning and financing and assembling a good technical team for innovation strategy.

- Innovation management means management of innovation processes.
  - setting up the internal environment and conditions for innovation processes
  - designing a frame and a standard innovation process
  - carrying out the individual innovation projects

# Innovation Management



Two phases:

1. Idea management → To find the right product (project) (effectivity)
2. Project management → To develop the product efficiently (to achieve the goals, targeted costs and schedule)

Thus, to understand the whole of innovation, one needs to understand: (1) how engineers and scientists think and (2) how marketing, production, and financial managers think.

# Effectivity and Efficiency



- To be successful with innovations effectivity and efficiency have to be ensured.

Effectivity: To do the right things.

Efficiency: To do the right things in a good effort/result relation

- Efficiently organized innovation processes only pay out, when the strategically right topics and projects have been chosen (effectivity).

# Departments at a business for commercialization of a radical innovation



Within a business at this micro-level, there are several business functions for operating the business and innovating new products/services:

- Hard-good businesses require a ***production function*** for producing a hardware product; this is usually organized as a factory, or production unit.
- Businesses require a ***marketing function*** of selling their products/services; and this is usually organized as a marketing department.
- Businesses require a ***finance function*** of controlling the finances of the business operation; and this is usually organized as a finance department.
- Businesses require an ***administration function*** for managing the personnel and operations in a business; and this is usually organized as an administration department.
- Businesses now require an ***information function*** to acquire and manage information and communication technologies for business operations, and this is usually organized as an information technology (IT) department.
- Businesses require an ***engineering function*** for the capability to design new products and services; and this is usually organized as an engineering department.
- High-tech businesses also require a ***research function*** for the capability of inventing and developing new technology, and this is usually organized as a corporate research laboratory.

# Case Study: How DuPont invented Nylon



- **DuPont was a small explosives manufacturer and had in this century become a diversified chemical company.**
- Charles Stine listed four reasons why DuPont should spend its money on this new kind of industrial chemical research
  - The scientific prestige and public relations value to be gained through the presentation and publishing of papers.
  - Interesting scientific research would improve morale in the department and make the recruiting of Ph.D. chemists easier.
  - The results of DuPont's pure science work could be used to trade for information about research in other institutions.
  - Pure science might give rise to practical applications.
- Beginning in April 1927, fundamental research in DuPont's new research center was to receive $25,000 a month. (Microsoft R&D budget in 2009: $10 bln)
- Stine received $115,000 to build a new laboratory for fundamental research.
- With the new building under construction, Stine began to look for twenty-five scientists.
- A central management responsibility of laboratory director is the establishment of proper procedures by which scientists are selected as research project leaders.
- Nylon= artificial silk: chaining smaller molecules into longer chains of molecules synthetically
- Finally, nylons went on sale nationally in May 1940, and the demand was overwhelming.
- Convinced that nylon would prove superior to silk, DuPont initially set its price 10% higher than that of silk