THE COUNCIL FOR CHEMICAL RESEARCH

CCR Phase II Study

"Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine"

Donald B. Anthony, Sc.D.
President & Executive Director

Council for Chemical Research

The Council for Chemical Research (CCR) was created in 1979 to improve trust and collaboration between the public and private research sectors.

"CCR's purpose is to benefit society by advancing research in chemistry, chemical engineering, and related disciplines through leadership collaboration across discipline, institution, and sector boundaries."

CCR Membership & Goals

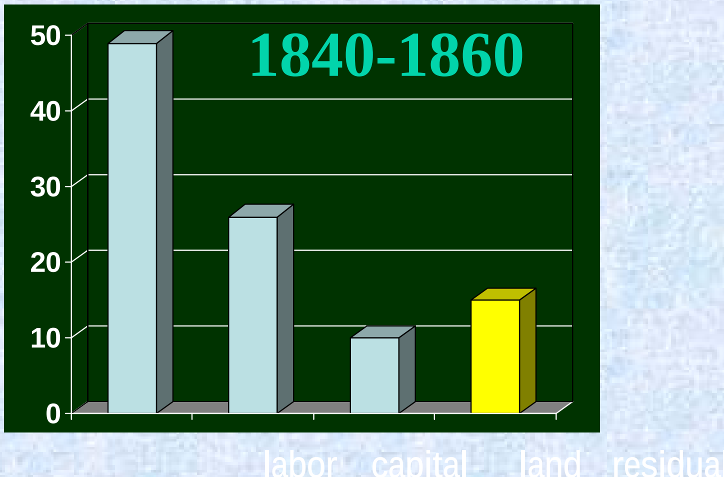
- **Represents research leadership in 3 sectors**
  - **Industrial (27 corporations)**
  - **Academic (134 research universities)**
  - **Governmental (10 national labs and 1 international affiliate)**
- **Goals**
  - **Advance research collaboration**
  - **Advocate research investment**
  - **Enrich graduate education**
  - **Address long-range issues**

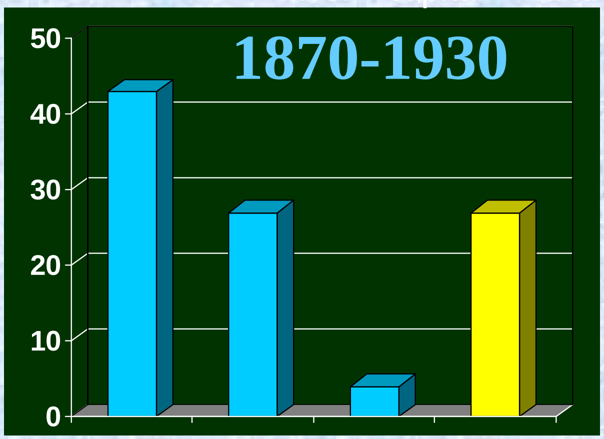
1987 Nobel Prize

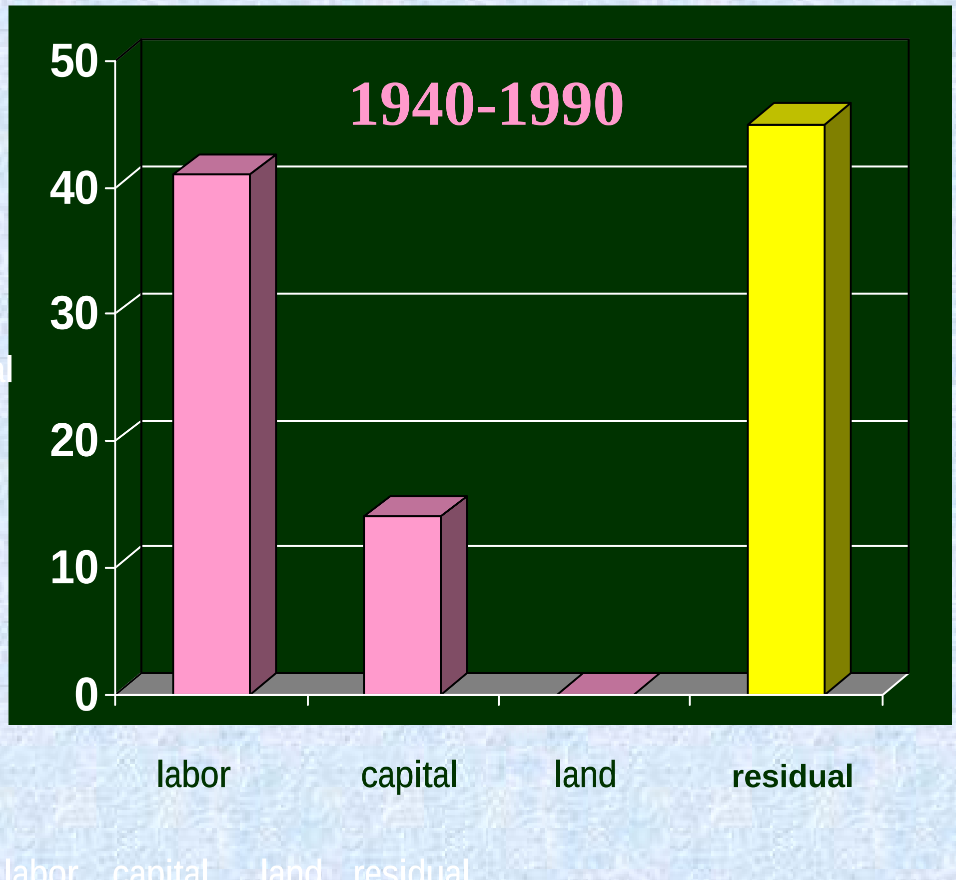
Robert M. Solow, a professor at the Massachusetts Institute of Technology, was awarded the 1987 Nobel Prize for Economics for identifying technological change as the chief factor underlying economic growth.

His 1957 article, *"Technical Change and the Aggregate Production Function,"* showed that half of economic growth cannot be accounted for by increases in capital and labor. He then demonstrated that technological change—ignored by mainstream theory—is responsible for that unaccounted-for portion of economic growth—now called the "Solow residual."

Measuring the "Solow" Residual







CCR Study

In the Fall 1999, the CCR commenced a special study with the objective:

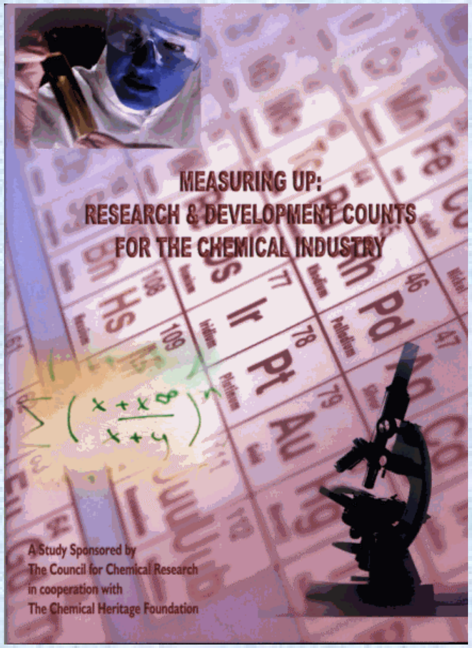
Measure the impact (return or payoff) of chemical research and development

- Provide comprehensive and quantitative results
- Use leading edge methodologies
  - Econometric production function (Dr. Baruch Lev, NYU)
  - Bibliometric analysis (Dr. Francis Narin, CHI Research, now ipIQ)

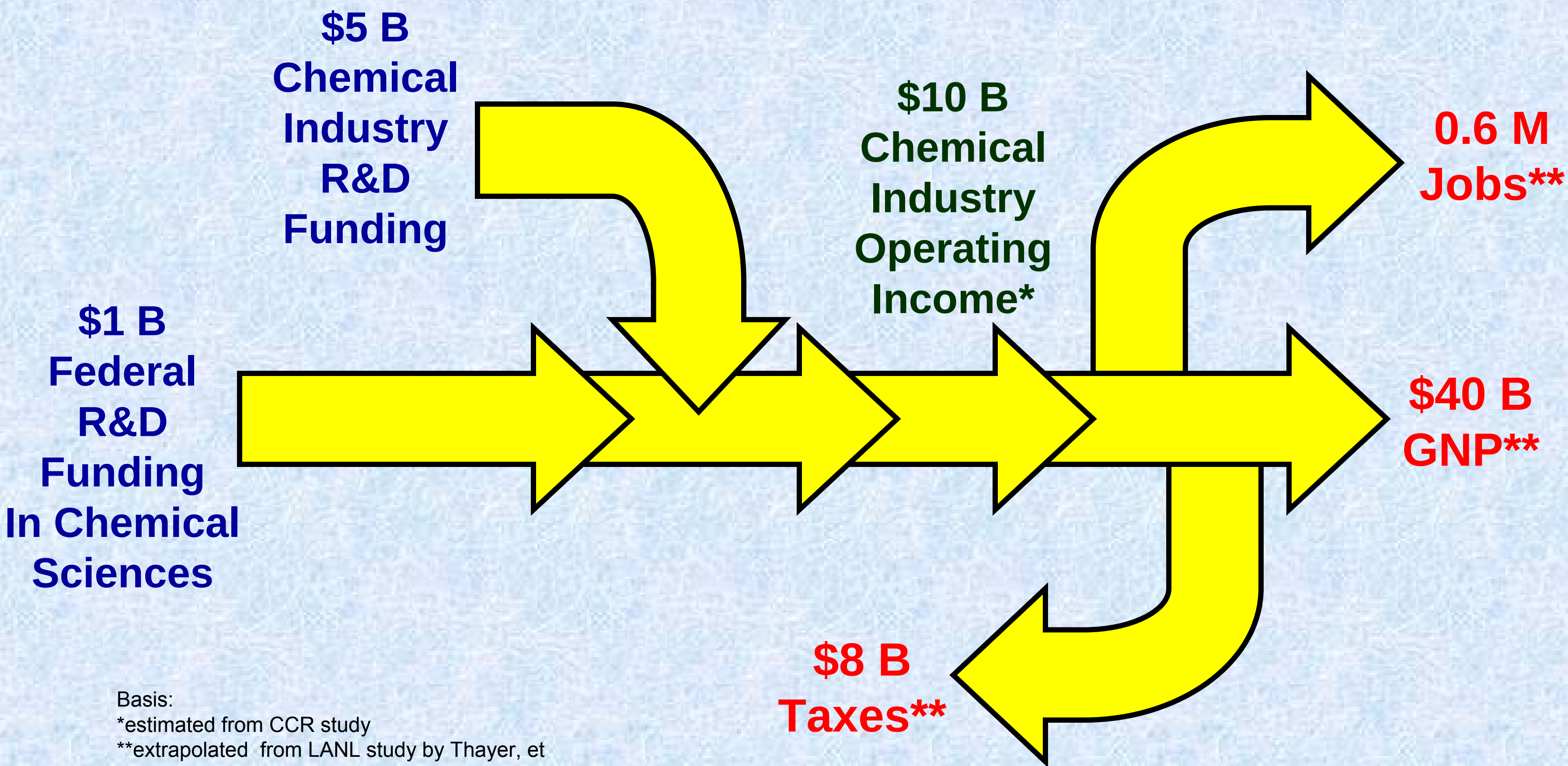
Phase I Results

- $2 Operating income per $1 R&D invested
  - 17% after tax return
- Publicly funded science links highly to chemical patents, 6 citations per patent
- Published Summer, 2001:

“Measuring Up: R&D Counts for the Chemical Industry”



Macroeconomic Implications



Basis:
*estimated from CCR study
**extrapolated from LANL study by Thayer, et al., April 2005 using REMI economic model

Phase II Results

- **Published February 2006**

"Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine"

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
- What industries are significantly impacted by the chemical sciences?
- How long does it take for public funded science to yield commercial innovation?

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Approach to Question 1

Determine any correlations between chemical companies' patent holdings and their financial performance

Financial measures included:

- Sales
- Market to book value
- Stock price

Bibliometric methodology (Patrick Thomas and Michael Albert, ipIQ)

Patent Portfolio Indicators

Current Impact Index (CII)

– a measure of the impact of a company's patents, based on how frequently its patents are cited by subsequent patents

Science Linkage (SL)

– average number of citations a company's patents make to scientific papers, a measure of its links to scientific research

Innovation Speed (IS)

– measures median age of the patents cited by a company's patents, an indicator of its speed of innovation

Introduction to Patents and Patent Citation Analysis

Backward Citations (References)

Forward Citations

14 U.S. Patents

2 Foreign Patents

32 Science References

IS

SL

Dow Patent No. 5, 272,236 Issued 1993

CII

Ext CII

510 U.S. Patents

A Starting Patent references prior art, and is cited by later patents

Time

1970-93 **1993** **1994-2006**

Highly Cited Chemical Patents

- U.S. Patents 5,064,802, 5,272,236, and 5,278,272
- Awarded to Dow in 1991, '93 and '94
- "Metal complex compounds", and "Elastic substantially linear olefin polymers"
- With Exxon's discoveries, launched a rebirth of the polymers industry

- U.S. Patent 5,055,438
- Awarded to Exxon in 1991
- "Olefin polymerization catalysts"
- With Dow's discoveries, launched a rebirth of the polymers industry

Chemical & Engineering News,
September 11, 1995

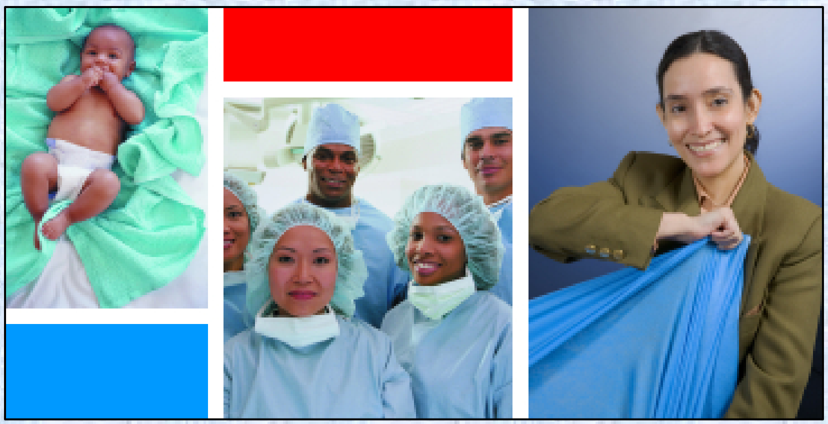
Metallocene Catalysts Initiate New Era In Polymer Synthesis

Well-defined catalysts now allow producers to design polymers with exact properties and to create as yet unknown materials

Examples of “Metallocene” Polymers

Improved "non woven" fabrics reduce healthcare and childcare costs with more comfortable and less expensive disposable garments

Agricultural and greenhouse films with longer service life, increased crop yields, and thinner films lower food costs and solid waste volumes



Highly Cited Chemical Patents

- U.S. Patents 3,953,566 and 4,482516
- Awarded to W. L. Gore in 1976 and 1984
- “Process for producing porous products” and “Process for producing a high strength porous polytetrafluoroethylene product having a coarse microstructure”
- Gore-Tex® grafts and implants, clothing, and cable shielding

Highly Cited Chemical Patents

- U.S. Patent 4,576,850
- Awarded to 3M in 1986
- “Shaped plastic articles having replicated microstructure surfaces”
- Technology underlying all reflective traffic signs as well as impacting contact lenses, video discs, indirect lighting, biosensors, etc.

Highly Cited Chemical Patents

- U.S. Patent 5,085,698
- Awarded to DuPont in 1992
- "Aqueous pigmented inks for inkjet printers"
- Over 254 follow-on citations covering every aspect of inkjet printing

Conclusion:
Strong Technology Pays Off

Chemical companies with strong patent portfolio indicators tend to exhibit consistently strong financial performance, such as higher stock market valuations (35-60% higher on average)

- **Correlation between CII (patent impact) and financial performance is particularly strong**
- **Correlations between financial performance and SL (science linkage) and IS (innovation speed) are also positive**

Phase II

- What are the financial payoffs for technology quality, innovation speed and strong scientific links?
- What industries are significantly impacted by the chemical sciences?
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Approach to Question 2

Examine patent database to determine which industries

- Patent chemical technology vs. other technologies
- Reference chemical technology patents vs. other technology patents
- Reference chemical science literature vs. other sciences

Bibliometric methodology (Michael Albert, Diana Hicks and Peter Kroll, ipIQ)

The 15 Industries (1151 companies)

- Automotive* (90)
- Biotechnology* (41)
- Chemicals* (143)
- Computers & Semiconductors* (164)
- Electrical & Electronics* (116)
- Energy (34)
- Engineering, Oil Field Services (5)
- Food, Beverage & Tobacco* (28)
- Forest, Paper, Textiles* (37)
- Health Care (78)
- Instruments & Optical (49)
- Materials (24)
- Metals & Mechanical (238)
- Pharmaceuticals* (58)
- Telecommunications* (46)

* - denotes names that are very similar to the names of a technology

The 29 Technologies

- Aerospace & Parts
- Agriculture
- Biotechnology*
- Chemicals, Plastics, Polymers & Rubber*
- Computers & Peripherals*
- Electrical Appliances & Components
- Fabricated Metals
- Food & Tobacco*
- Glass, Clay & Cement
- Heating, Ventilation & Refrigeration
- Industrial Machinery & Tools
- Industrial Process Equipment
- Measurement & Control Equipment
- Medical Electronics
- Medical Equipment
- Miscellaneous Machinery
- Motor Vehicles & Parts*
- Office Equipment & Cameras
- Oil & Gas, Mining
- Other
- Other Transport
- Pharmaceuticals*
- Power Generation & Distribution
- Primary Metals
- Semiconductors & Electronics*
- Telecommunications*
- Textiles & Apparel*
- Wood & Paper*

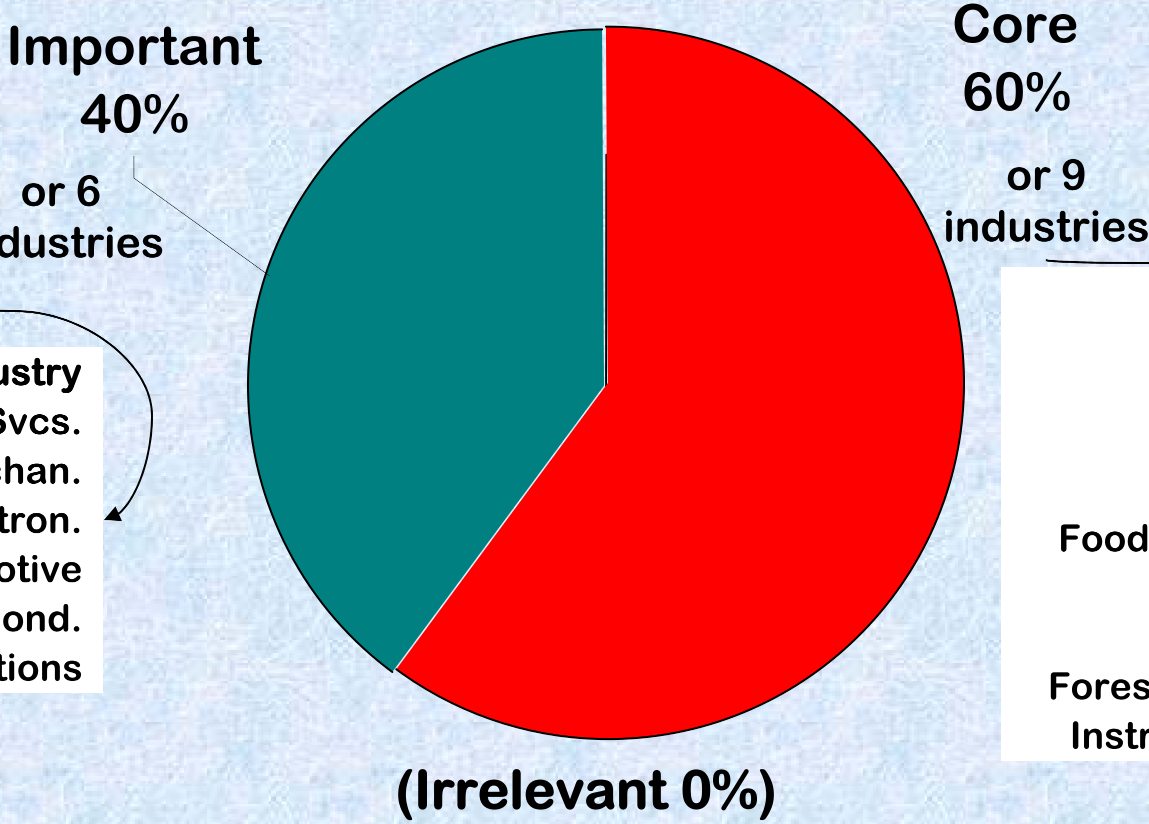
* – denotes names that are very similar to the names of an industry

How many industries build on chemical technology?

- **Definitions:**
  - ■ **Core technology: Technology accounts for at least 10% of patents or citations for an industry**
  - ■ **Important technology:Technology accounts for between 1% and 10% of patents or citations for an industry**
  - □ **Irrelevant technology: Technology accounts for less than 1% of patents or citations for an industry**

Chemical technology creation is core or important in all 15 of the industries

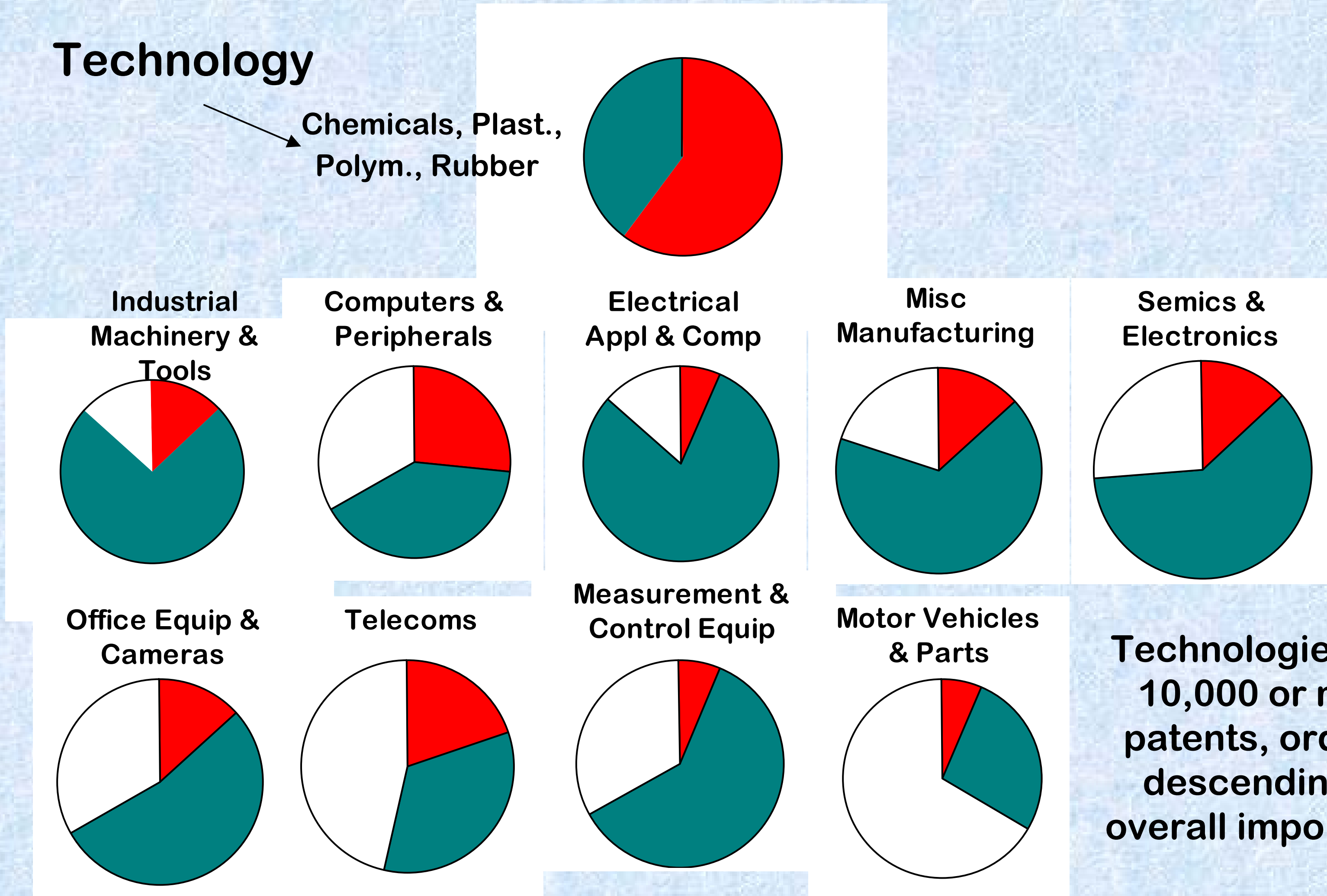
Chemicals, Plast., Polym., Rubber



Industry
Engrng., Oil Field Svcs.
Metals & Mechan.
Electrical & Electron.
Automotive
Computers & Semicond.
Telecommunications

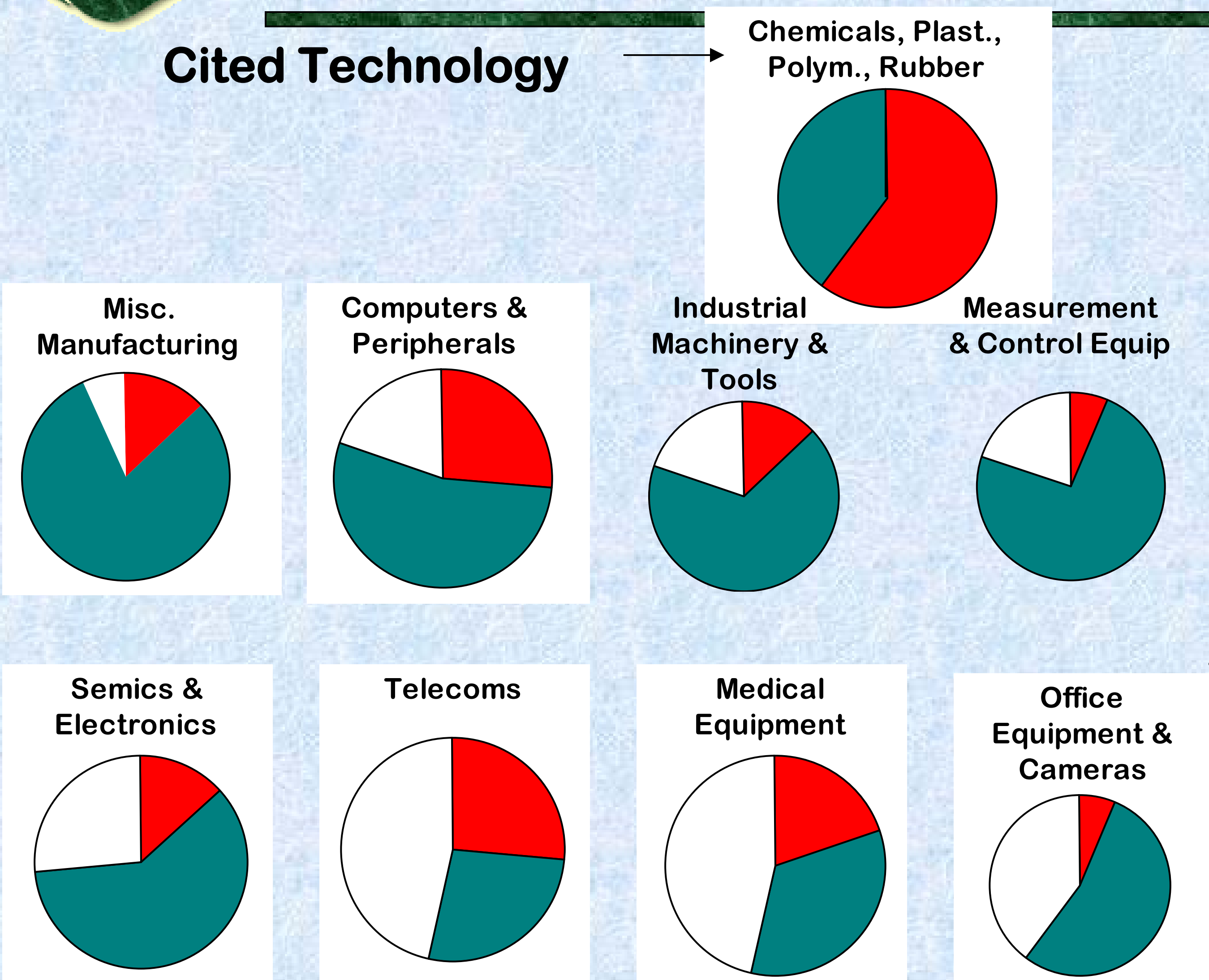
Industry
Chemicals
Energy
Pharmaceuticals
Biotechnology
Food, Bev. & Tobacco
Health Care
Materials
Forest, Paper, Textiles
Instrument. & Optical

No other technology comes close



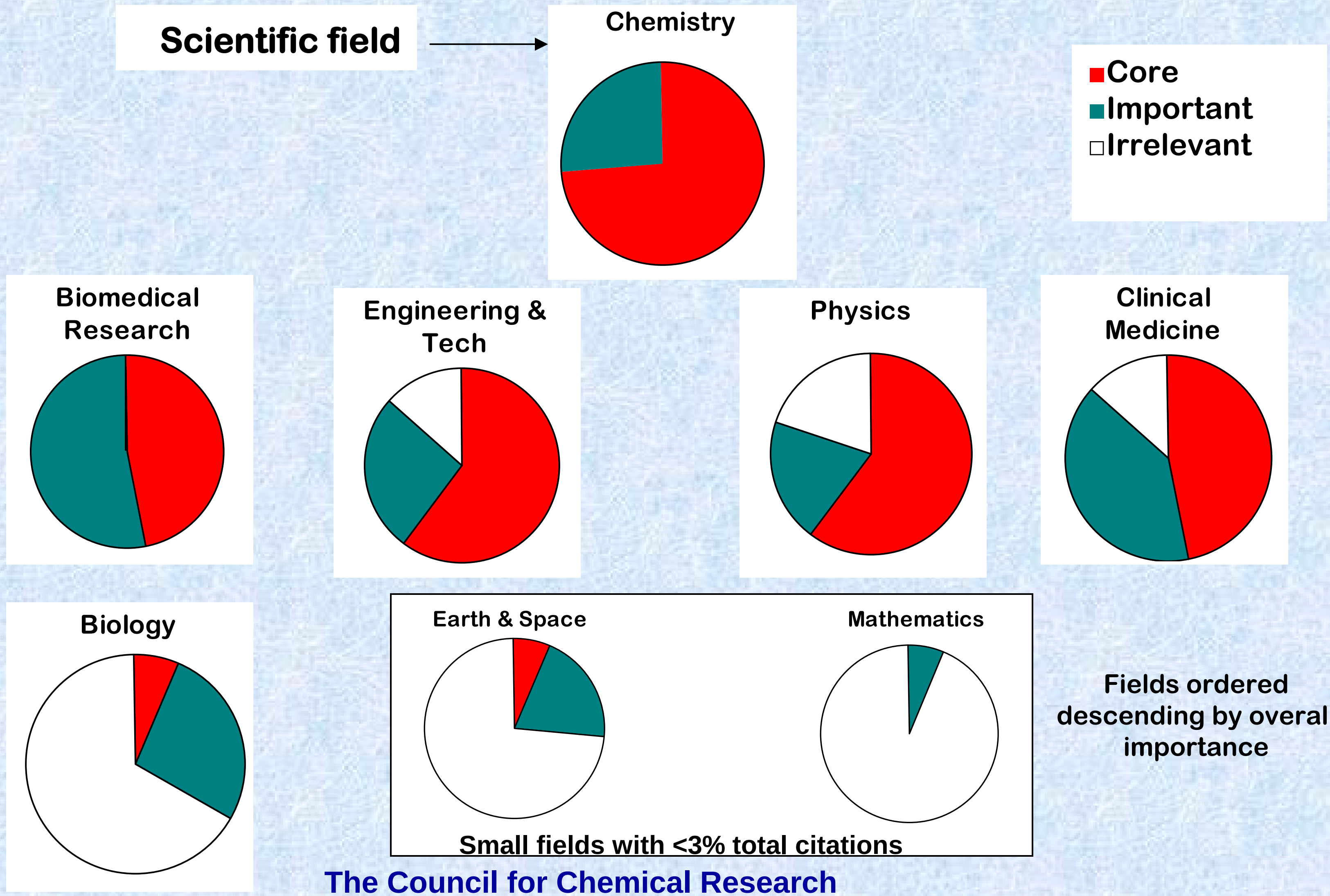
Technologies with 10,000 or more patents, ordered descending by overall importance

Again, no other technology comes close



Technologies whose patents earned at least 60,000 citations, descending by overall importance

Science Base Across Industries: Chemistry Ranks First

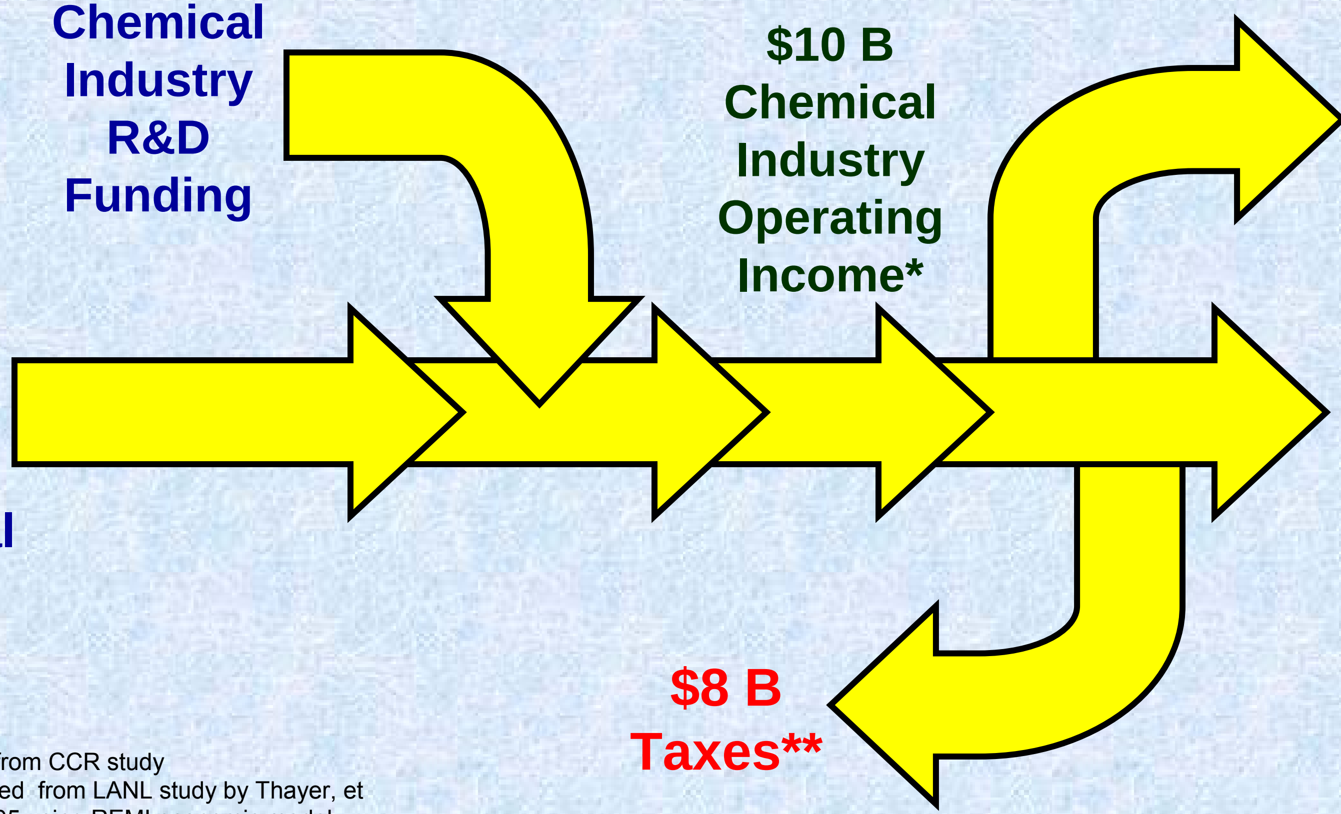


Conclusion: Chemistry is the most enabling science / technology

More than any other technology:

- **All industries create chemical technology.**
  Evidence: patent counts
- **The underpinning of all industries' technology relies on chemical technology.**
  Evidence: industry-to-technology patent citations
- **Chemistry is an important part of the science base of all industries.**
  Evidence: patent-to-paper citations

Macroeconomic Implications



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Approach to Question 3

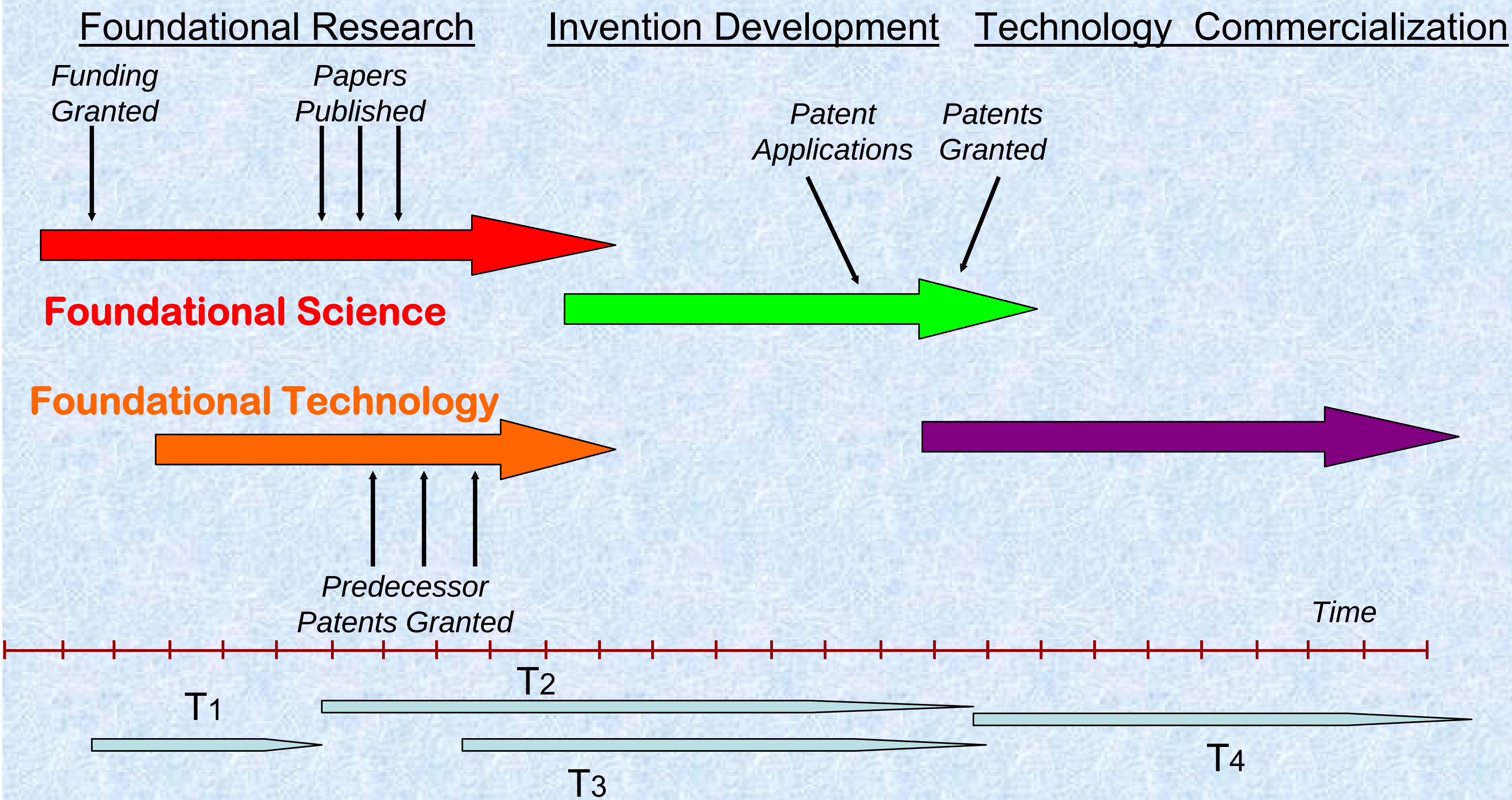
Trace the average time spans from successful commercial innovations back to originating patents and scientific literature citations. Determine start of funding from literature acknowledgements.

Time intervals to determine:

- T_1 = time from grant funding to paper publication
- T_2 = time from paper publication to citing patent grant date (Science-to-Technology Cycle Time)
- T_3 = time from predecessor patent issuance to patent grant date (Technology Cycle Time)
- T_4 = time from patent issuance to product commercialization

Bibliometric methodology (Peter Kroll, ipIQ)

Timeline from Conception to Market



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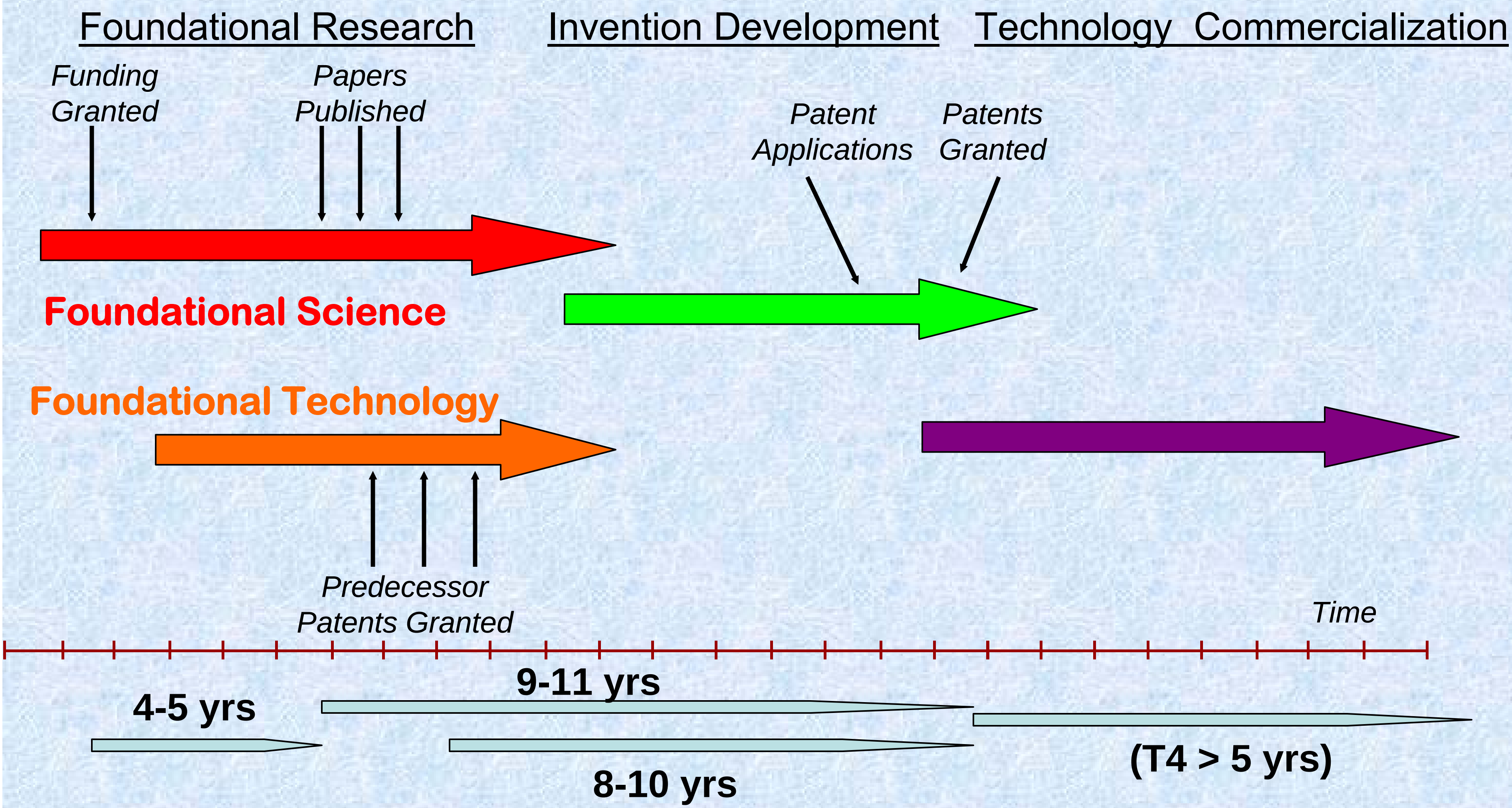
Timeline from Conception to Market



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Conclusion: Big Opportunity to Reduce Innovation Cycle Time

- Industry focused on later stages of innovation, in particular, applied research and patenting to commercialization
- Limited collaboration at basic research stage
- Significant upside financial value if 20 year innovation cycle is shortened

Overall Conclusions

- Chemical companies get $2 of operating income for every $1 of R&D invested; that's a 17% after tax return.
- Technology quality, innovation speed and strong scientific links deliver greater shareholder value.
- Chemical technology is highly dependent on publicly funded chemical science research
- All industries are significantly impacted by the chemical sciences. It is the most enabling science and technology.
- The big opportunity is to reduce the 20-year innovation time lag from initial public research funding to commercialization.

Acknowledgements

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