

MEETING CHEMISTRY'S CHALLENGES : TEACHING AND RESEARCH AT THE MOLECULAR FRONTIERS



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What is Chemistry?



It is about making forms of matter that never existed before eg. plastics, detergents, drugs, Insecticides etc.

**Design &
make**

Analysis

**Why and how
reactions occur**

**Quality control
Environment
Health care
Crime detection**



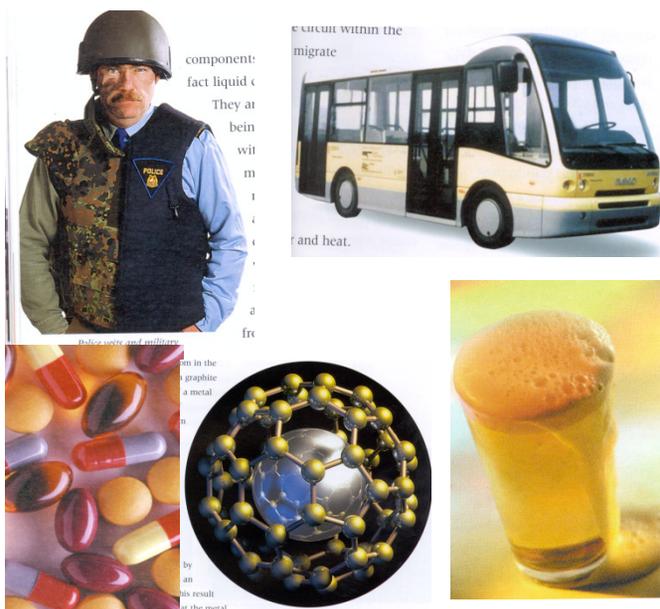
**Chemistry has
extraordinary impact on
society**

Chemistry is the central, useful and creative science - Ronald Breslow



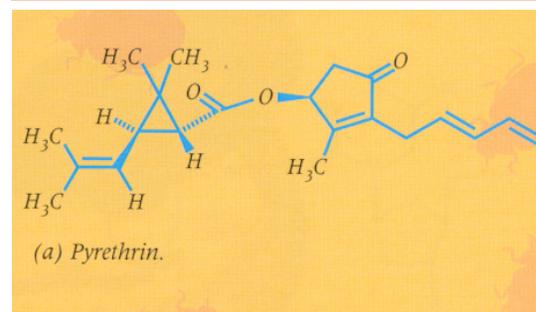
Central

Underpins many other scientific disciplines
Biology, geology, material science



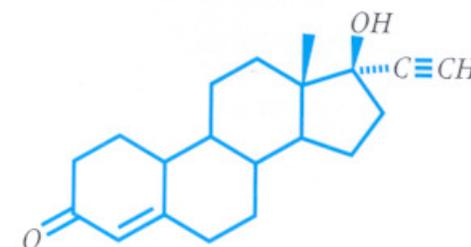
Creative

Designs structures with new and unique properties



Useful

Provides many materials essential to everyday life,
Knowledge to better human, veterinary and plant care, better food, environment



Norethindrone (Norlutin)

Figure 14. Norlutin, the first contraceptive pill.



Chemistry creates its own objects. This creative power, similar to that of arts distinguishes it fundamentally from the other natural and historical sciences

Bertholet, 1860



CHEMISTRY : CENTRAL SCIENCE

- **Central to the sustenance of civilization on earth**
- **Key to management of resources on this planet**
- **Key to understanding the mysteries of life**



CHEMISTRY OF MATERIALS

- Natural materials
- Synthetic materials
- Blends, hybrids and Composites
- Nanomaterials

CHEMISTRY OF LIFE

- Origin of life
- Understanding biological processes
- Understanding diseases/ search for cure
- Deeper insight into consciousness and human aging

CHEMICAL SCIENCES

CHEMISTRY OF ENERGY

- Newer forms of energy and their storage
- Interconversion of energy
- Efficient use of energy

CHEMISTRY OF ENVIRONMENT

- Global climatic changes
- Stratosphere ozone depletion
- Conservation of biosphere
- Quality of air / water
- Adverse consequence of excessive consumption on environment



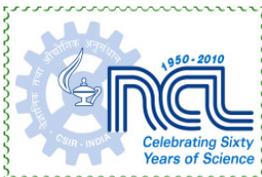
CHEMISTRY OF LIFE

- **Synthesis using soft chemistry**
 - **Molecular recognition**
 - **Self assembly**
 - **Weak bonds**
- **Interaction of small molecules with large biomolecules**
 - **Chemical genetics**
 - **Structure function relationships**
 - **Target driven and diversity oriented molecular synthesis**
- **Chemistry of bio-macromolecules**
 - **Structure and conformation**
 - **Synthesis of natural / unnatural bio-macromolecules**



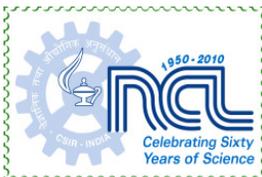
CHEMISTRY OF MATERIALS

- **Natural materials**
- **Synthetic materials**
 - **Organic**
 - **Inorganic**
 - **Hybrids**
- **Blend of natural and synthetic materials**
- **Nanomaterials**
- **Environmentally compatible materials**



CHEMISTRY OF ENERGY

- **Minimize energy in intensity for chemical conversions**
 - **Chemical catalysts**
 - **Biological catalysts**
- **Minimize energy intensity in processing and fabrication**
 - **New materials**
- **Energy harvesting from renewable resources**
 - **Sunlight**
 - **Biomass**
 - **Hydrogen**



CHEMISTRY OF ENVIRONMENT

- **Analytical chemistry / sensors**
- **Kinetics and chemical reaction modeling**
- **Computational chemistry**
- **Efficiency in use of materials**
- **Chemical / Biological fixation of CO₂**
- **“Green” chemistry and technology**
 - **Clean chemistry**
 - **Zero effluent / by product**
 - **Atom economy**
 - **Chemistry in aqueous medium**
 - **High yields / selectivities**
 - **Biological processes for chemical conversion**
 - **Economic use of by products / waste products**
 - **Recycling**

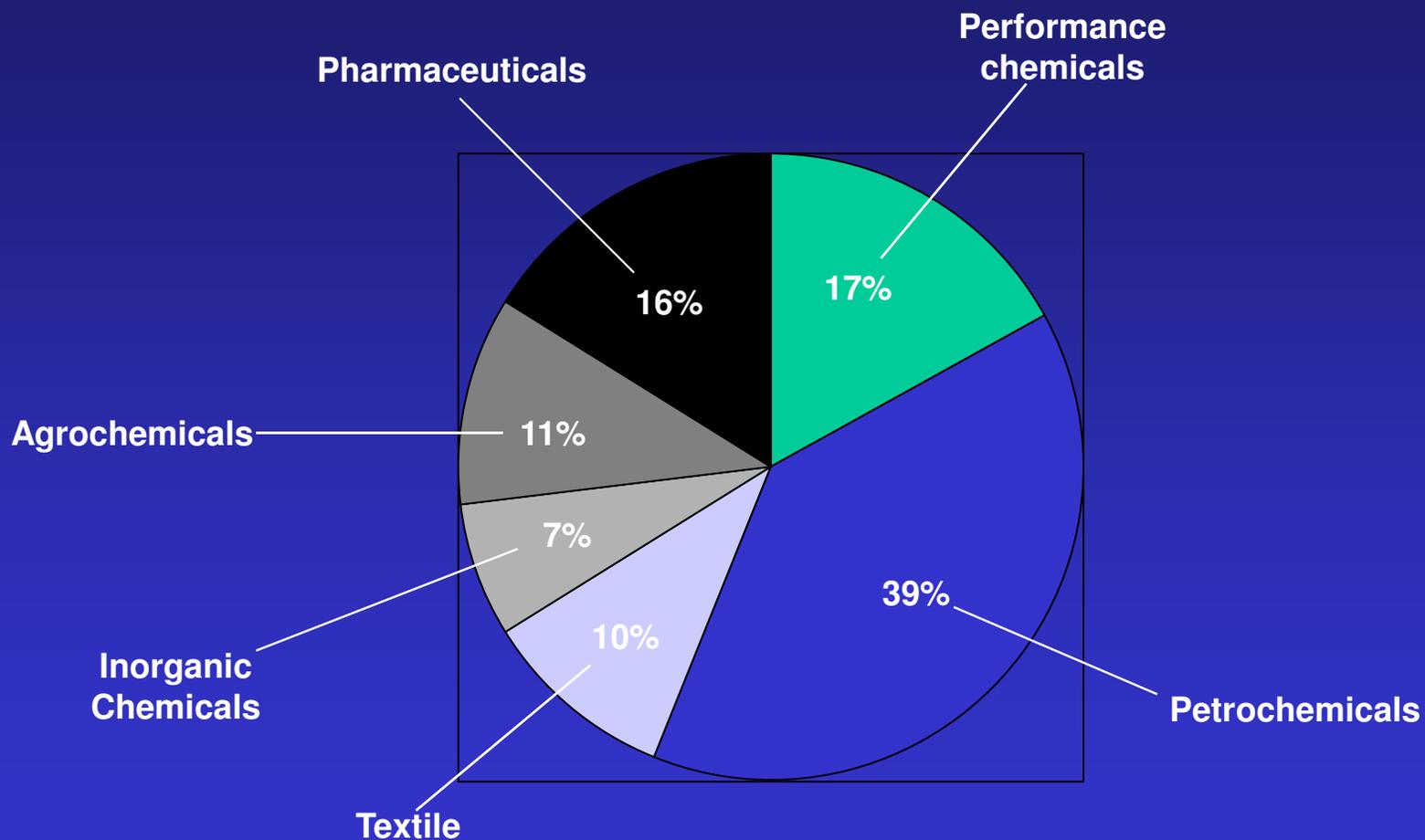


WHY DO WE NEED CHEMISTRY

- **To understand molecules**
- **Engineer functions**
- **Design new drugs**
- **Make materials by design**
- **Create new ways to generate energy**
- **Build a cell / bacteria**
- **Conserve our natural resources**
- **Protect our environment**
- **Understand the origin of life and consciousness**

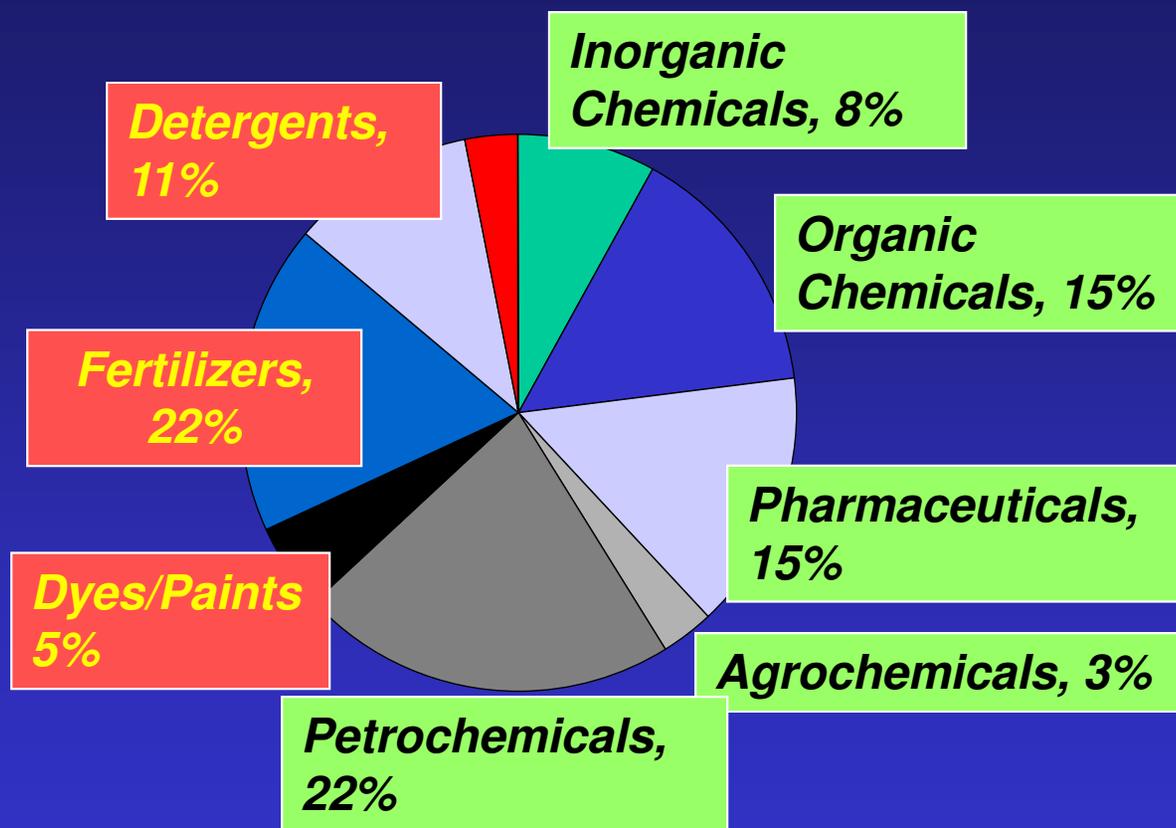
WORLD CHEMICALS MARKET

A THREE TRILLION \$ INDUSTRY



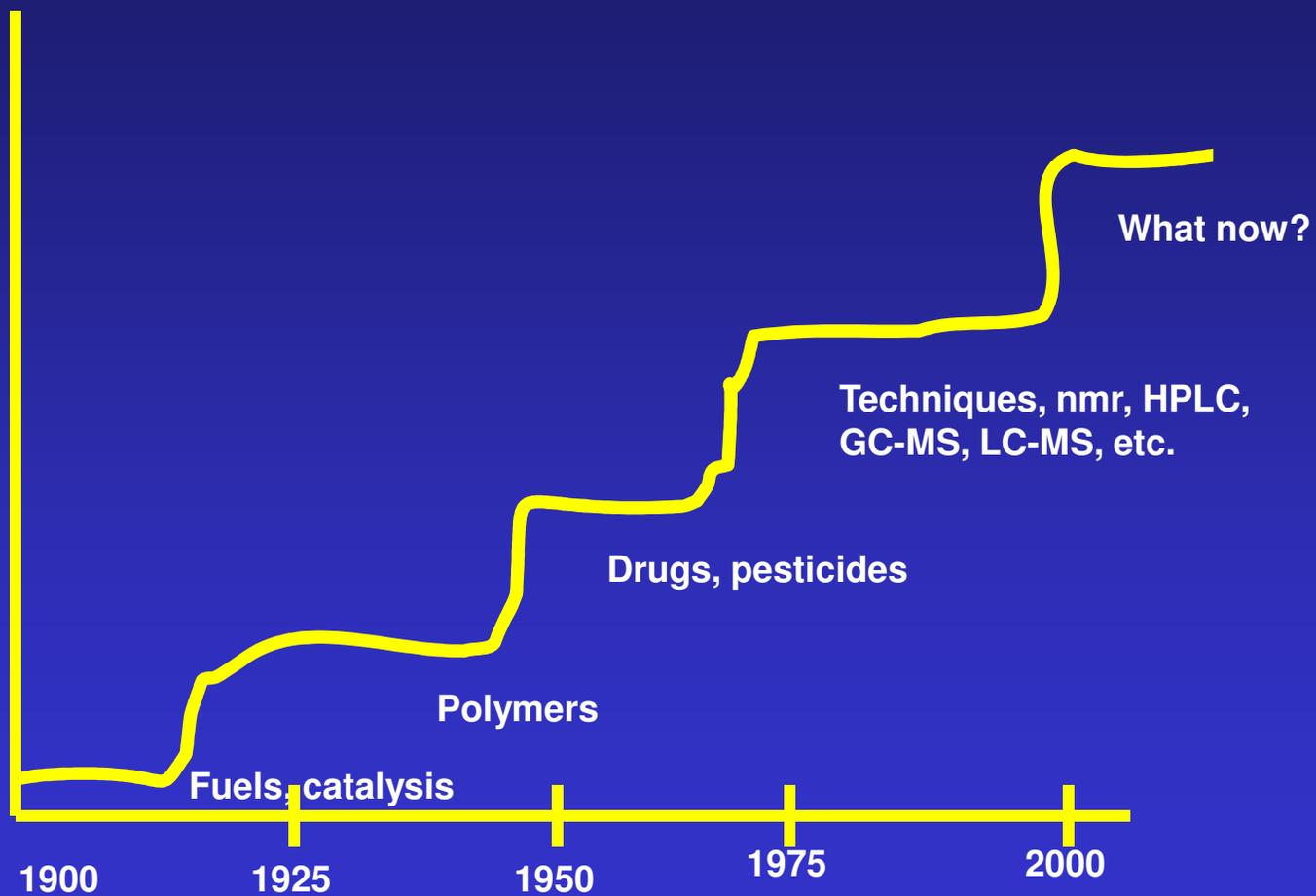
INDIAN CHEMICAL INDUSTRY

- Chemical industry in India contributes to 3 % of its GDP and 14 % of its exports
- Revenues : US \$ 55 billion in 2007-08 and CAGR of 11 % (2002-07)
- Projected to grow to US\$ 75 billion by 2011
- Indian Chemical industry 12 th largest in the world and 3 rd largest in Asia



Commodity chemical industry is technologically mature; all innovations are incremental in nature

CHEMISTRY : THE NEXT FRONTIER ?





SOME PROBLEMS OF CHEMISTRY

- **Simple molecule chemistry**
 CO_2 , H_2 , H_2O , CH_4 , NO_x , O_2
- **Energy production**
- **Understanding earth : Global stewardship**
- **Impossible materials**
GMR, Negative index of refraction, High T_c , self healing materials, etc.
- **Complex systems : Systems biology, environmental modeling, the cell**
- **Origin of life**
- **Chemical basis of consciousness**



CHEMISTRY AT CROSSROADS

- **Chemistry is at the end of one wave of development and struggling to begin another**
- **There are still many important opportunities in both fundamental and applied science**
- **Chemistry offers fewer puzzles to solve; What confronts are number of problems**
- **Longer term curiosity driven research is more important than in the past, but harder to justify**

**In the future, functions will be more important than molecules.
Molecules are no longer enough (they never really were)**



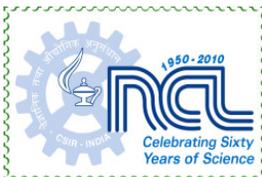
IDENTITY CRISIS

What does a field do :

Biology : Understands life processes, cures diseases,

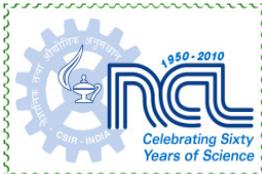
Physics / Astrophysics : Studies exploding stars, quarks, energy, matter, nuclear weapons, computers, semiconductor chips, internet

Chemistry : ?



Chemistry has not lost its identity; it has instead gained important footholds within the domains of other sciences – albeit rarely at the initiative of chemists

D. Seebach



PUBLIC PERCEPTION OF CHEMISTRY

- **Chemistry is invisible to the public**
- **Chemistry is considered a “mature” science**
- **Chemistry is associated with pollution, disasters and global warming**



Only the chemistry prize has preserved the traditional aura of obscurity. It goes to Gerhard Ertl for his studies on the role of surfaces in catalysing chemical reactions. Since an awful lot of industrial chemistry is catalysed and the chemical industry lies at the base of most manufacturing, there is good argument this is the most important prize. But glamorous? Sadly not .

The Economist , October 13, 2007



CHEMISTRY WILL AND MUST CHANGE

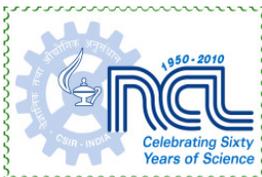
**Chemistry
The Profession**

Reinvention

New problems

**Absorption or
evaporation into**

**Biology
Materials
Energy
Environment**



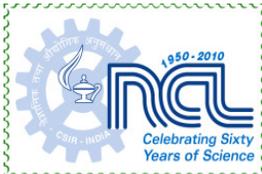
ALIGNING CORE AREAS TO LARGER SOCIETAL NEEDS

Core areas

- **Catalysis**
- **Physical Chemistry**
- **Analytical chemistry**
- **Organic Chemistry**
- **Theoretical chemistry**
- **Polymer Science**
- **Chemical Engineering**
- **Biology**
- **Materials chemistry**

Areas of coalescence

- **Energy**
- **Environment**
- **Functional materials**
- **Information Technology**
- **Computational science**
- **Health and human wellness**
- **Sustainable processes**



FUTURE OF CHEMISTRY

- **Systems, not molecules**
- **Functions, not molecular structure**
- **Problems, not puzzles**

No longer “What is it?” but “What does it do?”



PUZZLE AND PROBLEM

Puzzle :

“Though the outcome can be anticipated, often in detail so great that what remains to be known itself is uninteresting, that the way to achieve that outcome remains very much in doubt

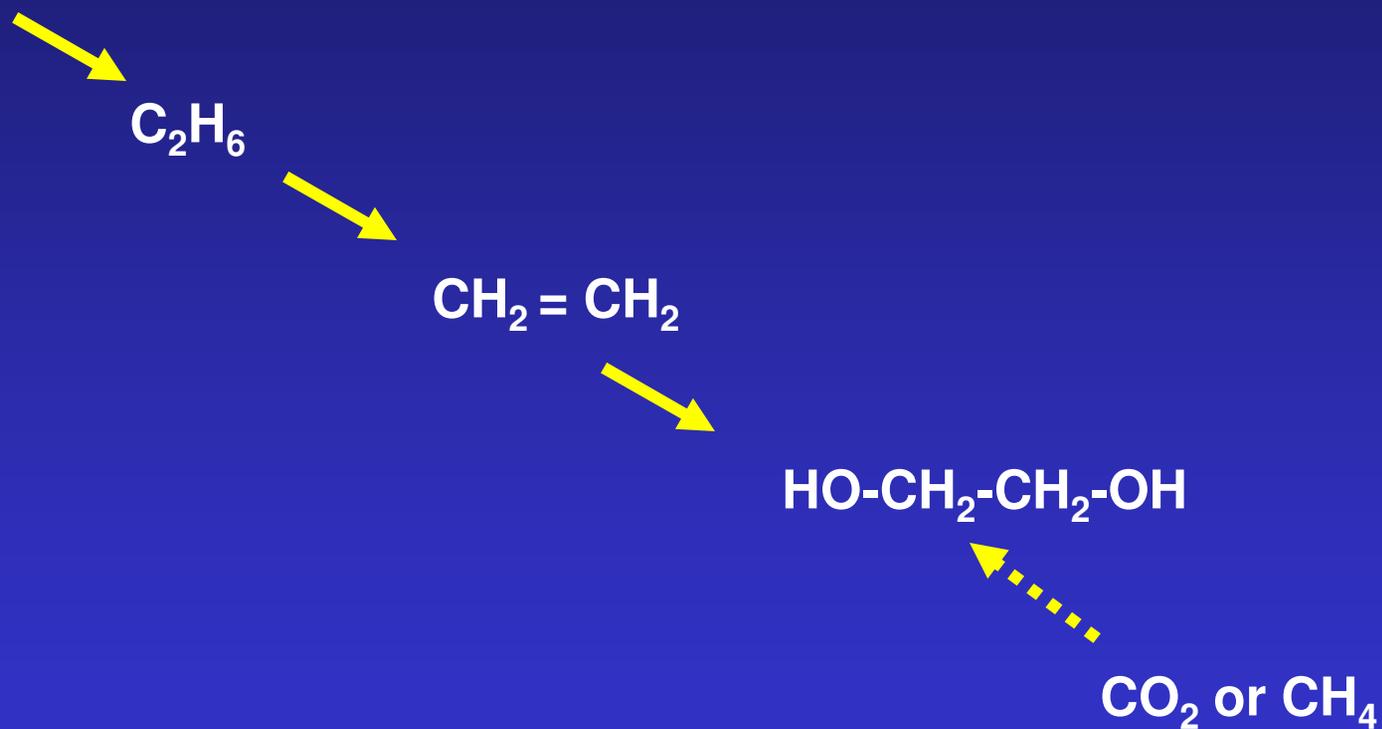
Problem :

“The really pressing problems, e.g. a cure for cancer or creation of an inexhaustible source of clean energy, are often not puzzles at all, largely because they may not have any solution”

Thomas Kuhn
The Structure of Scientific Revolutions

REINVENTING THE CHAIN

Petroleum (complex hydrocarbon)





TEACHING AND EDUCATION

- **Archaic**
- **Non-demanding**
- **Not very relevant**



CHANGING FACE OF CHEMISTRY

- **Chemistry is becoming more and more interdisciplinary pursuit**
- **However, students usually learn chemistry in isolation**
- **Is there a case for teaching science in an integrative fashion ?**
- **Can principles of chemistry be illustrated using familiar biological phenomena or ecosystem behavior or semiconductor physics ?**
- **Structure and function constitute the central theme of chemistry. All chemistry must be taught in the context of this theme**
- **We tend to teach chemistry in the chronological order of its evolution. This is unnecessary**
- **We should teach chemistry in the context of contemporary knowledge. The origins of chemistry must be covered in a module called “History of Science”**

In the world of research traditional disciplines are not relevant; Why don't we teach chemistry the way it is practiced ?



INTEGRATION OF TEACHING WITH PRACTICE

- Students at a very early stage of their learning must experience the thrill of doing chemistry
- Chemistry, in the ultimate, is a sensual science. Its beauty lies not in the pages of drab textbooks, but in the perception of its colors, smell and even sound !
- Students must practice chemistry in all its dimensions
- Experiments must be open ended and must inculcate the discipline of inquiry based learning
- It is never too early to get students involved in research. Small research modules can completely replace traditional laboratory experiments
- Students must be given opportunity to do science so that they can discover whether “research is for me”

If we have to infect young minds with the thrill of doing research, we should let student experience what goes on in the life of a scientist In a research laboratory



I am absolutely certain that synergy between research, education and industry is one of the great aspects of modern chemical science and one of the best investments a society can make in future. Unfortunately this happy relationship is still not widely appreciated nor practiced

***Elias J. Corey
Priestley Medal Address
Anaheim, CA, 2004***



THANK YOU

