TEACHING CHEMISTRY AS AN INTEGRATED SCIENCE:BRIDGING GAPS BETWEEN CONCEPTS AND PRACTICE

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INFORMATION AND KNOWLEDGE

Information: Facts, comments, opinions,expressed through words, images, sounds…It can be stored, circulated...

Knowledge: The output of the reconstruction of information by a person, according to his/her history and context. It depends on the person.

Information can be transmitted. Knowledge must be acquired and constructed.The objective of education is to teach students how to transform acquired information into applicable knowledge

DATA AND ACCESS WILL NOT BE LIMITING

- *Data* : from one billion terrabyte in 2010 to 35 billion terrabyte in 2020
- *Access* : from 120 million to 500 million
- *Devices* : Over a billion mobile and smart phones and low cost Tablets and Laptops

Access to information will no longer be a challenge; the question will be what do we do with all the information ?

What then will be the challenge to education ***?***

The most important thing in science is not so much to obtain new facts as to discover new ways of thinking about them

William Bragg

SCIENCE LITERACY : KEY TO INFORMED SOCIETY

- Science is uniquely positioned to address problems of great importance to our economy and public policy, such as, food, water, energy, shelter, environment, climate change and health

- A scientifically literate society will be better able to make informed decisions about public health, economic, environmental, and public policy issues.

Goal of education : To provide future generations with the tools, skills and knowledge to address the challenges facing humanity

PURPOSE OF SCIENCE EDUCATION

- Critical thinking
- Provide observational experiences
- Teach students about uncertainty in measurements
- Gain deductive (“explain the experiment”) and inductive experience (“experiment , then explain”)

In short, connect concepts with practice

PURPOSE OF SCIENCE EDUCATION

Train students for successful careers in science

Problem solving skills, ability to be comfortable with open ended problems, skills of quantitative reasoning, effective communicators

Train students to become useful citizens and pursue careers outside of science, such as, business, law, media and government

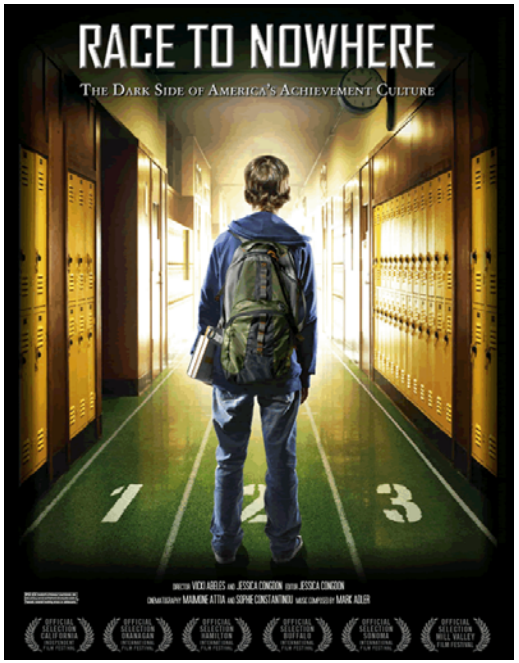
Understand the relationship between science and society; impart ability to make evidenced based rational and informed decisions

TEACHING AND EDUCATION

- Archaic
- Non-demanding
- Lacks innovation and experimentation
- Rigid pedagogy boxed in by overbearing bureaucracy

EDUCATION IS NOT A RACE

- Competitive pressures generate debilitating sense of anxiety and takes the joy out of learning
- Research on motivation tells us that attention exclusively on scholastic performance destroys the intrinsic interest the subject might have had.
- Education can become more relevant if the subject is connected to student`s personal life and interests.
- Opportunities to solve multi-dimensional problems, designing solutions through experimentation and working collaboratively can make a student more emotionally engaged with the subject
- In life, problem solving and critical analysis skills are far more important than being able to give correct answer to questions



D.Stipek, Science, 332,24 June 2011; Motivation in Education :Theory , Research and Applications, Prentice Hall, 2007

THREE PILLARS OF EDUCATION

- ***Critical inquiry***; inability to evaluate options, logically and coherently; reflective independent thinking
- ***Entrepreneurial thinking***: openness, creativity, Imagineering
- ***Academic integrity***: Ethics, propriety, ascribing credit and source of information; critical in this age of ubiquitous access to information

EDUCATION IN SCIENCE MUST CULTIVATE

- Curiosity and inquisitiveness
- A keen eye – power of observation
- Courage to ask simple or even stupid questions
- Seek unity in nature; “nature does not play dice”
- Differentiate puzzles from problems
- Imagination and whole brain thinking

Creativity is applied imagination

Every great advance in science has been issued from a new audacity of ***imagination***

John Dewey

INTEGRATIVE LEARNING

"Making connections within disciplines, between fields, between curriculum, co-curriculum, or between academic knowledge and practice"

Awbrey, S.M, Dana, D., Miller, V.W., Robinson, P., Ryan, M.M. and Scott, D.K. (Eds.), (2006). Integrative Learning and Action: A Call to Wholeness (Studies in Education and Spirituality),New York: Peter Lang Publications

WHAT IS INTEGRATED SCIENCE ?

- Integrated Science is an attempt to break down traditional disciplinary barriers
- A series of courses taken in the first and second years provides students with first-rate preparation for a major in any of the core scientific disciplines and in such a way that helps retain the connections to the other disciplines.
- **The curriculum is founded on the expectation that much of the most important science of the future, though based on the classical disciplines, will lie in areas that span two or more of them.**

Foundation in several fields necessary to address the most important problems confronting society today.

WHAT IS THE INTEGRATED SCIENCE CURRICULUM ?

- The curriculum covers the core material of introductory physics, chemistry, biology (genetics and biochemistry), and computer science, all in an integrated manner. The central role of mathematics as a universal language of science is emphasized throughout. In every area of science, students learn in part through quantitative problem solving; to this end computational methods are taught and integrated into the entire program
- Collaborative problem solving is stressed over memorization and regurgitation of facts.

People are distinguished not by what they know but how they deal with the unknown

CHANGING FACE OF CHEMISTRY

- Chemistry is becoming more and more an 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"

Why don't we teach chemistry the way it is practiced ?

STRUCTURE OF CHEMISTRY

- Laws, axioms, theory, concepts and principles
- Visualization in the spatial dimensions (stereochemistry, configuration, conformation)
- Visualization in temporal dimensions (atomic and molecular motions, collisions, bond making and breaking events)
- Relationship of structure to properties and functions (origins of color, smell, taste, tactile sensations etc)

CONTEXT LED APPROACH TO EDUCATION IN CHEMISTRY

- Instead of teaching chemistry in the traditional way, context led approach relies on engaging students natural curiosity to understand the world around them
- It teaches them to solve real life problems by exploring the underlying chemistry
- Its emphasis is on interpretation and analysis rather than the breadth of conceptual coverage
- The teaching does not subdivide chemistry in terms of traditional disciplines ; instead it teaches chemistry through illustrative examples from everyday experiences that a student can easily relate to

D. K. Smith, Nature Chemistry, 3,681, 2011

PHYSICS, CHEMISTRY AND BIOLOGY: STYLE AND APPROACH

Physics

✓Search for “simple” systems to test “theory” based *hypothesis on the structure of matter*

Chemistry

✓Understand molecular and structural diversityin the organization of matter, mostly “non-living”

Biology

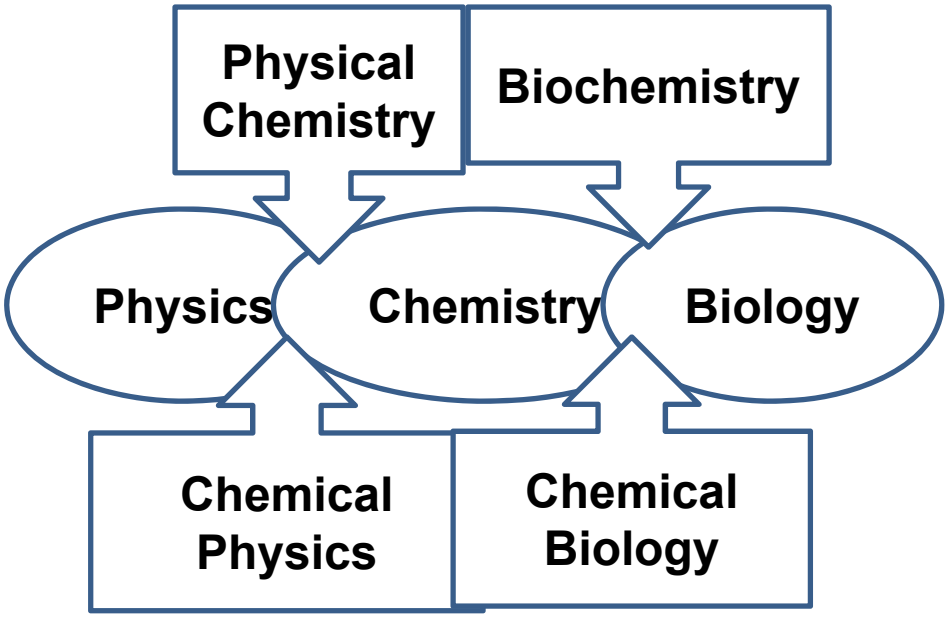
✓Understand molecular and structural diversity in the organization of matter, mostly living

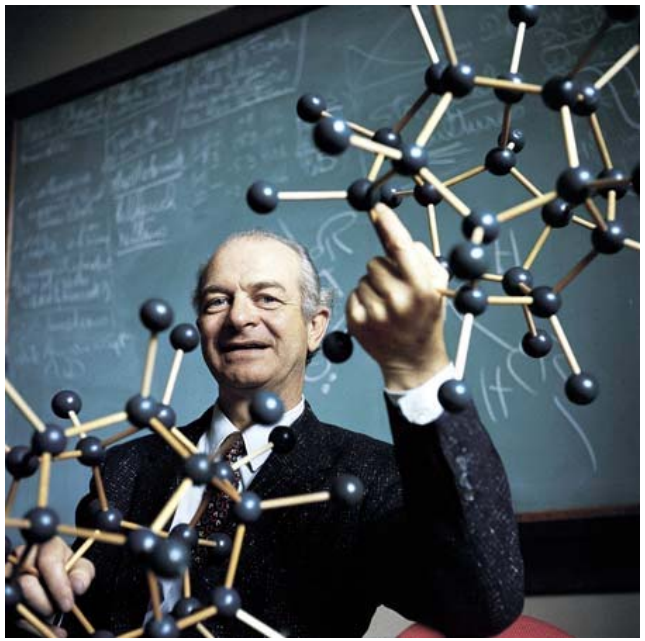
Chemistry and biology are two distinctive cultures and the rift between them is serious, generally unappreciated and counter productive.

Arthur Kornberg, 1987

LINUS PAULING AND THE NATURE OF THE CHEMICAL BOND

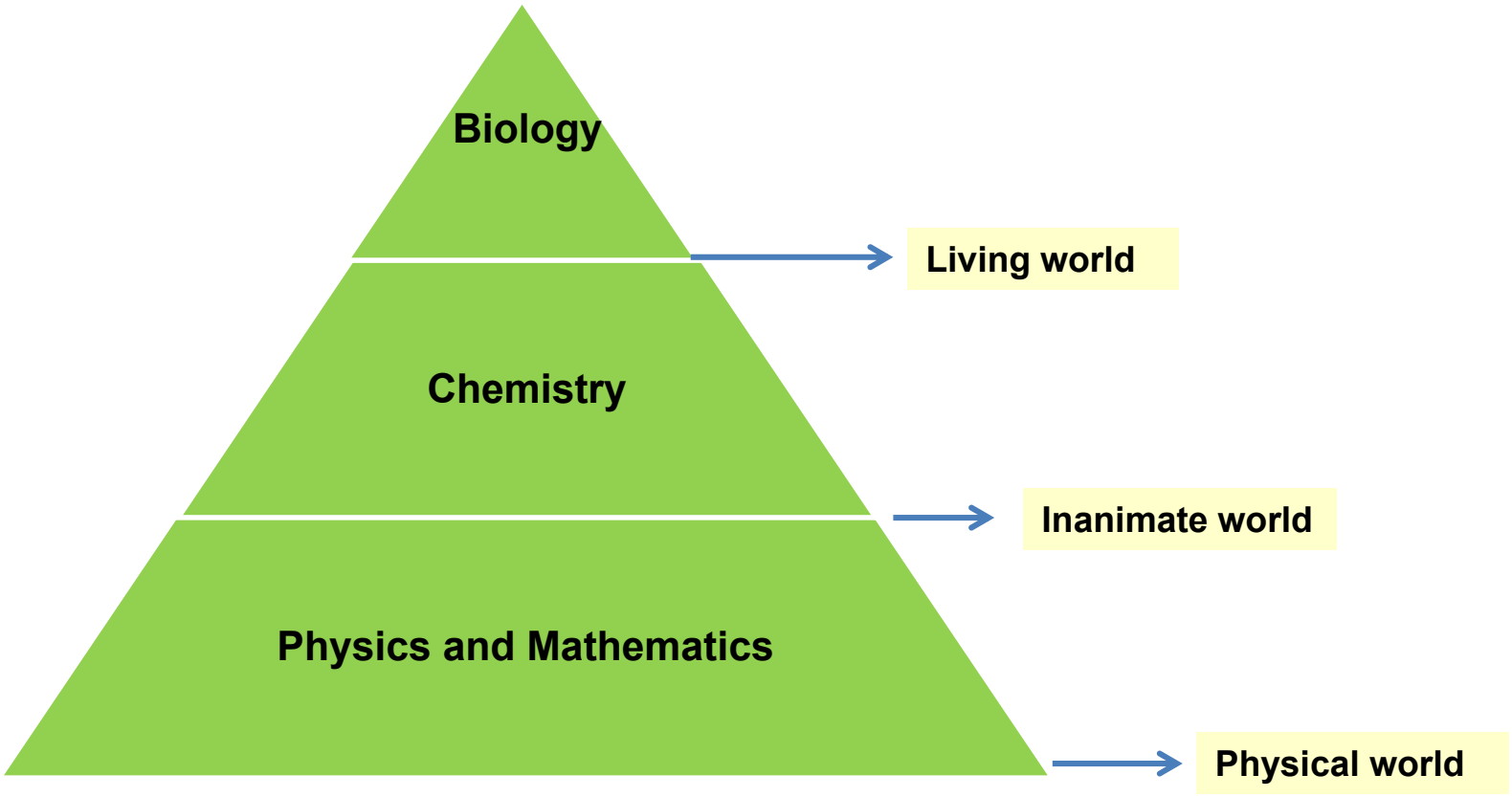
Established chemistry as an overarching science that bridges physics on one side and biology on the other





1901- 1994
Nobel Laureate, 1954

HEIRARCHY OF SCIENCE



P. Oppenheim and H. Putnam, Unit of science as a working hypothesis, H. Feigl, M. Scriven, G. Maxwell (eds.), Concepts, Theories and the Mind – Body Problem, Vol.2, University of Minnesota Press, 1958

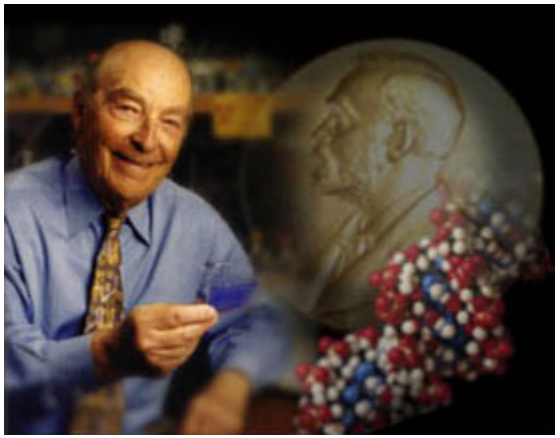
LANGUAGE OF CHEMISTRY

Language of Chemistry

Physical World

Biological World

The Two Cultures: Chemistry and Biology,
A. Kornberg, Biochemistry, 26, 68888 (1987)



Arthur Kornberg 1918-2007 Nobel, 1959

COMPLEX MATTER via SUPRAMOLECULAR SELF ASSEMBLY

Supramolecular Chemistry

Molecular Recognition and Self Organization

Physical World

Biological World

Jean-Marie Lehn, Science, 295, 29 March 2002

J-M Lehn
1939
Nobel, 1987

CHANGING FACE OF BIOLOGY AND CHEMISTRY

Structure, function and dynamics constitute the central theme of chemistry. All chemistry must be taught in the context of this theme

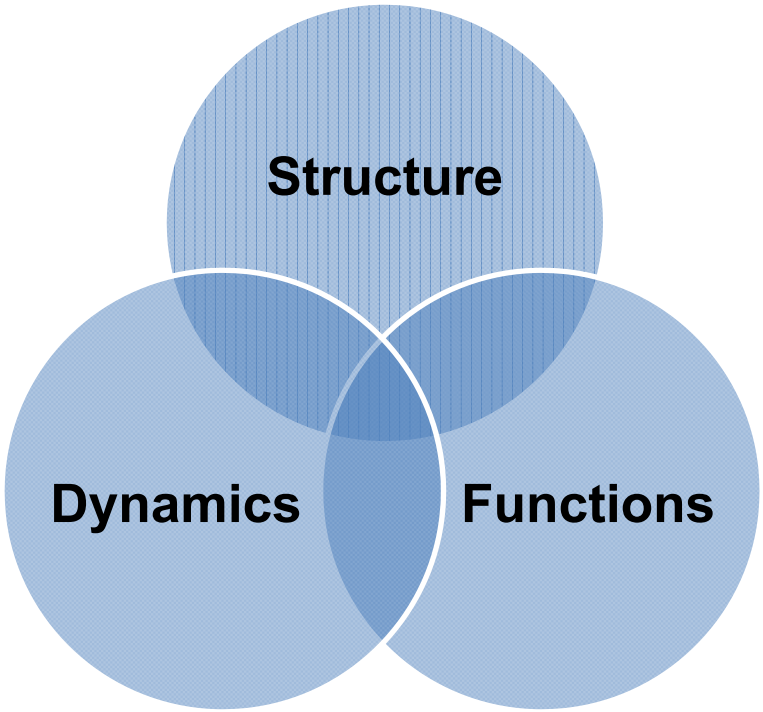
Why don't we teach chemistry and biology the way it is practiced today ?

INTEGRATION OF CHEMISTRY AND BIOLOGY

Molecules can be organic, inorganic or biologically derived, small or big, single or assemblies and involving a range of inter and intra-molecular forces

CHEMISTRY

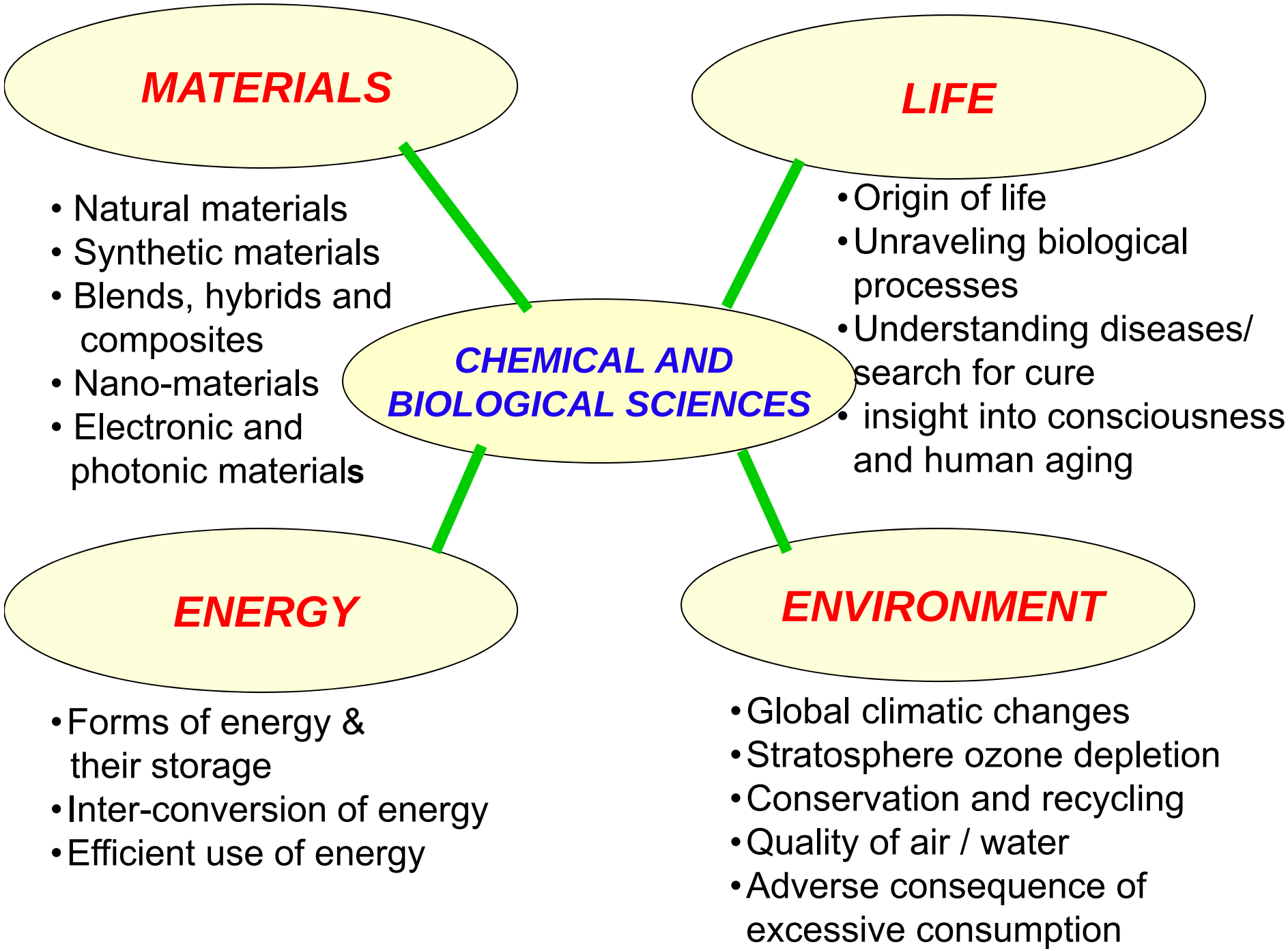
Progression from atoms to molecules to larger molecular assemblies



BIOLOGY

Progression from whole organisms to molecular structure

J. Chemical Education, 88, 1257, 2011


MATERIALS
• Natural materials
• Synthetic materials
• Blends, hybrids and composites
• Nano-materials
• Electronic and photonic materials
LIFE
• Origin of life
• Unraveling biological processes
• Understanding diseases/ search for cure
• insight into consciousness and human aging
CHEMICAL AND BIOLOGICAL SCIENCES
ENERGY
• Forms of energy & their storage
• Inter-conversion of energy
• Efficient use of energy
ENVIRONMENT
• Global climatic changes
• Stratosphere ozone depletion
• Conservation and recycling
• Quality of air / water
• Adverse consequence of excessive consumption

EDUCATION IN CHEMISTRY

What is the objective ?

To teach students *what we know or how to think*

- We must tailor distinctive curriculum to those who will go on to become scientists and those who will not ; Differentiate between educating the masses and educating the few who are committed to pursue science as a career.
- The former will require a conceptual approach to scientific knowledge, in the form of rigorous facts and principles, often taught in an abstract manner
- The latter will require to be provided with basic scientific literacy, allowing them to understand the world they live in and engage in a meaningful way with scientific developments that will have impact on their lives

Inclusive education does not imply reducing it to the lowest common denominator

INTEGRATION OF TEACHING WITH PRACTICE

- Students at a very early stage of their learning must experience the thrill of doing chemistry
- Chemistry, is in the ultimate, 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

CHEMISTRY EDUCATION IN THE INTERNET ERA

- Information and facts abound in the world wide web; era of distributed teaching and learning
- Information retrieval no longer a rate limiting step
- However, one needs higher order skills to get the true value of available information
- Interpretation, making creative connections between data from different sources and spot the needles in the ever expanding information haystacks
- Shift from acquiring knowledge to sharpening the cognitive skills
- Providing facts to students no longer relevant; need to reinvent the classroom(flipped classroom)
- The objective should be to make a student active and independent learner
- From “chalk and talk” to “ learn to connect and create”

CHEMISTRY EDUCATION IN THE INTERNET ERA

- Classroom lectures followed by homework followed by exams is a recipe for educational failure
- From " teach a syllabus" and "teach to test" to " teach to learn"
- From " factual " to " analytical"
- From " fill the mind with facts" to "open the mind with empty spaces"
- From "teacher centric" to "student centric"
- Teach to understand why chemistry is critical to their everyday life

➢ ***Nature Publishing Group has launched its first of its kind digital book "Principles of Biology"***

➢ ***Pay for access on internet; available on Laptop, Tablet or Smart Phone***

➢ ***Interactive, dynamic illustrations, audio and video clips***

➢ ***A book aimed at learning not reading***

➢ ***Introduces students to primary literature summaries, explains how biology impacts the quality of life, introduces real world skills and talks about careers***

➢ ***Teachers in the classroom will have to compete with "teachers" in the cyberspace .***
➢ ***Will teachers become an endangered species?***

WHOM ARE WE TEACHING ?

How well do we understood the demands of the millennial generation?

- Attitudes and aspirations
- Thinking
- Differently wired
- Constant mental stimulation
- Short attention span
- Comfort levels with technology
- Engagement, involvement, interaction and social media

Need: To make the transition from teacher centric to student centric education

STUDENTS VIEW OF TEACHING

- We do not study because teachers do not manage to generate interest
- Course content too theoretical and does not connect theory to applications
- We prefer old fashioned black board teaching to use of power point slides
- We get excited about understanding science through everyday experiences

Students wish to see science at work not as mere pages in a text book

FOUR QUESTIONS

- *What should we be teaching ?*
- *How should we be teaching ?*
- *Why should we be teaching ?*
- *How do we know that we have managed to teach ?*

“Unless we understand the future for which we are preparing, we may do tragic damage to those we teach”

A. Toeffler, Learning for Tomorrow: The Role of the Future in Education, Vantage Press, New York, 1974

Tell me and I forget. Teach me and I remember. Involve me and I learn

Benjamin Franklin

THANK YOU