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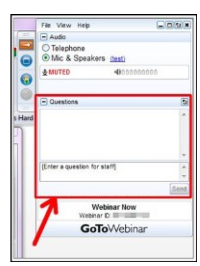

Type them into questions box!

"Why am I muted?"
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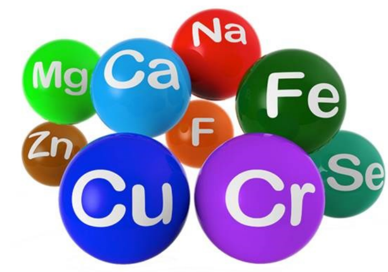

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"This ACS Webinar allowed me as an undergraduate student explore more of how chemistry can be used to change and benefit the world. With my graduation coming in a few weeks I'm reassured that there is a whole network of professionals who share the same passion for creating a healthier planet."

Quote in reference to: http://bit.ly/TacklingToxics

Fan of the Week

Emily Dowdy
Bachelor of Science, Chemistry
Moravian College Class of 2016

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ACS Chemistry for Life

ChemIDP.org

Upcoming ACS Webinars

www.acs.org/acswebinars

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Thursday, September 15, 2016

Unveiling the Mysteries Behind HPLC and GC Resolution: From Theory to Practice in 30 minutes

Lee Polite, President and Laboratory Director, Axion Analytical Labs, Inc. and Axion Training Institute, Inc.

Bryan Tweedy, Manager, Career and Professional Resources, American Chemical Society

Thursday, September 22, 2016

Chemistry of Longevity: Rapamycin's Secret Past and Potential for a Longer Life

Matt Kaeberlein, Professor of Pathology, University of Washington

Bethany Halford, Senior Editor, Chemical & Engineering News

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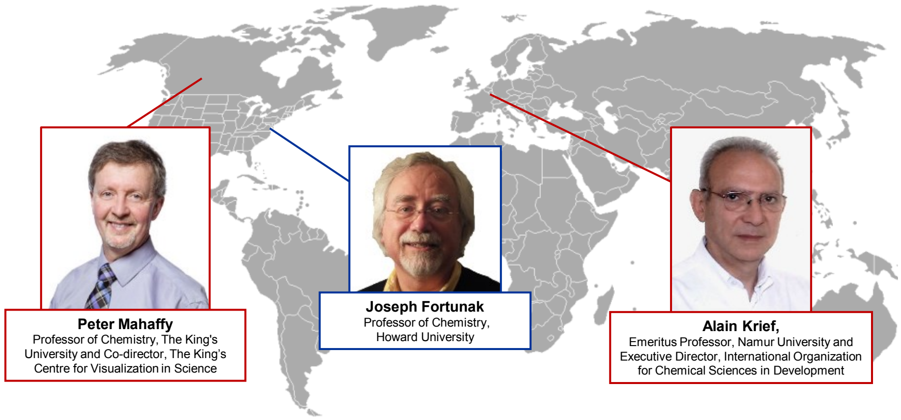
"Systems Thinking To Re-imagine Chemistry"



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This ACS Webinar is being co-produced by the ACS Green Chemistry Institute

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Systems Thinking To Reimagine Chemistry

Peter Mahaffy
The King's University
THE KING'S UNIVERSITY

Alain Krief
IOCD

International Organization for Chemical Sciences in Development (IOCD)

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Systems Thinking To Reimagine Chemistry

Assertion

"The practice and overarching mission of chemistry needs a major overhaul to be fit for purpose in the 21st Century and beyond."

One-world chemistry and systems thinking

Stephen A. Matlin, Goverdhan Mehta, Henning Hopf & Alain Krief
Affiliations | Corresponding author

Nature Chemistry **8**, 393–398 (2016) | doi:10.1038/nchem.2498
Published online 22 April 2016

nature chemistry

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Chemistry: Outstanding Successes Over 2 Centuries!

- Understanding properties and behaviour of substances
- Platform for developing other "molecular" sciences – i.e. biochemistry, molecular biology, materials, nanosciences…
- Diverse applications that have improved the human condition, vastly expanded the wealth of some countries
  - Medicines
  - Agriculture and food
  - Plastics and synthetic polymers
  - Energy
  - Clean water
  - Materials

ACS Chemistry for Life®

"To advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people."

14

Chemistry…for the benefit of Earth's people…

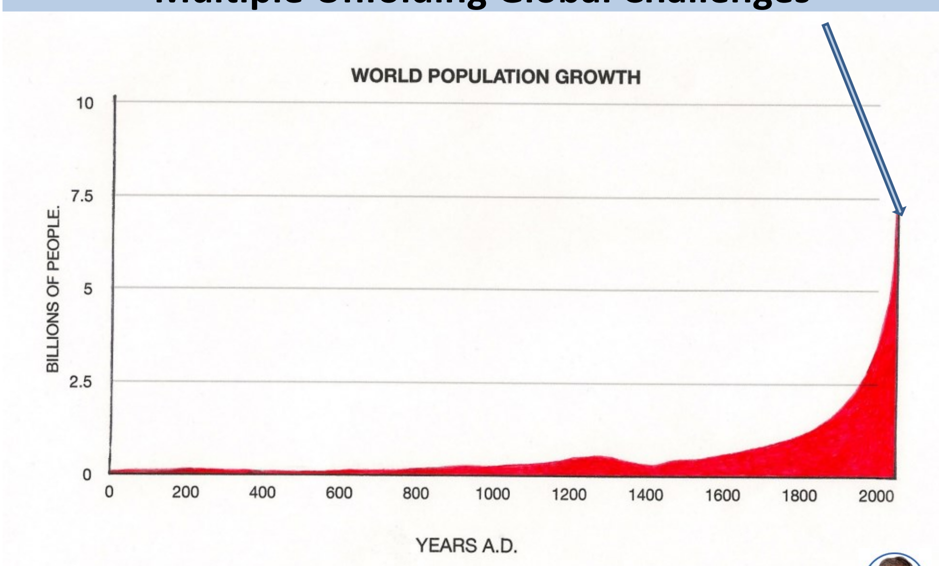
"When you travel in Hunan or Jiangsu, through the Nile Delta or the manicured landscapes of Java, remember that the children running around or leading docile water buffalo got their body proteins via the urea their parents spread on the fields, from the Haber–Bosch synthesis of ammonia. Without this, almost two-fifths of the world's population would not be here - and our dependence will only increase as the global count moves from six to nine or ten billion people."

Vaclav Smil
University of Manitoba

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

15

But 7.4 Billion People Also Create Multiple Unfolding Global Challenges



www.stephenbolwell.com

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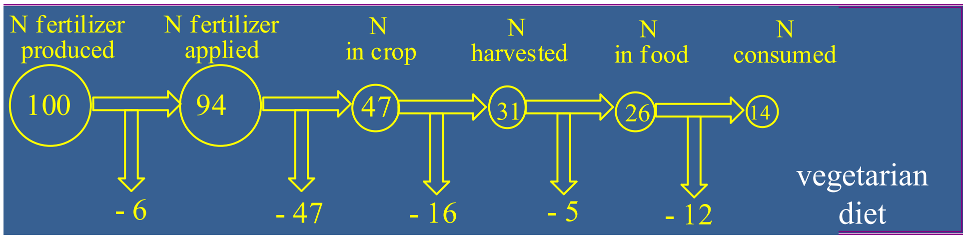
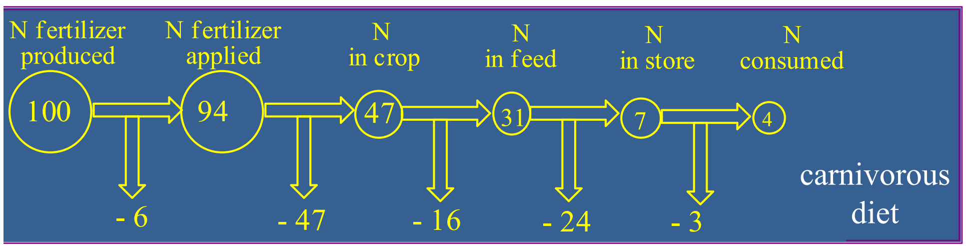
A Failure of Systems Thinking?

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$





Mahaffy, Bucat, Tasker, et. al, *Chemistry: Human Activity, Chemical Reactivity*, Nelson/Cengage, 2015, adapted from J. N. Galloway & E. B. Cowling, 31, Ambio, March 2002

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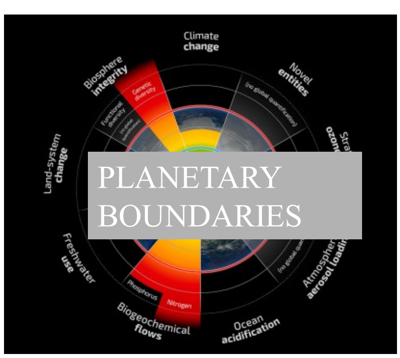
Multiple Unfolding Global Challenges Both for Earth and Its People

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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Marc Imhoff, Craig Mayhew, Robert Simmon NASA/GSFC; Christopher Elvidge NOAA/NGDC

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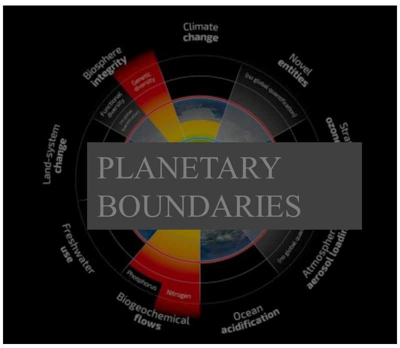
Multiple Unfolding Global Challenges Both for Earth and Its People

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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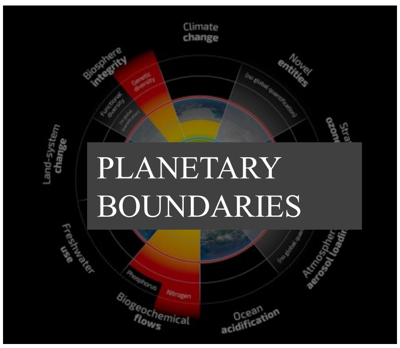
Multiple Unfolding Global Challenges Both for Earth and Its People

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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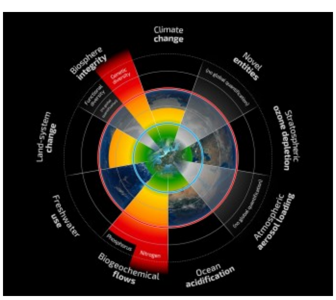

nature Vol 461|24 September 2009

FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

Planetary boundaries: Guiding human development on a changing planet

Will Steffen,[1,2*] Katherine Richardson,[3] Johan Rockström,[1] Sarah E. Cornell,[1] Ingo Fetzer,[1] Elena M. Bennett,[4] R. Biggs,[1,5] Stephen R. Carpenter,[6] Wim de Vries,[7,8] Cynthia A. de Wit,[9] Carl Folke,[1,10] Dieter Gerten,[11] Jens Heinke,[11,12,13] Georgina M. Mace,[14] Linn M. Persson,[15] Veerabhadran Ramanathan,[16,17] B. Reyers,[1,18] Sverker Sörlin[19]

Science

Science 13 Feb 2015:
Vol. 347, Issue 6223,
DOI: 10.1126/science.1259855

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship

Stockholm University

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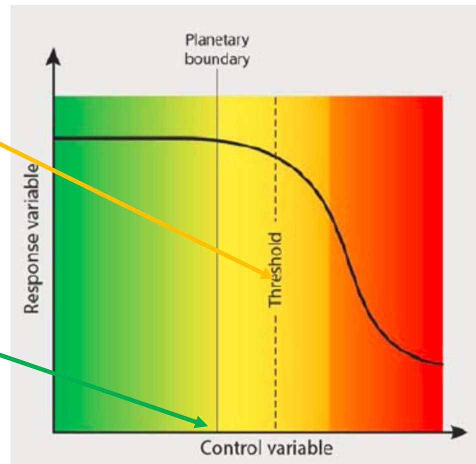
Planetary boundaries: Guiding human development on a changing planet

- Thresholds are "tipping points," places: non-linear transitions in the functioning of coupled human-environmental systems.
- Planetary boundary: Remain at safe distance from the threshold



W. Steffen et al., **Science** 347, (2015).
DOI: 10.1126/science.1259855

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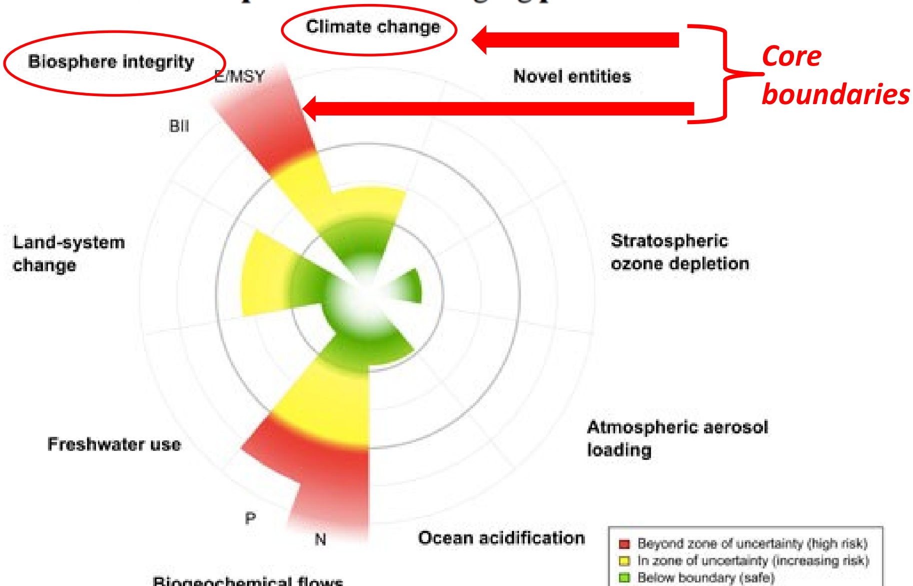
Planetary boundaries: Guiding human development on a changing planet



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Steffen et. al, 16 January 2015, Science

Multiple Unfolding Global Challenges Both for Earth and Its People

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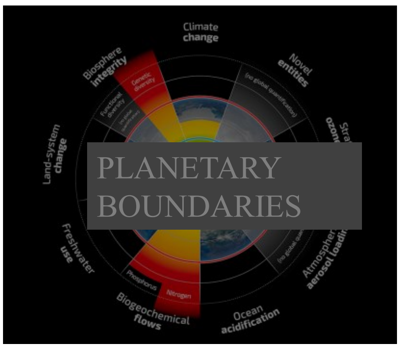
17 GOALS TO TRANSFORM OUR WORLD



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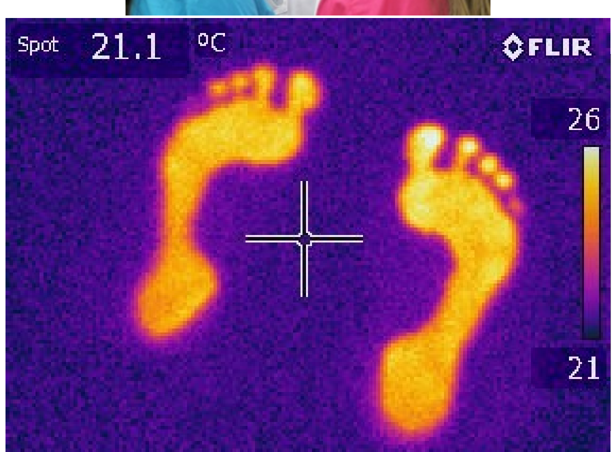

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A new geological epoch, the Anthropocene, has begun, scientists say

Humans have left mark in rock record like the meteor that ended Late Cretaceous, wiped out dinosaurs

By Emily Chung, CBC News Posted: Jan 07, 2016 2:44 PM ET | Last Updated: Jan 07, 2016 4:32 PM ET

Science 8 January 2016:
Vol. 351 no. 6269
DOI: 10.1126/science.aad2622

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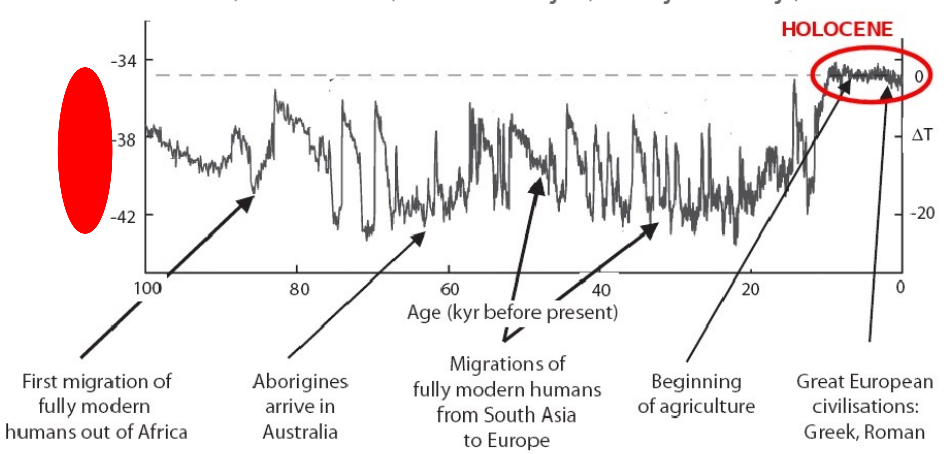
The Anthropocene is functionally and stratigraphically distinct from the Holocene

Colin N. Waters[1,*], Jan Zalasiewicz[2], Colin Summerhayes[3], Anthony D. Barnosky[4], Clément Poirier[5],



Science 8 January 2016:
Vol. 351 no. 6269
DOI: 10.1126/science.aad2622

Adapted from Young and Steffen, 2009

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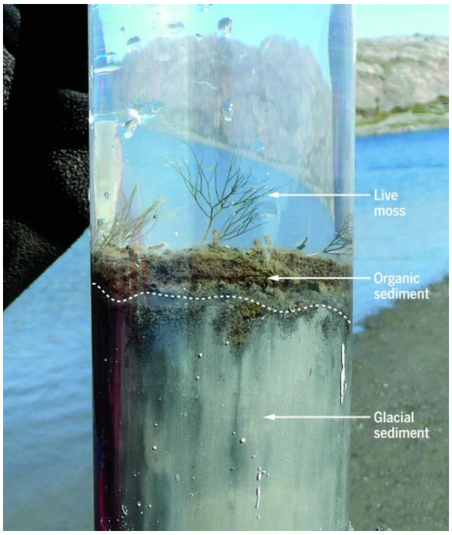
Indicators of the Anthropocene in recent lake sediments differ markedly from Holocene **signatures.**



Colin N. Waters et al. Science 2016;351:aad2622

- Many other indicators differ markedly from Holocene signatures - plastics, fly ash, radionuclides, metals, pesticides, reactive nitrogen, greenhouse gas impacts.
- Greenland glacier retreat due to climate warming gives an abrupt stratigraphic transition from proglacial sediments to nonglacial organic matter, marking the onset of the Anthropocene.

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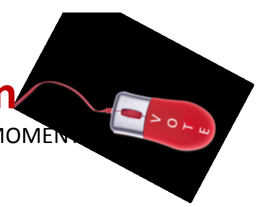
Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



Have you related chemistry using any of the following?

- the UN Sustainable Development Goals
- The planetary boundaries framework
- the change in our Geologic Time Scale to the Anthropocene Epoch
- None of the above

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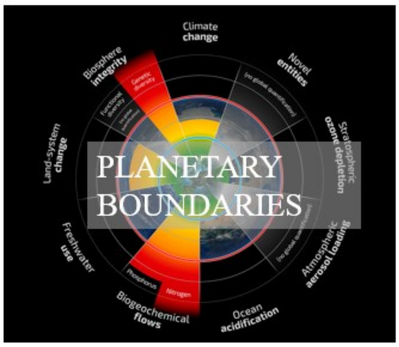
Addressing Multiple Unfolding Global Challenges
Do they Require an Overhaul of Chemistry?

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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Marc Imhoff, Craig Mayhew, Robert Simmon NASA/GSFC;
Christopher Elvidge NOAA/NGDC

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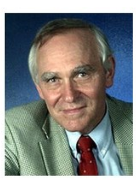
Systems Thinking To Reimagine Chemistry



Prof. Henning Hopf
New Braunschweig, Germany

Prof. Alain Krief
Namur, Belgium

Prof. Stephen Matlin
London, UK

Prof. Goverdhan Mehta
Hyderabad, India

One-world chemistry and systems thinking

Stephen A. Matlin, Goverdhan Mehta, Henning Hopf and Alain **NATURE CHEMISTRY** | VOL 8 | MAY 2016 |

The practice and overarching mission of chemistry need a major overhaul in order to be fit for purpose in the twenty-first century and beyond. The concept of 'one-world' chemistry takes a systems approach that brings together many factors, including ethics and sustainability, that are critical to the future role of chemistry.

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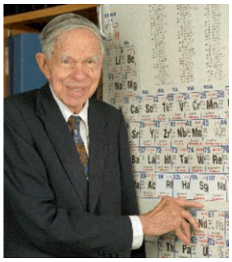
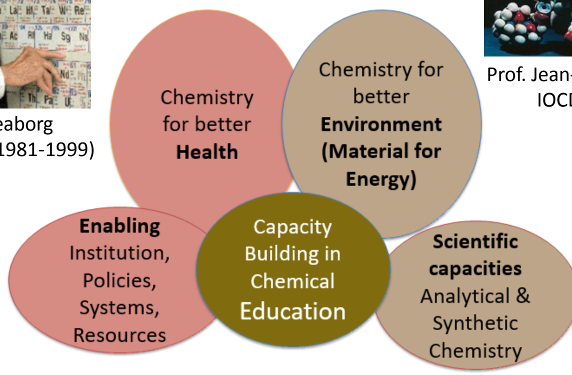
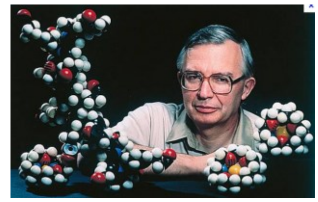
An International Organization for Chemical Sciences in Development (IOCD) Initiative



Prof. Glen Seaborg
IOCD President (1981-1999)





Prof. Jean-Marie Lehn (Strasbourg)
IOCD President (1999-)

Promoting chemical sciences for human development and economic growth

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Systems Thinking To Reimagine Chemistry

- Reimagined chemistry – Must go beyond 'being a science' to 'being a science for the benefit of society.'
- Triple role:
  1) creating new scientific knowledge
  2) translating knowledge into useful applications
  3) helping to meet the emergent challenges of multiple unfolding global crises. *

  ***a new imperative for chemistry*

NATURE CHEMISTRY | VOL 8 | MAY 2016 | www.nature.com/naturechemistry

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Systems Thinking To Reimagine Chemistry

Implications for Industry and Chemistry Practice

- "Overhaul" to bring much stronger basis in systems thinking, including life-cycle analyses.
- Chemistry cannot be considered apart from its contexts and many interconnected systems.
- Human and animal health are interconnected to biophysical parameters and boundaries of our planet.
- Special responsibility for chemistry in meeting UN Sustainable Development Goals

NATURE CHEMISTRY | VOL 8 | MAY 2016 | www.nature.com/naturechemistry

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Systems Thinking To Reimagine Chemistry

Implications for Chemistry Education

- Re-orient teaching and learning to focus on 'a science for the benefit of society'.
- Emphasis on problem solving
- Systems perspective that includes physical, biological, environmental, and other systems
- Chemistry must be taught in contexts – not just the context of 'applications' but relevance to society, contribution to meeting global challenges, and fostering skills in cross-disciplinary working

NATURE CHEMISTRY | VOL 8 | MAY 2016 | www.nature.com/naturechemistry

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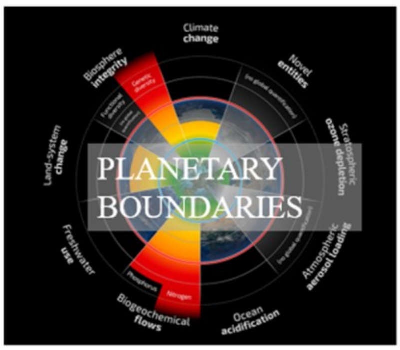
Systems Thinking can Transform Chemistry
Are There Good Examples?

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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Emerging Systems Thinking in the Practice of Chemistry

Responsible Care® Our commitment to sustainability.

1985 – Chemistry Industry Association of Canada

Green CHEMISTRY | ACS Green Chemistry Institute®

1993 – US EPA implements green chemistry program
1997 ACS Green Chemistry Institute incorporated

Green Chemistry and Engineering **-** Go beyond concerns over hazards from toxicity to include chemical & engineering systems – energy conservation, waste reduction, life cycle considerations, including sustainable and renewable feedstocks.

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Emerging Systems Thinking in the Practice of Chemistry – *Green Chemistry Principles*

- **Reaction efficiency:** Minimizing the quantities of chemicals (reactants, reagents, solvents, etc.), energy and water used to make a chemical, material or product
- **Efficiency metrics:** Calculating efficiency of reactions or processes, for example through process mass intensity, atom economy or other efficiency metrics
- **Renewables:** Utilizing renewable feedstocks in place of petroleum feedstocks
- **Catalysis and recycling:** Replacing stoichiometric reagents with catalysts or recycling reagents or solvents
- **Process efficiency:** Reducing the number of synthetic/ process steps to produce chemicals, materials and products

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Emerging Systems Thinking in the Practice of Chemistry – *Green Chemistry Principles*

- **Lifecycle impacts of chemicals:** Understanding how chemicals are produced and the social, environmental and economic impacts of their extraction or manufacture
- **Chemicals in the environment:** Understanding the fate, persistence and degradability of man-made chemicals in the environment
- **Chemical hazards and exposure**: Identifying environmental, safety and health hazards, as well as potential sources of exposure. Selection and design of chemicals that are less hazardous alternatives to known chemicals and products

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ACS GCI Pharmaceutical Industry Roundtable

Mission: To catalyze the implementation of green chemistry and engineering in the pharmaceutical industry globally

Inform and Influence the Research Agenda	Define and Deliver Tools for Innovation
Promote Education and Training	Enable Global Collaboration

ACS Green Chemistry Institute

Strategic Priorities

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Key Research Challenges Identified by ACS GCI Pharmaceutical Industry Round Table

- Current Reactions
  - Amide Formation, OH activation, Amide Reduction, Green Mitsunobu reactions, Oxidation/Epoxidations
- More Aspirational Reactions
  - C-H activation or aromatics, chiral amine synthesis, Asymmetric Hydrogenation, Green Fluorination Methods, N-Centred Chemistry
- Key Ideas outside the Reaction theme
  - Solventless Reactor Cleaning
  - Green alternatives to polar aprotic solvents

ACS Green Chemistry Institute

*Constable, et. al. *Green Chemistry* **2007**, *9*, 411-420

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Catalyzing Systems Thinking: ACS GCI Pharma Round Table research Grants

Recipient	University	Year
J. Xiao	University of Liverpool	2007
R. Maleczka & M. Smith	Michigan State University	2007
C.J. Li	McGill University	2008
M. Krische	University of Texas- Austin	2008
R. Crabtree	Yale University	2009
D. Cole-Hamilton	University of St. Andrews	2010
S. Stahl	University of Wisconsin	
R. Maleczka (GOALI)	MSU	
W. Zhang	UMass-Boston	

Recipient	University	Year
C. Liotta	Georgia Institute of Technology	2012
N. Garg	UCLA	2012
J. Scott	University of Bath	2013
D. Weix	University of Rochester	2013
P. Chirik	Princeton University	2013
N. Mankad	University of Illinois – Chicago	2014
M. Bellar	Leibniz-Institut für Katalyse	2014

$1,845,980 in grants (21 total) have resulted in 64 publications that have been cited 2272 times!

$1.3 million leveraged from federal funding agencies

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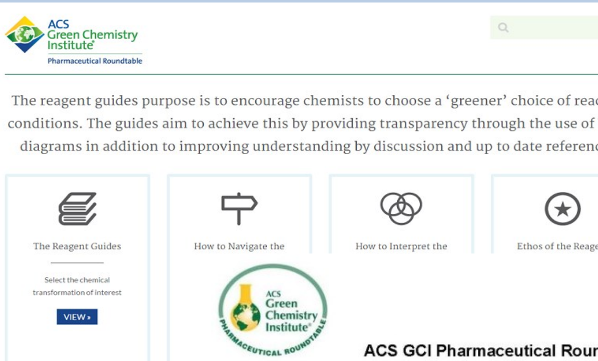
Turning Systems Thinking into Practice: Tools Such as Solvent Selection Guides

ACS Green Chemistry Institute®



ACS Green Chemistry Institute® Pharmaceutical Roundtable

ACS GCI Pharmaceutical Roundtable Solvent Selection Guide
Version 2.0 Issued March 21, 2011
www.acs.org/gcipharmaroundtable

Substance Information			Scoring Information				
Solvent Class	Solvent Name	CAS Number	Safety	Health	Env (Air)	Env (Water)	Env (Waste)
Acid	ACETIC ACID	64-19-7	3	6	6	3	6
Acid	ACETIC ANHYDRIDE	108-24-7	3	6	6	2	7
Acid	FORMIC ACID	64-18-6	2	6	5	4	7
Acid	METHANE SULPHONIC ACID	75-75-2			6	6	10
Acid	PROPIONIC ACID	79-09-4	2	5	6	4	6
Alcohol	1-BUTANOL	71-36-3	3	5	5	5	3
Alcohol	1-PROPANOL	71-23-8	4	4	6	2	6
Alcohol	2-BUTANOL	78-92-2	4	5	6	3	5
Alcohol	2-METHOXYETHANOL	109-86-4	4	9	5	3	7
Alcohol	BENZYL ALCOHOL	100-51-6	4	3	4	2	4
Alcohol	ETHANOL	64-17-5	4	3	5	1	6
Alcohol	ETHYLENE GLYCOL	107-21-1	3	3	5	1	7
Alcohol	ISOAMYL ALCOHOL	123-51-3	3	4	5	3	4
Alcohol	ISOBUTANOL	78-83-1	3	5	4	3	3
Alcohol	ISOPROPYL ALCOHOL (IPA)	67-63-0	5	5	6	2	6

Emerging Systems Thinking in the Practice of Chemistry – *The Hague Ethical Guidelines*

Report of the Second Workshop on Ethical Guidelines for the Practice of Chemistry under the Norms of the Chemical Weapons Convention, Sept 2015

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Emerging Systems Thinking in the Practice of Chemistry – *The Hague Ethical Guidelines*

- **Starting Point.** The responsible practice of chemistry improves the quality of human life and the environment, while recognizing that chemicals can be misused - including the use of chemicals and technologies to produce chemical weapons.
- **Core guideline.** Achievements in the field of chemistry should be used for the benefit of humankind and the environment.

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Key Elements of The Hague Ethical Guidelines

- **Sustainability** – Responsibility to address UN Sustainable Development Goals
- **Education** – Equip practitioners and others with the knowledge and tools to take responsibility to ensure that chemicals are used only for beneficial and peaceful purposes.
- **Awareness & Engagement** – Multiple uses of chemicals
- **Ethics** – education, research and innovation must meet the highest ethical standards
- Promote a strong culture of **safety, health, and security**
- **Accountability** to avoid illegal, harmful, or destructive uses of chemicals
- **Oversight** – responsibility extends to those who oversee non-chemists
- Promote the **free exchange of information** related to the development of chemistry for peaceful and beneficial purposes.

OPCW

IUPAC

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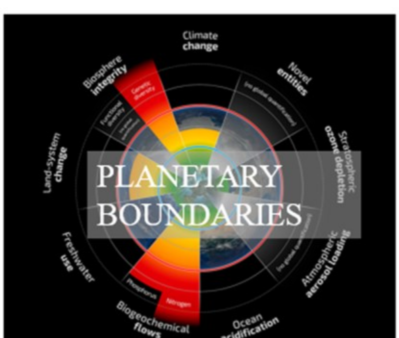
Emerging Systems Thinking in Chemistry
Is it Comprehensive and Fast Enough?

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD



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Marc Imhoff, Craig Mayhew, Robert Simmon NASA/GSFC; Christopher Elvidge NOAA/NGDC

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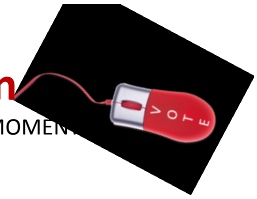
Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



I believe systems thinking in chemistry is emerging rapidly and comprehensively enough to address these multiple unfolding global challenges.

- True
- False

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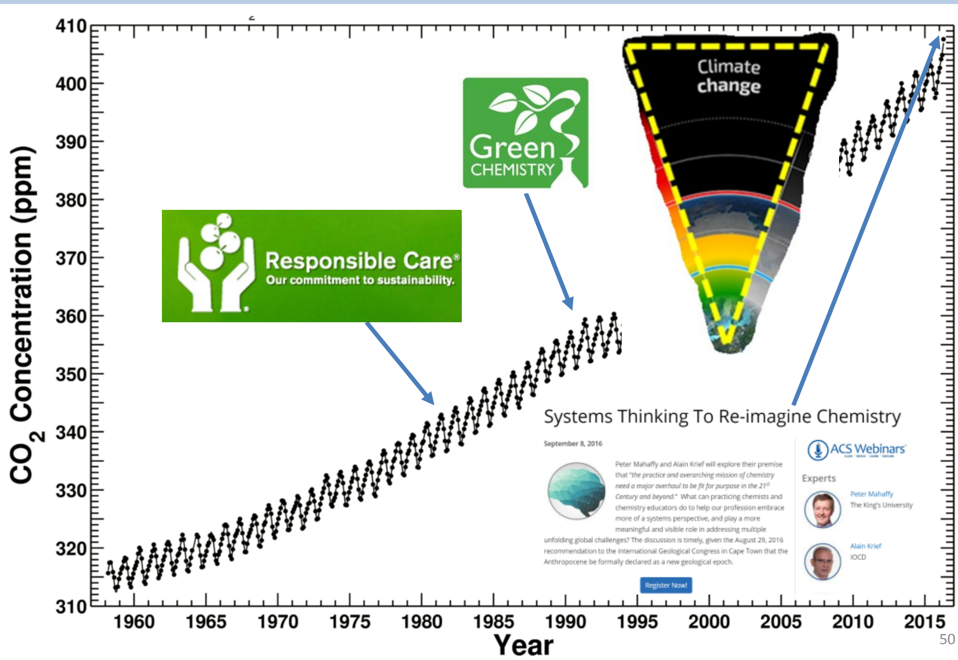
Systems Thinking: Comprehensive & Fast Enough?



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The Challenge for Re-imagination of Chemistry Education to Embrace Systems Thinking

JOURNAL OF CHEMICAL EDUCATION
Editorial
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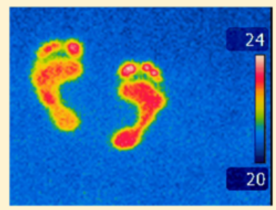
Telling Time: Chemistry Education in the Anthropocene Epoch

Peter G. Mahaffy*

Department of Chemistry, The King's University College, Edmonton, Alberta T6B2H3 Canada

ABSTRACT: An International Union of Geological Sciences working group is expected to soon formalize a determination that we have moved from the Holocene to the Anthropocene Epoch on the geologic time scale. In addition to reaching consensus on the scientific evidence for this change, this initiative is meant to raise awareness in other scientific communities of the effects of large-scale human activity on fundamental earth system parameters. In parallel, work is being done to understand the resiliency of our planet to the large human footprint, and to define and quantify the planetary boundaries that define a safe operating space for humanity. Many of these planetary boundaries are quantified by chemical measurements. We explore the implications of these parallel developments for chemistry educators.



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Chemistry For the Benefit of Earth & Its People

General Chemistry Educator's View

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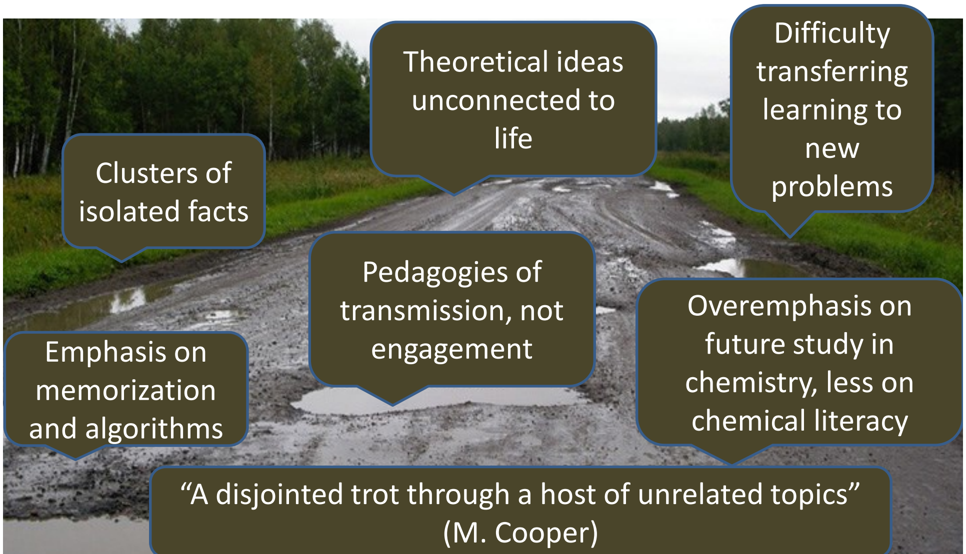
Chemistry For the Benefit of Earth & Its People



The View of Chemistry Learners?

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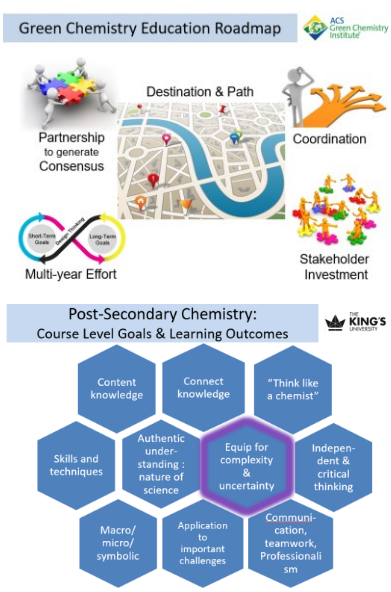
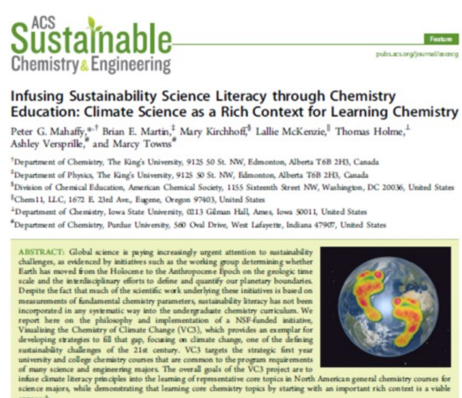
Emerging Systems Thinking in Chemistry Education – Examples




ACS Sustainable Chemistry & Engineering — Feature — pubs.acs.org/journal/ascecg

Infusing Sustainability Science Literacy through Chemistry Education: Climate Science as a Rich Context for Learning Chemistry

Peter G. Mahaffy,*,† Brian E. Martin,‡ Mary Kirchhoff,§ Lallie McKenzie,∥ Thomas Holme,⊥ Ashley Versprille,# and Marcy Towns#

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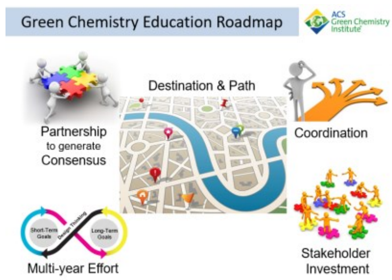

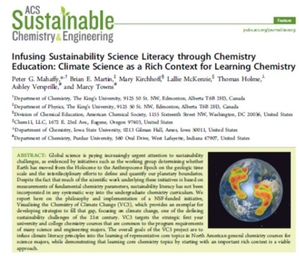

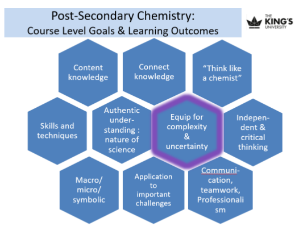

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How Could the Green Chemistry Education Roadmap Help Educators?

The Road map will define and clarify the needs for green chemistry education and…

- Make it easier to find and adopt the best materials and approaches
- Make it easier to get funding to develop and adopt materials
- Build capacity to adopt and teach green chemistry topics and themes
- Build capacity to create and develop innovative new materials

Resulting in..

- Clearer learning objectives and assessment
- Increased impact of teaching efforts
- Greater opportunities to engage in green chemistry education

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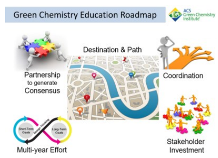
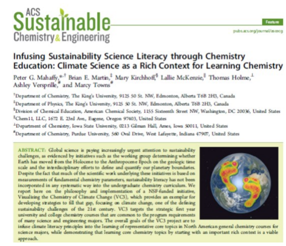
Emerging Systems Thinking in Chemistry Education – Examples

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Post-Secondary Chemistry:
Course Level Goals & Learning Outcomes

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Content knowledge
Connect knowledge
"Think like a chemist"
Skills and techniques
Authentic under-standing : nature of science
Equip for complexity & uncertainty
Indepen-dent & critical thinking
Macro/ micro/ symbolic
Application to important challenges
Communi-cation, teamwork, Professionalism

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Systems Thinking: Teaching/Learning from Rich Contexts

- The implementations of case studies or context-based learning that provide deep and rich opportunities for learning diverse concepts through contexts, and that nurture the use of higher order cognitive skills to connect concepts and apply the knowledge gained to new contexts.
- Motivating context is the starting point to develop scientific content for students rather than the more traditional approach of systematically building up general chemistry concepts and then introducing applications of those ideas."
- Potential to facilitate achieving affective domain objectives

P. Mahaffy, (2015). Chemistry Education and Human Activity, Chapter 1 in *Chemistry Education: Best Practices, Opportunities and Trends*, Garcia, J. Ed., Wiley-VCH: Weinheim.

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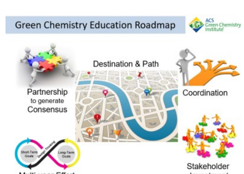

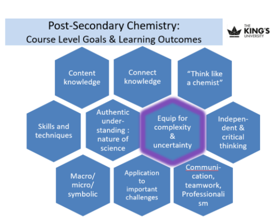

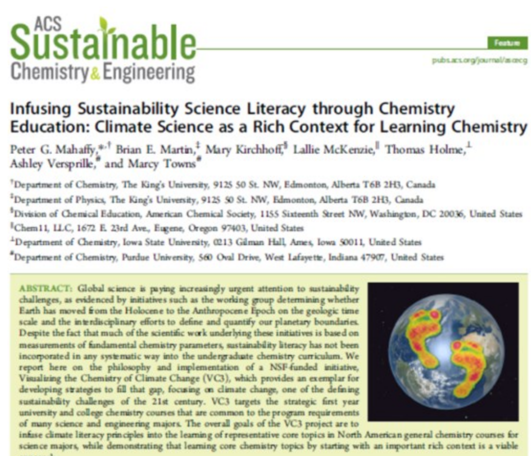
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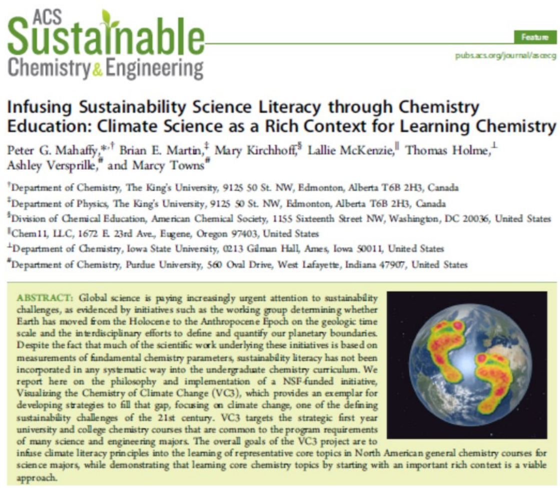
Visualizing the Chemistry of Climate Change



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ACS Sustainable Chem. Eng. 2014, 2, 2488–2494

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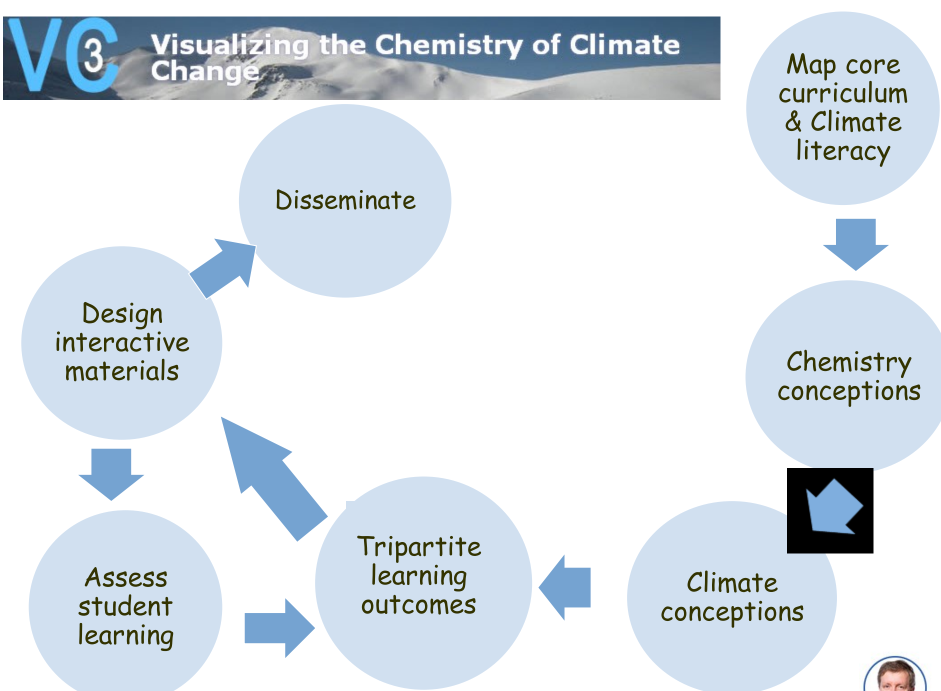
Visualizing the Chemistry of Climate Change



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Rich Context Concept Questions that Nurture Systems Thinking in Students

- **Isotopes**: How is 800,000 years of temperature data determined from ice core samples?
- **Gases:** Which atmospheric gases support life directly? Which gases support life by regulating the energy balance of our planet?
- **Acids/Bases:** How does atmospheric carbon dioxide influence the pH of the ocean? What are the implications for marine ecosystems?
- **Thermochemistry:** How is the way we power our planet altering Earth's energy balance?

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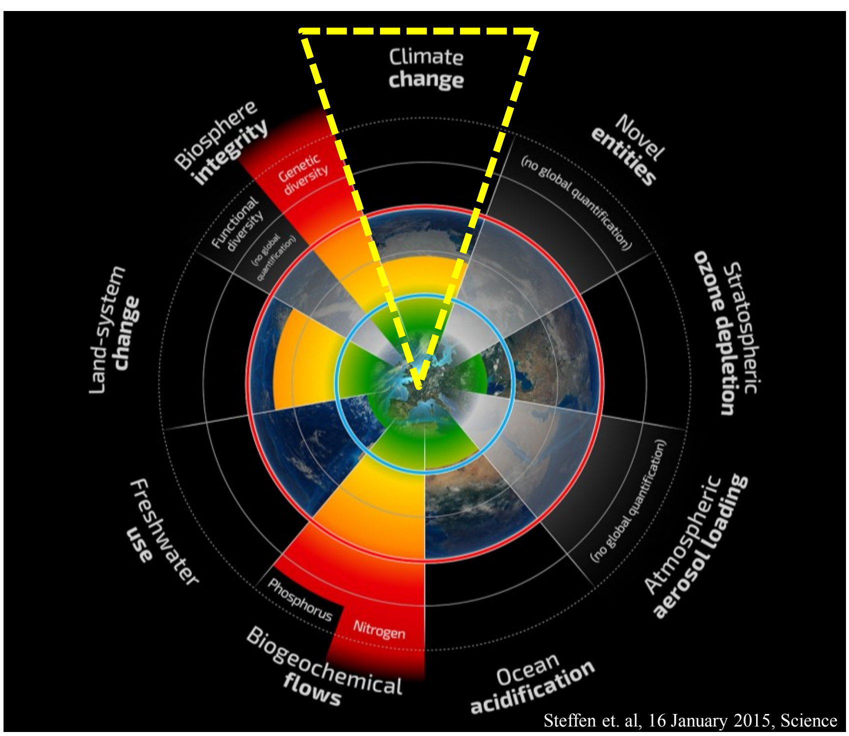

Steffen et. al, 16 January 2015, Science

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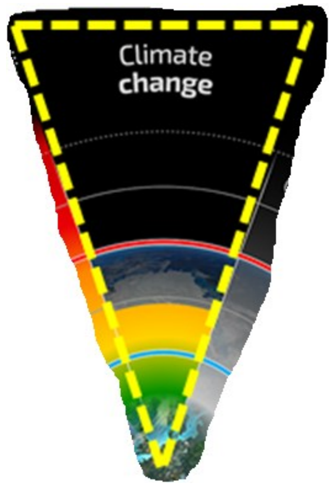

Control variable(s)	Planetary boundary (zone of uncertainty)	Current value of control variable
Atmospheric CO_2 concentration, ppm Energy imbalance at top-of-atmosphere, W m^{-2}	350 ppm CO_2 (350-450 ppm) Energy imbalance: +1.0 W m^{-2} (+1.0-1.5 W m^{-2})	396.5 ppm CO_2 2.3 W m^{-2} (1.1-3.3 W m^{-2})

Steffen et. al, 16 January 2015, Science

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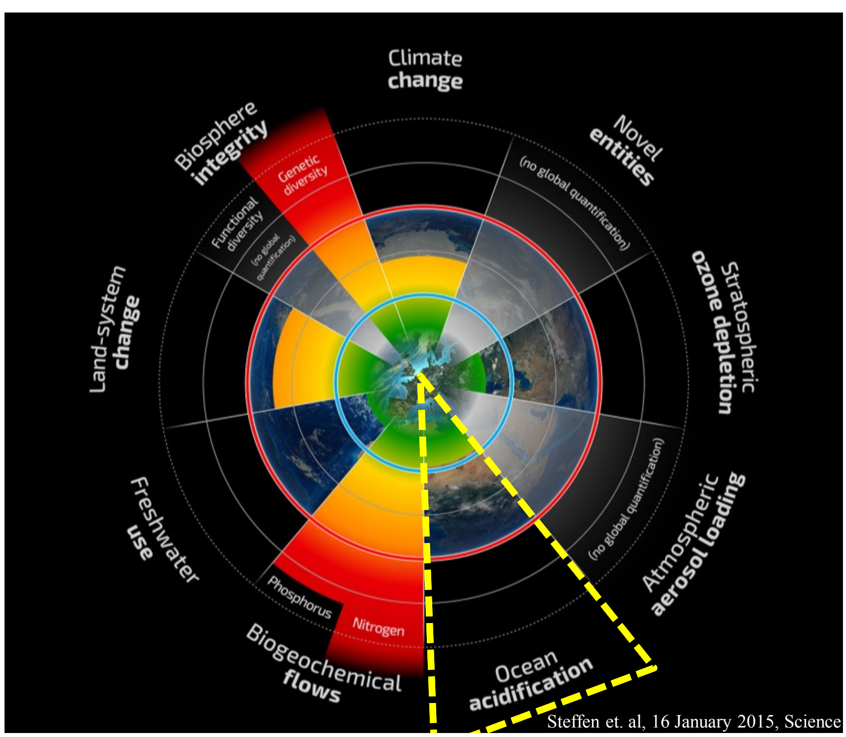

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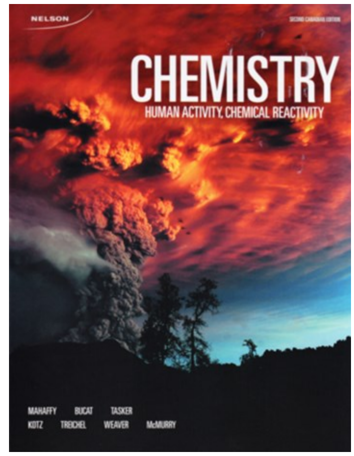
The Other CO_2 Problem
Effect of pH on Speciation of Carbon



Mahaffy, Bucat, Tasker, et. al, *Chemistry: Human Activity, Chemical Reactivity*, Nelson/Cengage, 2015.

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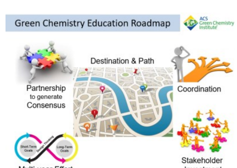

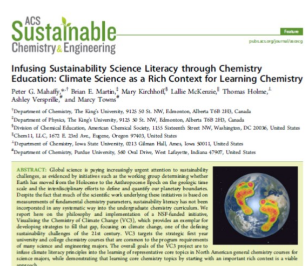
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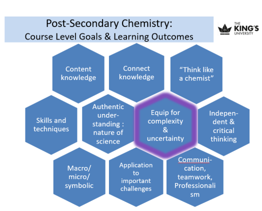

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How can chemistry education be re-imagined to better help the next generation guide human development on a rapidly changing planet?

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How can chemistry education be re-imagined to better help the next generation guide human development on a rapidly changing planet?

- We must meaningfully include systems thinking and multiple unfolding global challenges in our learning objectives and assessments!
- One small step: Proposal underway for an IUPAC project to articulate program and course level learning objectives based on systems thinking and with the goal of helping the next generation to guide human development on our rapidly changing planet.
- Recommend change strategies for implementation
- Consider how to best assess completion of these LO, including in program accreditation standards and incorporation into standardized exams.

Contact peter.mahaffy@kingsu.ca for more information

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Acknowledgements


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New Braunschweig, Germany


Prof. Stephen Matlin
London, UK


Prof. Goverdhan Mehta
Hyderabad, India


Jenny MacKellar

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- Marcy Towns and Ashley Versprille (Purdue)
- Brian Martin (King's, Edmonton, Canada)
- Mary Kirchhoff (ACS)
- Lallie McKenzie (Oregon)
- Cathy Middlecamp (Wisconsin)
- Tom Holme, Evaluator (Iowa State)

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VC3 Visualizing the Chemistry of Climate Change

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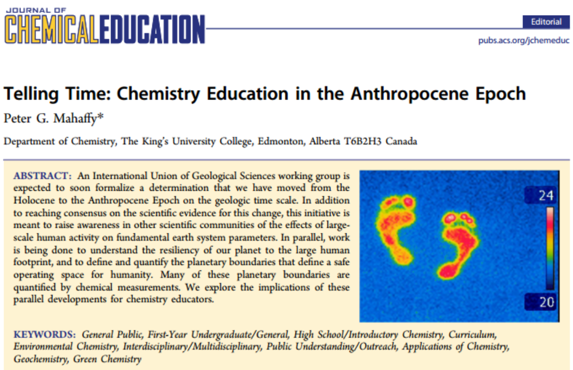
Taking it Further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Editorial

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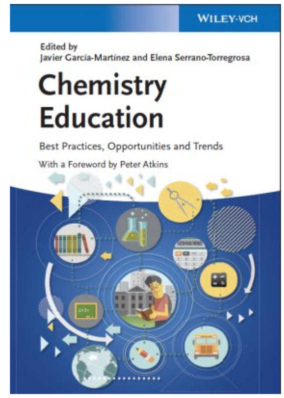

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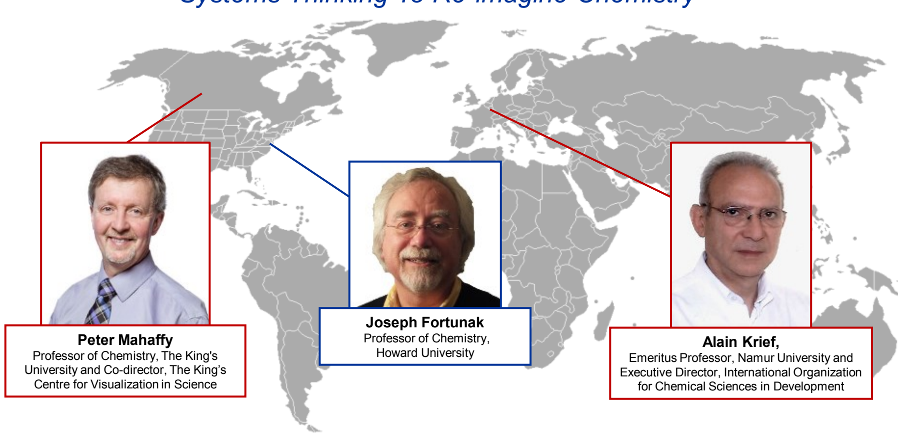

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Bryan Tweedy, Manager, Career and Professional Resources, American Chemical Society

Thursday, September 22, 2016

Chemistry of Longevity: Rapamycin's Secret Past and Potential for a Longer Life

Matt Kaeberlein, Professor of Pathology, University of Washington

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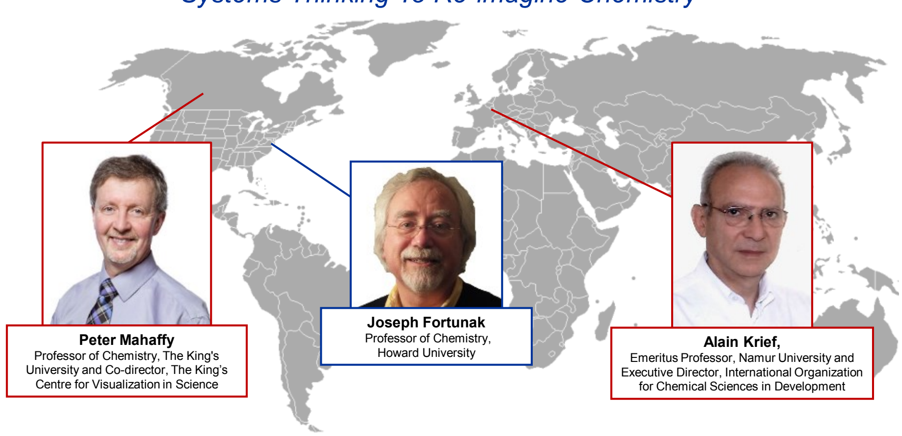

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Matt Kaeberlein, Professor of Pathology, University of Washington

Bethany Halford, Senior Editor, Chemical & Engineering News

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