CHEM 489 – Spring 2020
Advanced Environmental Chemistry
Introduction to Green Chemistry
Dr. Brush

February 18 (Tuesday):

- **Journal Club-4 papers due Today**
- **Worksheet-3 due Today**
- **Return of WS 1 & 2 (answer keys posted)**
- **Class Presentation Project – Topic due Today**
- **Journal Club-4 presentations - Thursday, Feb 20**
- **Class Presentations Begin – Tuesday, Feb 25**
- **TODAY: Introduction to Green Chemistry:**
  - **Systems Thinking**

Green & Sustainable Chemistry….making connections

- Risk = Hazard x Exposure x Vulnerability

- Green & Sustainable Chemistry: **maximize efficiency** & **minimize hazardous effects** on human health and the environment.

- Sustainable Development: Meeting the **Economic, Environmental and Social** needs of the present without compromising the ability of future generations to meet their own needs.

Green & Sustainable Chemistry:
Sustainability at the Molecular Level

12 Principles of Green Chemistry

1) Prevention
2) Atom Economy
3) Safe Processes
4) Safer Chemicals
5) Safer Solvents
6) Energy Efficiency
7) Renewable Feedstocks
8) Reduce Derivatives
9) Catalysis
10) Bio-degradation
11) Real-time analysis
12) Accident Prevention

- Efficient use of raw materials (present and future)
- Waste management
- Limit negative impacts on health, safety and the environment

Role of Chemistry in addressing Global Challenges

- ***The World's "to-do" list.*** An agenda for all countries to address world-wide challenges of poverty, protecting the planet and ensuring prosperity.

- Chemists have more to do with making the world more sustainable than any other profession.

- **Unique learning experience for students to study and address global issues from a <u>multidisciplinary</u> perspective.**

Green & Sustainable Chemistry Education

Improving Teaching & Learning;

- Our pedagogy must evolve to better **engage** students in the learning process through teaching/learning **partnerships** focused on the **interconnections of chemistry with global sustainability challenges**.

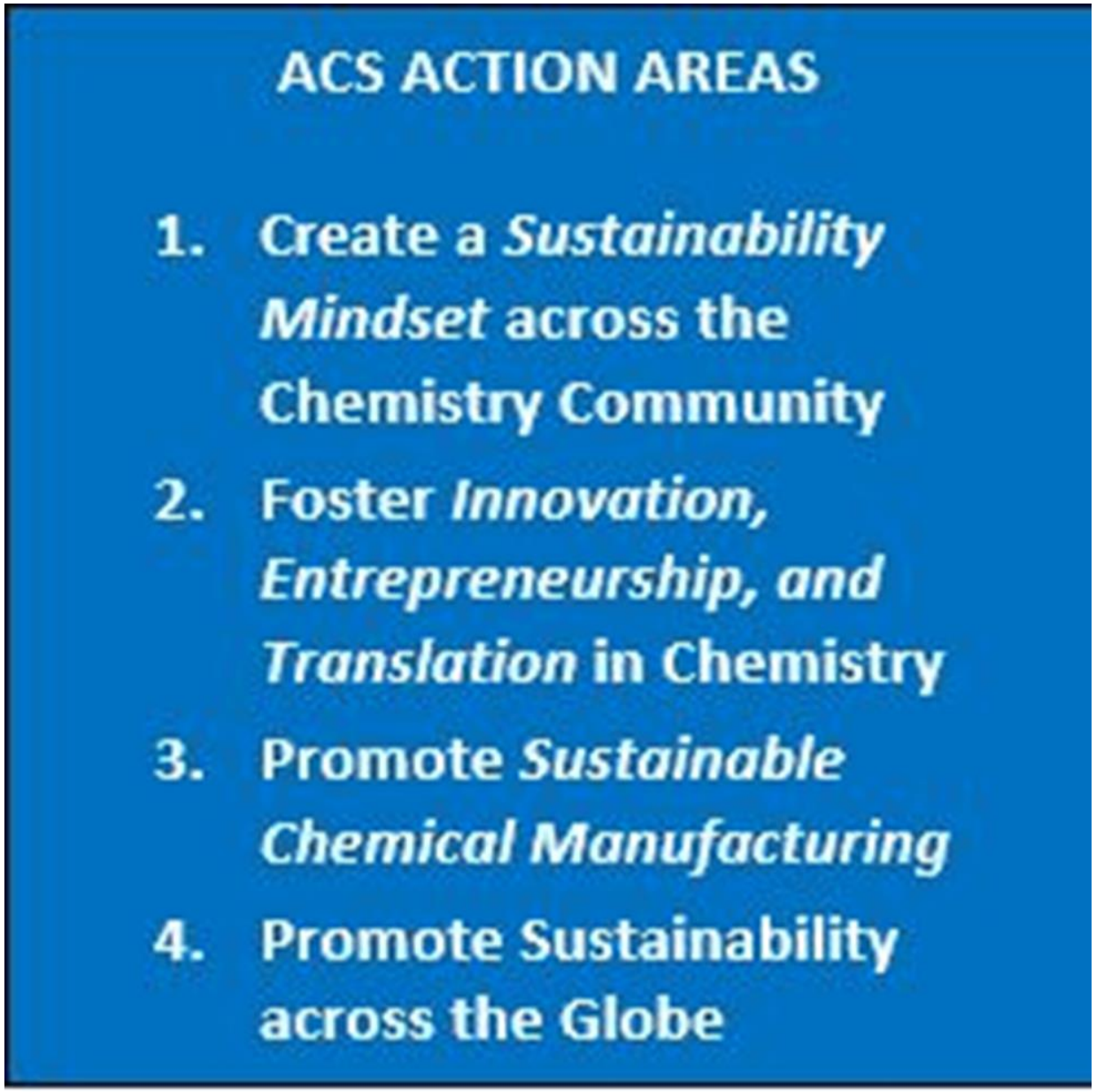
- Evolving to teaching/learning **partnerships** focused on the interconnections of chemistry with global sustainability challenges.

Paradigm shift in chemistry education

- **The chemistry enterprise is NOT sustainable:**
  - Create sustainability mindset in how we think about and do chemistry
  - Change the role and perception of chemistry in the world
  - We can define modern chemistry education: paradigm shift

Green Chemistry Institute Action Plan for the Chemistry Enterprise

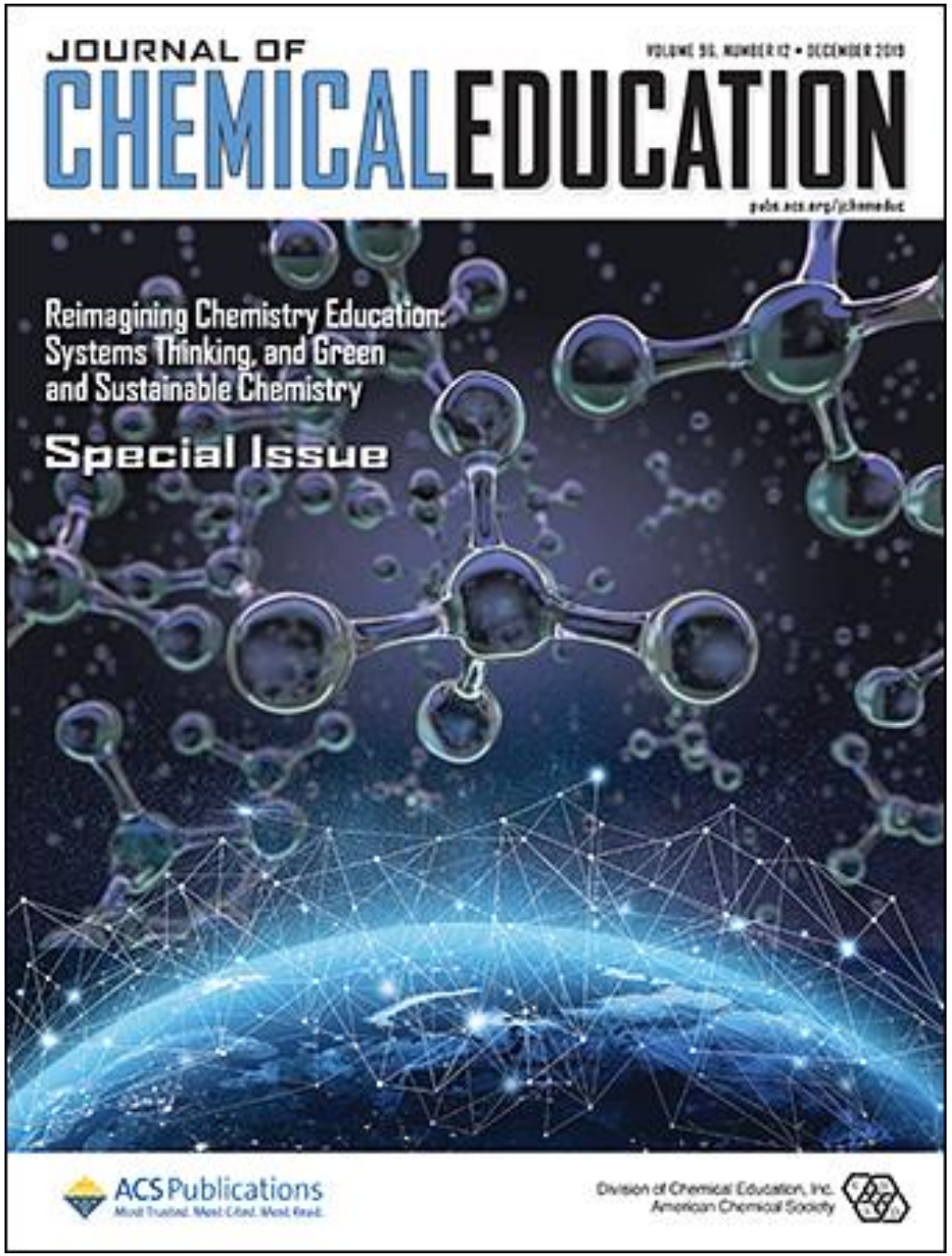
- **ACS-CEI Project:** Engage chemistry educators to integrate and scaffold **green and sustainable chemistry, systems thinking and the UN Sustainable Development Goals** into teaching, research and outreach.



Systems Thinking - in Chemistry Education

Systems Thinking in Chemistry Education - Complementary approach in teaching, learning and research for studying and understanding complex global challenges.

- The IUPAC STICE Project aims to use systems thinking to educate students about the **molecular basis of sustainability**.
- Goal is for chemistry majors to graduate with an understanding of major global challenges, and knowledge of how to address those in the UN SDGs.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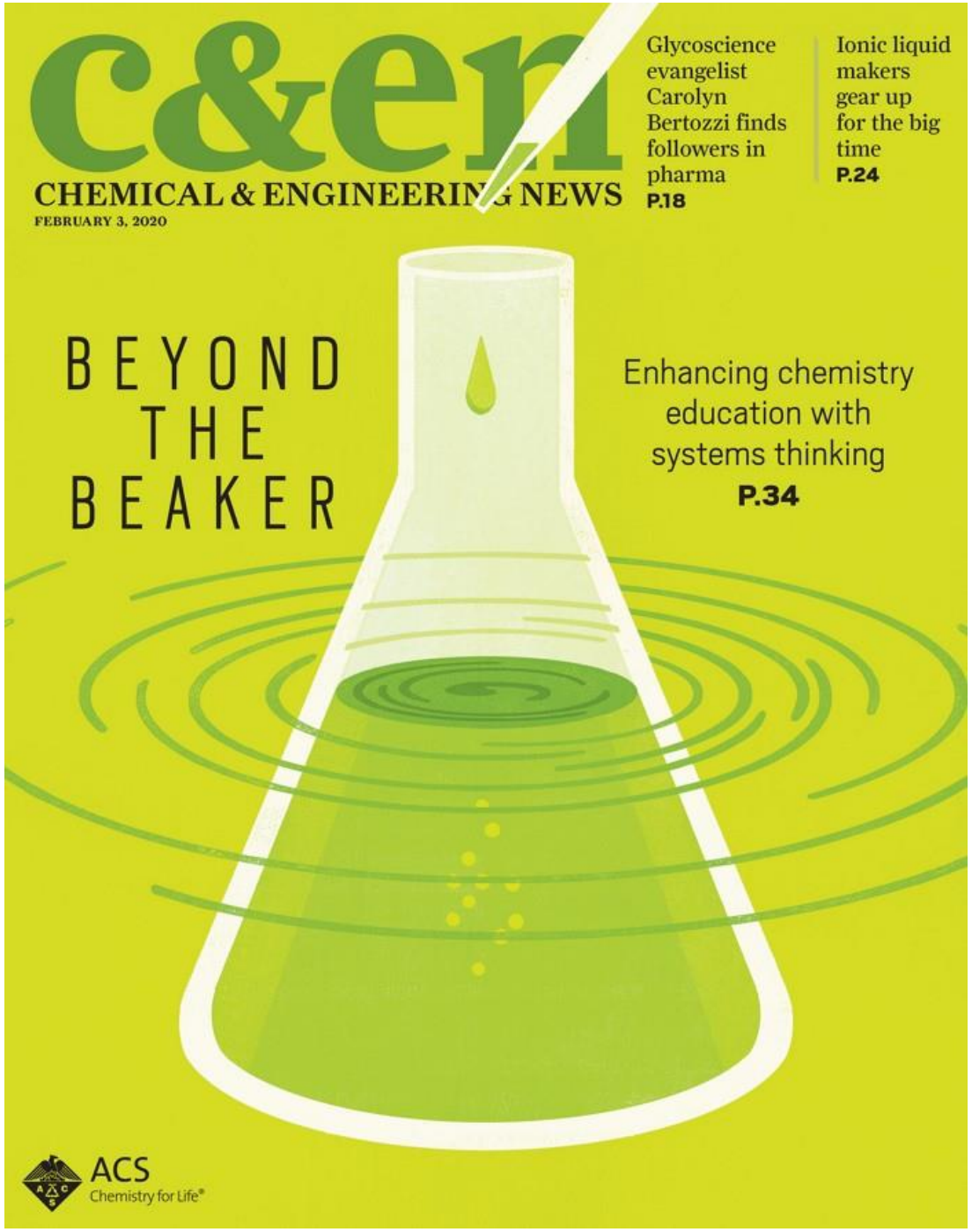
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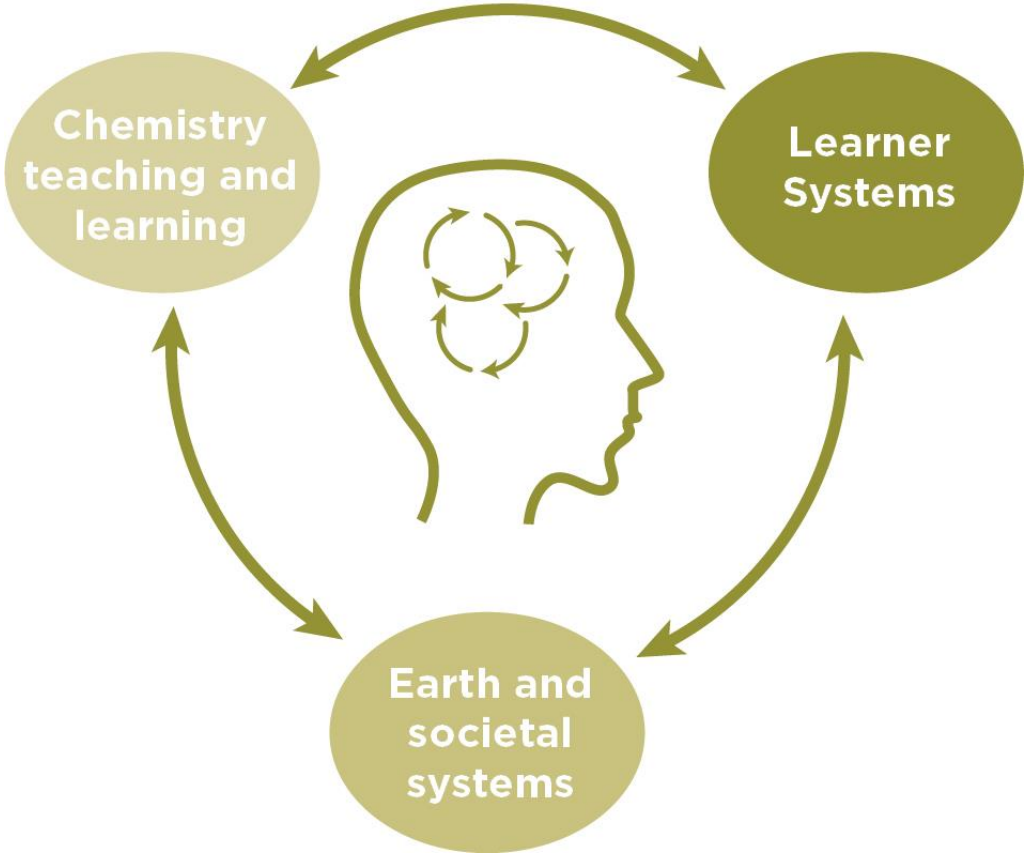
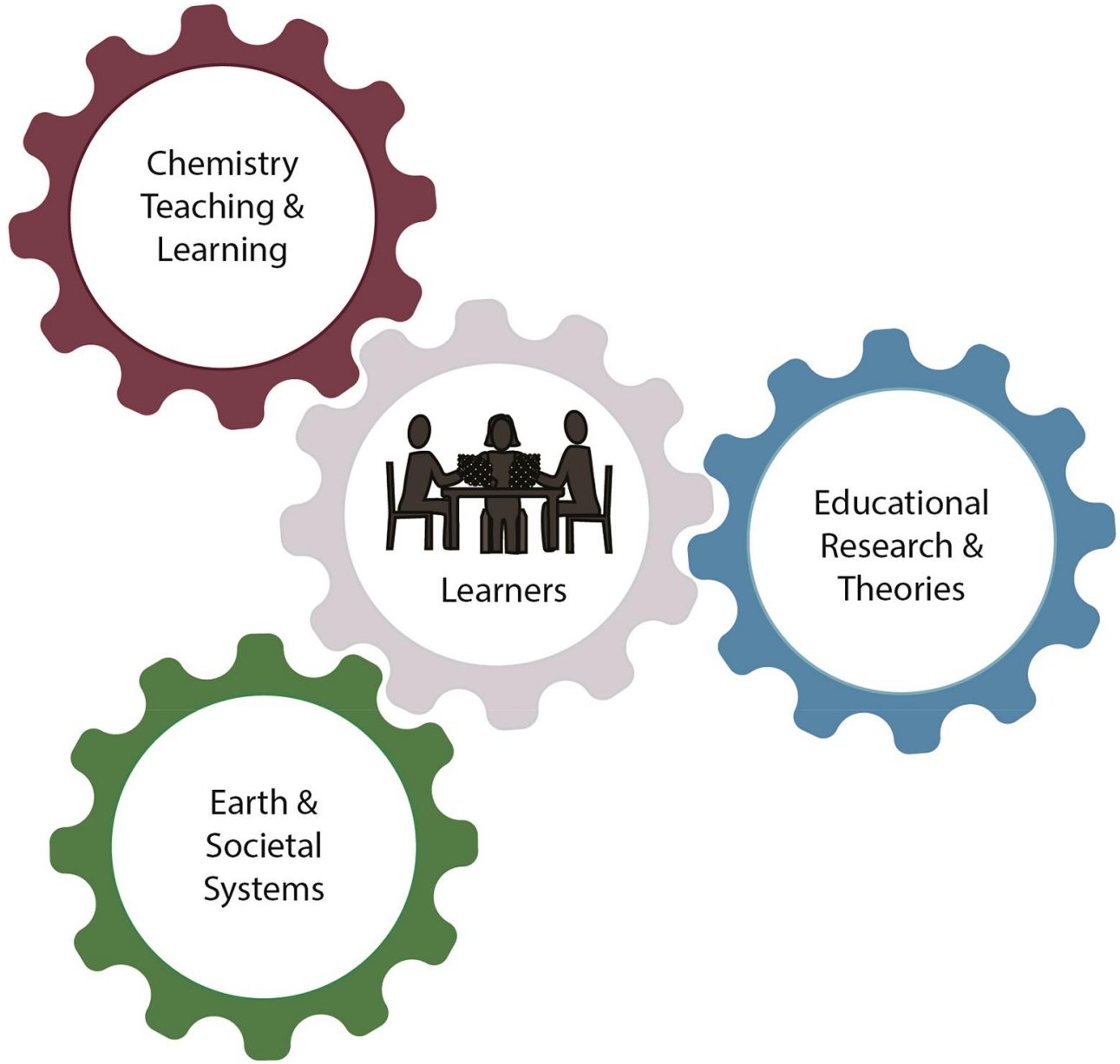
Systems Thinking Terminology

- NOW – Fragmented knowledge of chemical reactions & processes (example is any orgo reaction/lab).
- **Systems Thinking** – Holistic understanding of how knowledge of chemistry connects to the dynamic, complex social, technological, economic, and environmental systems at work in our world.



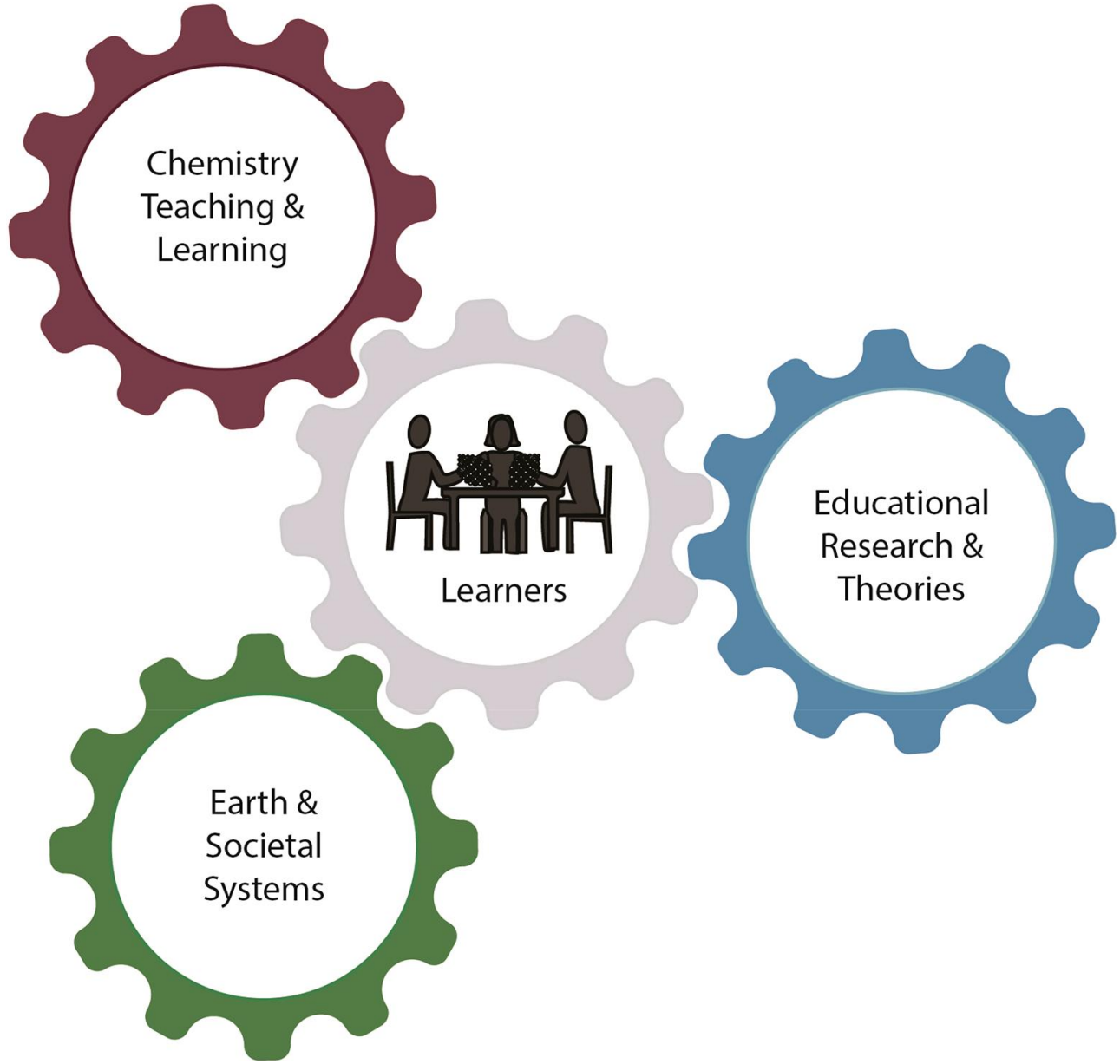
Systems Thinking Terminology

- Learner (researcher) is in the center of a system of learning and exploration or discovery. Three interconnected nodes or subsystems
- Dynamic interconnection of the nodes as a part of a system of learning/discovery, and the influence that the activity of each element of learning has on the others.



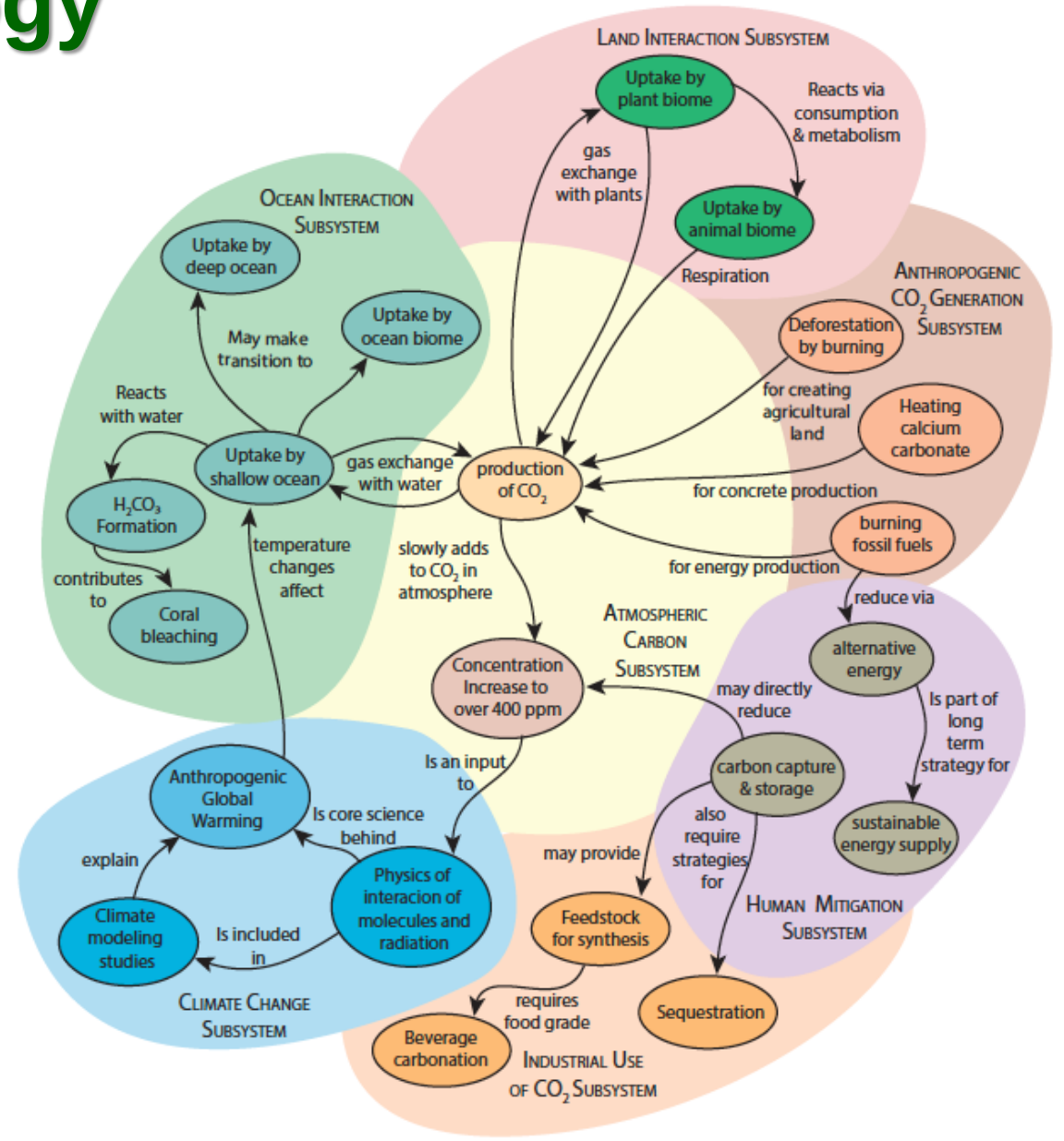
Systems Thinking Terminology

- Systems thinking framework is a central guiding theme of the **molecular basis of sustainability**.
- Chemists will be better equipped to address multiple global challenges
- Tied to the material basis of society, economy and environment (3P's).
- How present and future generations can live within the material limits of the natural world.



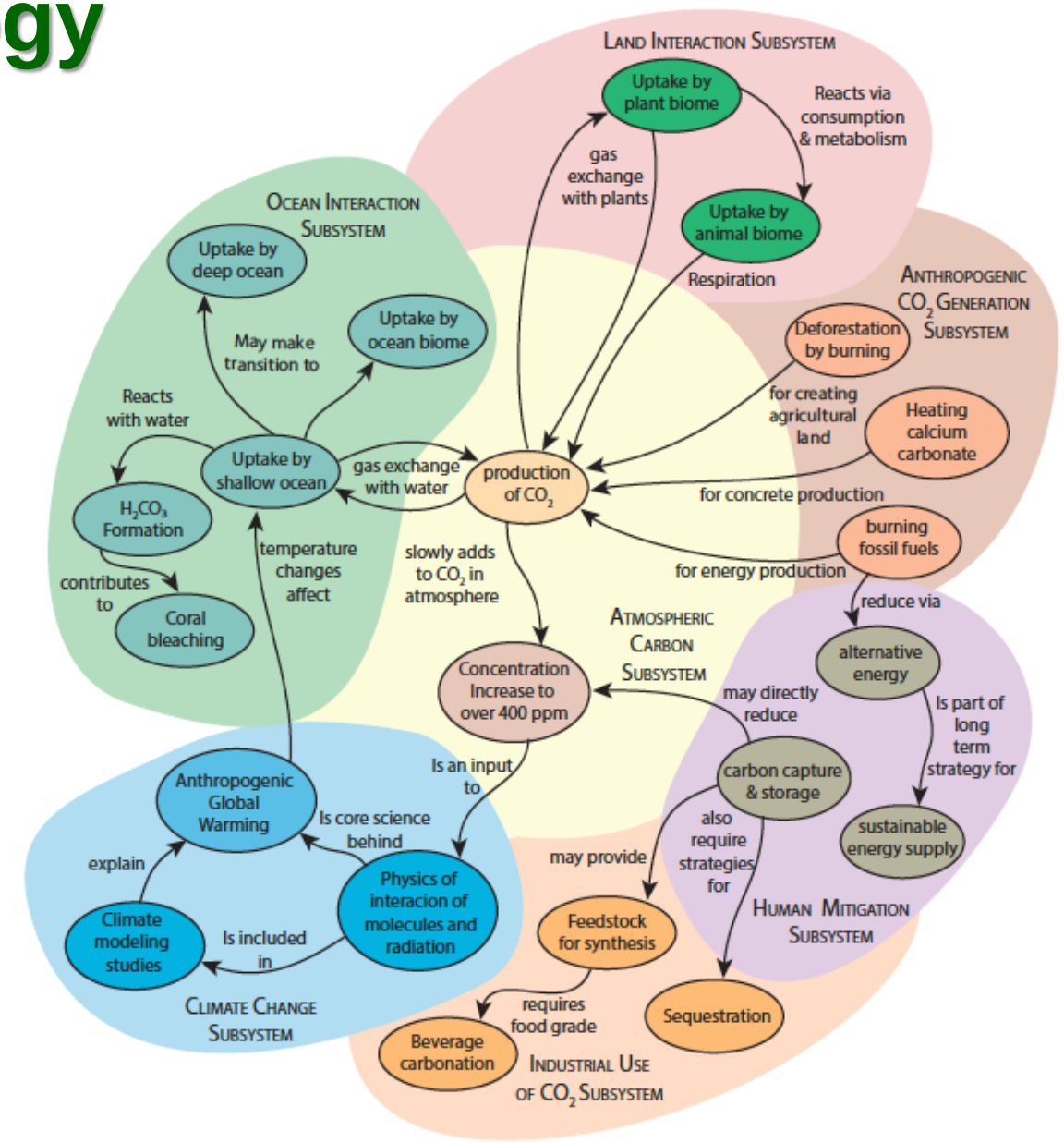
Systems Thinking Terminology

- Systems thinking develops strategies for problem solving, and tools to visualize interconnections and relationships among parts of a system.
- Visualization tool: **System-Oriented Concept Map Extension (SOCME).**
- Examines how the behavior of the system changes over time.
- Studies interactions among systems parts.
- Research project!



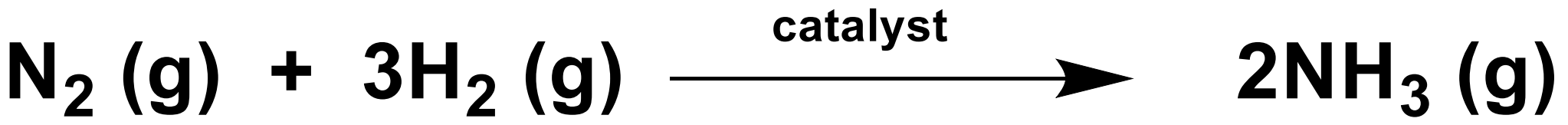
Systems Thinking Terminology

- SOCME – Organize and visualize the complex interplay of chemical “processes” with scientific, societal and environmental inputs, outputs and consequences, as well as intended and unintended consequences.
- Where materials come from, how they are transformed and used, what happens at the end of their life span, and the role they play in societal and environmental systems.



Example: Haber-Bosch Process

- Presentation of chemical reactions and processes as isolated facts intended to demonstrate aspects of descriptive chemistry, fundamental concepts, principles, or mathematical calculations related to thermodynamics and equilibrium systems.
- Recipients of Nobel Prizes in Chemistry.
- How does this knowledge address the sustainability of earth and societal systems?

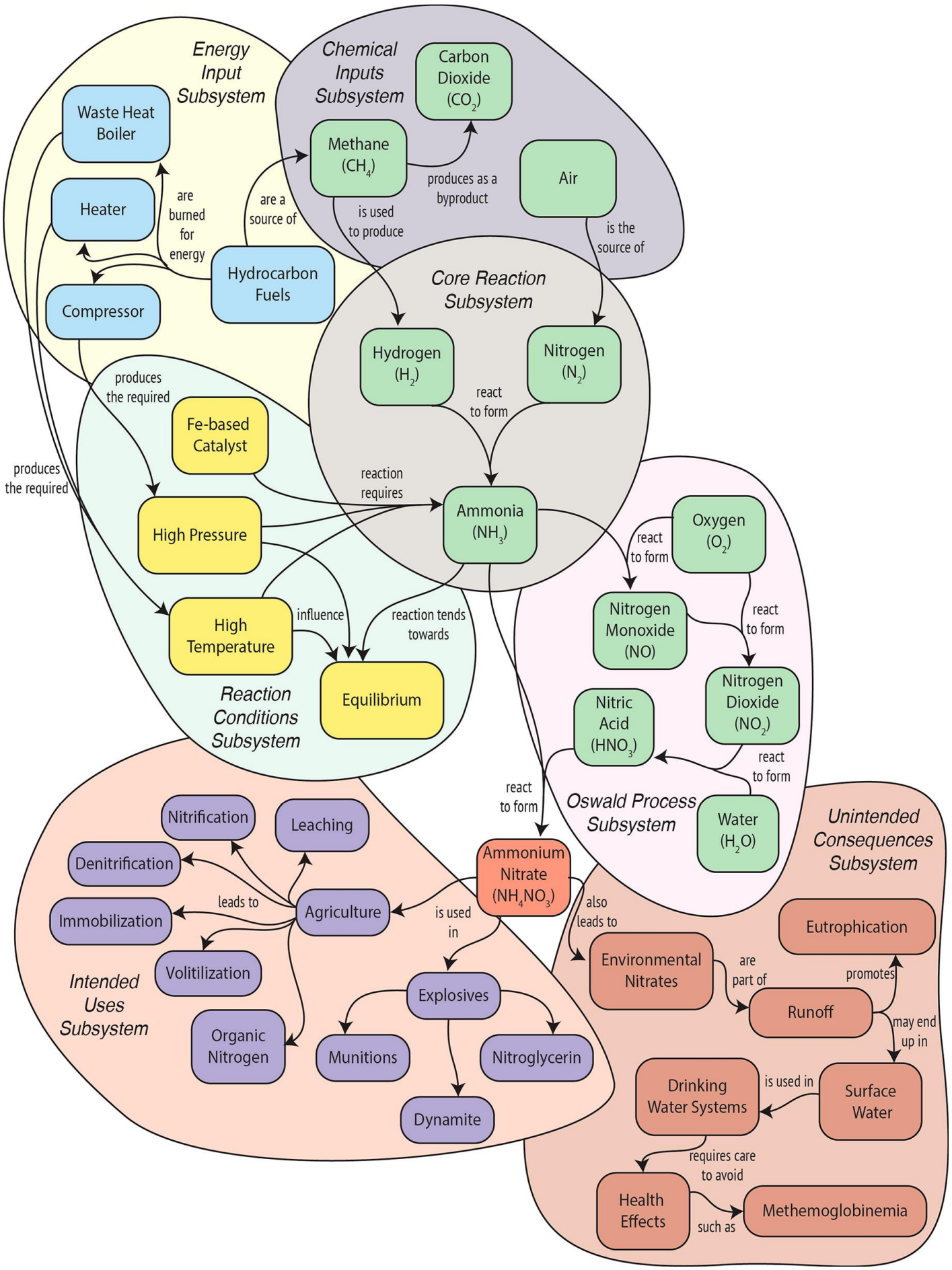


Example: Haber-Bosch Process

- Systems thinking can equip instructors to zoom out from a narrow consideration of the reaction to a more integrated approach to teaching.
- Highlights ways that important compounds of nitrogen participate in **intended** ways in societal and economic systems, the resultant **unintended** impacts
- Also, chemical and energy inputs, the reaction conditions, the products arising from the Ostwald process, and the intended and unintended uses of those products, with consequences for society
- Note boundaries around those subsystems.

Systems Thinking (SOCME)

- A system-oriented concept map extension (SOCME) showing some of the relevant subsystems of the core Haber−Bosch reaction that connect the core reaction/process to broader STI and earth and societal systems. Boundaries can be drawn around subsystems based on learning outcomes for a particular course or topic.


Energy Input Subsystem
Waste Heat Boiler
Heater
are burned for energy
Hydrocarbon Fuels
Compressor
Chemical Inputs Subsystem
Carbon Dioxide (CO_2)
Methane (CH_4)
produces as a byproduct
are a source of
is used to produce
Air
is the source of
Core Reaction Subsystem
Hydrogen (H_2)
Nitrogen (N_2)
react to form
Ammonia (NH_3)
reaction requires
produces the required
Fe-based Catalyst
produces the required
High Pressure
High Temperature
influence
reaction tends towards
Equilibrium
Reaction Conditions Subsystem
Oxygen (O_2)
react to form
Nitrogen Monoxide (NO)
react to form
Nitrogen Dioxide (NO_2)
Nitric Acid (HNO_3)
react to form
Water (H_2O)
Oswald Process Subsystem
react to form
Ammonium Nitrate (NH_4NO_3)
Nitrification
Leaching
Denitrification
leads to
Agriculture
Immobilization
Volitilization
Organic Nitrogen
Intended Uses Subsystem
is used in
Explosives
Munitions
Nitroglycerin
Dynamite
also leads to
Unintended Consequences Subsystem
Eutrophication
Environmental Nitrates
are part of
Runoff
promotes
may end up in
Drinking Water Systems
is used in
Surface Water
requires care to avoid
Health Effects
such as
Methemoglobinemia