Type them into questions box!

“Why am I muted?”
Don’t worry. Everyone is muted except the presenter and host.
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How do ideas make it from the lab to the real world? Discover the ins and outs of the chemical industry whether you are looking to start a business or desire a priceless industry-wide perspective.

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- Search Examples from Green or Sustainable Chemistry
- One hour webinar with experienced CAS experts including Q&A
- Pick from two options on Friday, September 10:

German Young Chemists' Network
JungChemikerForum (JCF) of the Gesellschaft Deutscher Chemiker (GDCh)

- Personal & Professional Development for Young Chemists
- Modern Impulses for the Future of Chemistry & Chemical Societies
- Chemistry Outreach & Cooperation for the Benefit of Society

JCF Sustainability Team
The European Young Chemists’ Network

- Diverse team representing 35,000+ early-career chemists from 28 countries
- Members of the national chemical societies are automatically members of EuChemS and the EYCN!
- Projects: Workshops, Webinars, Photography and Video Contests, Awards, Podcast, European Young Chemists Meeting, Interviews, Information on studying and working in Europe, Science Policy and much more ...

The Green Evolution Webinar, 9th September 2021

www.eycn.eu/podcast

Chemistry Rediscovered
Sir Geoffrey Wilkinson EYCN Video Competition

Topic: Safety in Chemistry
Deadline: 30th of September 2021

www.eycn.eu/cr2021

Webinars
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and more

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ACS Webinars
Advancing Polymer Science with Organic Catalysts

Date: Wednesday, September 15, 2021 @ 2:30pm ET
Speaker: Andrew Dave, University of Birmingham, UK and Robert Waymouth, Stanford University
Moderator: Rachel Leter, University of Virginia

What You Will Learn:
- Application of organic catalysts for stereoccontrolled step growth polymerisation
- Development of high temperature organic catalysts for polymerisation and depolymerisation
- Using organic catalysts to selectively depolymerise plastic mixtures
- New designs for ultrasound organocatalysts polymerisation reactions
- Synthesis between continuous flow chemistry and rapid organocatalytic polymerisation reactions
- New catalytic enabling the design of emerging functional materials for gene delivery

Co-produced with: ACS Division of Polymer Chemistry

Designing Around Structural Alerts in Drug Discovery

Date: Friday, September 17, 2021 @ 2:30pm ET
Speaker: Nick Meanwell, Bristol Myers Squibb
Moderator: Deepak Dole, Cretex Pharmaceuticals

What You Will Learn:
- The identity of structural alerts that have been associated with problems in drug discovery and development
- The fundamental mechanistic organic chemistry underlying structural alerts that are subject to bioactivation
- Strategies and tactics to design around structural alerts

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

ACS Chemistry for Life®
Service Dogs in Your Chemistry Lab

Date: Wednesday, September 22, 2021 @ 2:30pm ET
Speaker: Patricia Neblin, Saint Peter’s University (Cayly Ramp, Empower Ability Consulting, LLC; Ashley Heyert, Independence Science
Moderator: Betha Buiu, Indiana University Purdue University Indianapolis

What You Will Learn:
- What does the Americans with Disabilities Act cover regarding access rights for service dogs?
- How is a service dog selected for certain jobs or disabilities, and what type of training is required?
- What types of service dogs exist and what is the process to obtain one

Co-produced with: Chemists with Disabilities (CWD) Committee, ACS Department of Diversity Programs, and ACS Chemistry Inclusion & Respect Advisory Board

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Welcome! Willkommen!

Webinar presented within the
ACS-GDCh co-operation agreement

September 9, 2021
The Green Evolution: Sustainable Chemistry in Global Scholarly Education

MARY KIRCHHOFF  
Executive Vice President of Scientific Advancement, American Chemical Society

H.N. CHENG  
2021 ACS President and Research Chemist, US Department of Agriculture

FRANK ROSCHANGAR  
Highly Distinguished Research Fellow, Boehringer Ingelheim and co-chair, ACS Pharmaceutical Roundtable

KLAUS KÜMMERER  
Director, Institute of Sustainable and Environmental Chemistry and Chair of Sustainable Chemistry and Material Resources, Leuphana University Lüneburg

Presentation slides are available now! The edited recording will be made available as soon as possible.  
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This ACS Webinar is co-produced with ACS on Campus, ACS Green Chemistry Institute, CAS, and German Chemical Society.

American Chemical Society

Green Chemistry – The Next Evolution of Chemistry Research

H. N. Cheng  
September 9, 2021
Sustainability and Green Chemistry

- Sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their own needs.
  - United Nations in 2015 adopted 17 Sustainable Development Goals (SDGs), trying to end poverty, protect the planet, and promote peace and prosperity
- Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.
In a global survey of 27,000 representatives from politics, business, science, and research in 2018-2019, what percentage of them is aware of the UN’s Sustainable Development Goals?

- Over three quarters (70%)
- About half (50%)
- About a quarter (25%)
- About a tenth (10%)
- About a twentieth (5%)


Economic Trends

- **Commoditization of chemical products**
  - Price pressure. Profit challenge.
  - New products needed to complement current products

- **Competitiveness of chemical products**
  - Product parity. Erosion of competitive advantages
  - Green technology may provide a new competitive edge

- **Feedstock supply**
  - Most current raw materials from petroleum sources. Supply/demand
  - Biobased materials represent sustainable and degradable alternatives

- **Corporate advantages**
  - Green chemistry can increase process efficiency, reduce waste, enhance safety, attract talent, and create new business opportunities
  - Green products may provide greater sales for some applications
Safety and Environmental Trends

- **Health and safety**
  - Negative publicity about chemicals and their effects on health and safety

- **Environmental stewardship**
  - Pollution of air and water

- **Improved analytical instrumentation**
  - Increased sensitivity of detection of lower levels of contaminants

- **Regulatory agencies in many countries and regions have tightened their regulations relating to chemicals**

- **Green chemistry can provide safer and more eco-friendly products and processes**
  - A good way to counter the negative image of “chemicals.”

Socio-Political Trends

Increasing international acceptance of sustainability as a useful and needed development - UN Sustainable Development Goals

Chemistry’s Role in the SDGs

- Chemistry, with its broad reach into technology, the economy, human health, and security, has a part to play in all SDGs
- Seven SDGs are seen as being particularly strategic and relevant to the chemistry community

Support for Sustainable Green Chemistry

The sustainability/green chemistry concept is catching on:

- U.S. House of Representative (2019) and Senate (2020) passed a bill to direct the White House Office of Science and Technology Policy to support sustainable chemistry and develop road map
- Active R&D is on-going in academia, industry, and government labs
- P&G unveiled sustainability goals, making the packaging of its top 20 brands 100% recyclable or reusable (4/22/18)
- DuPont announced its 2030 Sustainability Goals, including 9 goals relating to innovation, operations, and inclusivity (10/30/2019)
- Unilever will source 100% of its cleaning and laundry product formulations with renewable or recycled carbon (2/9/2020)
- Several other companies have also announced their plans for sustainable products or processes
Scientific Trends

• **Some chemical fields are mature**
  – The knowledge of synthesis and analysis is generally known
    • Chemistry professionals and students can be trained to do them
  – Many segments of chemical industry are mature
    • Examples are commodity industrial chemicals, fertilizers, paints, textiles, etc.

• **Some chemical fields are promising or emerging ("new frontiers")**
  – Nanotechnology and biotechnology affords further opportunities for chemistry
  – Other areas include energy storage, catalysis, self-assembly, sensors, organic electronics, quantum computing, sustainability/green chemistry

• **Multidisciplinarity**
  – Many advances are being made at the interface between chemistry and other disciplines, such as biology, medicine, physics, nanotechnology, and computer technology.
  – *Sustainability* is a good example of the need for multidisciplinary approaches

• **New applications of chemical skills**
  – Examples include the grand challenges today (such as *sustainability*, energy, clean air and water, food, population, climate change, diseases)

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Sustainability Publications

Number of papers including "sustainable", "sustainability", or "Green Chemistry" in the title or abstract. Thanks to Matt McBride of CAS for supplying the data, 9/1/21.
Conclusions

- **Sustainability/green chemistry represent the next evolution of chemistry research:**
  - The economic, socio-political, and environmental trends all favor them
  - They are compatible with the current scientific trends
    - New Frontiers (promising and emerging)
    - Multidisciplinary R&D
    - New applications of chemistry skills

- **They represent a great opportunity for the future**
  - Re-shape chemistry’s image
  - Work in an up-and-coming and interesting scientific area
  - Apply our creativity and ability to open up new avenues
  - Contribute towards a better world tomorrow

Audience Survey Question

How much average waste, per kg API, is co-generated during production of a commercial small molecule API, starting from commodity-type starting materials?

- 17 kg
- 99 kg
- 182 kg
- 1430 kg
Green Chemistry in Scholarly Education in Germany & Globally

Value Through Green Chemistry in the Pharmaceutical Industry

Frank Roschhangar, PhD, MBA
ACS Webinar ● September 9, 2021

About Sustainable Drug Development

We are committed to meet the needs of patients around the world while substantially reducing our environmental footprint!

Footprint of Pharmaceuticals *

182 kg of waste per kg API

* Based on iGAL aligned Gate-to-Gate assessment of 29 commercial small molecule APIs. ACS Sustainable Chem. Eng. 2021, ASAP. DOI: 10.1021/acssuschemeng.0c09940 (Open Access)
How can Green Chemistry tie into a Corporate Sustainability Strategy?

**ECO-DESIGN**
- Designing for Recoverability/Recyclability
- Designing for Reuse
- Designing for Energy Efficiency
- Packaging Minimization
- Life Cycle Thinking
- Material Safety
- Green Chemistry

**GREEN CHEMISTRY**
1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

*At BI, we intend to move towards a circular economy by incorporating the design principles of (1) Design for the Environment (Eco-design) and (2) Green Chemistry into the R&D of all pipeline medicines.*


Understanding a Medicine’s Life Cycle

![Diagram of a Medicine’s Life Cycle](image)

ACS Sustainable Chem. Eng. 2021, ASAP. DOI: 10.1021/acsuschemeng.1c01940 (Open Access)
How can Metrics Enable Green Chemistry?

**Enable Eco-Design**
- we can identify major contributors to the environmental footprint of a product
- we can compare alternatives (materials, unit operations and processes) to help make eco-friendly development decisions and identify opportunities to apply sustainable sciences, technologies and strategies

**Case study** of identifying environmental hot spots for two commercial APIs *

![API Breakdown](image)

**Solvents contribute the most to the footprint** → focus on solvent selection and on decreasing solvent use

* Cradle-to-Gate data obtained with PMI-LCA Tool from the ACS GCI Pharmaceutical Roundtable

How Green is your Green Chemistry? **iGAL 2.0** *

[Link to iGAL website](https://www.acsgcip.org/toolsforinnovationinchemistry/greenchemistry-innovation-scorecard-calculator/igal/)

- 13 pharmaceutical companies from 2 industry consortia
- 2 universities
- Prof. Sheldon

* ACS Sustainable Chem. Eng 2021, ASAP. DOI: 10.1021/acssuschemeng.1c01340 (Open Access)
An Industrial Application of Green Chemistry in Pharma

Industrial example of a biocatalytic cascade:*  

The pharma industry depends on motivated and creative green chemists to make a difference and bring innovative, effective, safe and sustainable medicines to patients


Green Chemistry and Sustainable Chemistry In Scholarly Education in Germany & Globally

Prof. Dr. Klaus Kümmerer
Institute of Sustainable Chemistry

LEUPHANA UNIVERSITY OF LÜNEBURG  
- A UNIVERSITY FOR FREEDOM AND RESPONSIBILITY  
- A HUMANIST UNIVERSITY  
- A SUSTAINABLE UNIVERSITY  
- AN ENTREPRENEURIAL UNIVERSITY
http://www.leuphana.de/en/institutes/isec.html

Research & Education
International Sustainable Chemistry Collaborative Center
www.isc3.org
The Back Side of “Success” Story of Chemical Industries

- Thereof approx. > 30,000 environmentally relevant, products of incomplete degradation not included (German EPA, 2010)
- Hazardous to health 62 % of chemicals volume used in Europe 2016 (Source: European Environmental Agency)
- Ca. 1.6 mill. deaths in 2016 attributable to chemicals, many more affected (Source: World Health Organization)
- Neurological behavioural disorders caused by chemicals: Costs >170 Bill. US $ per year in EU (Source: UNEP Environment 2019)
- Several hundred synthetic chemicals present in humans (Source: UNEP Environment 2019)
Trend
Use of Resources Will Double Until 2060

Non renewable

Mostly non renewable

Mostly renewable

Sustainability
(Most profound human value Proposition)

Broader Normative Framework

Human Value Proposition: Greener is better

Human Value Proposition: Circular is better

Human Value Proposition: More Sustainable is better

Chemistry for a Circular Economy

Chemicals
Processes
Materials
Products

Systems Thinking

Non Chemical Design

Alternative Business Model

Chemicals

Stakeholders

Ethics

Social Aspects

Function

Service

Without chemicals

Chemistry for Sustainability

Normative Framework

Chemistry for Greener Synthesis, Processing and Chemicals

Independent of Human Value Proposition

Chemistry Synthesis Properties

Non Normative Science

Future Thinking: Chemistry, Sustainability, and the Role of Chemists

Service

Function

Design

Synthesis

Resources

Recycling

End of Life

Unavoidable Losses

Audience Survey Question

How satisfied are you with green chemistry/sustainable chemistry in your country of residence?

- Very Satisfied
- Satisfied
- Neither Satisfied or Dissatisfied
- Dissatisfied
- Very Dissatisfied
2021 Survey GDCh Jungchemiker (Young Chemists) on Sustainable Chemistry in Education*
(https://jcf.io/teams/nachhaltigkeit)

- 503 participants, all continents (2/3 Europe), 46 countries, average age around ≈ 25
- Adequacy of SC in teaching: better in „developing“ countries, worse in „developed“
- > 90% of students ask for more
- > 80 expect that sustainability is more relevant for future professional life

* no differentiation between Green Chemistry (GC) and Sustainable Chemistry (SC)

---

Green Chemistry Education (GCE) and Sustainable Chemistry Education (SCE): Undergraduate & Graduate Level (including Education of Teachers)*

- Increasing number of programs for GC in higher education, e.g. Sichuan University (China), U York, U Amsterdam, U Nottingham, but still on low level, ...
- GCE often included in already existing context/modules, e.g. organic synthesis
- SCE rarely, if at all in teachers education
- Modules most often not mandatory
- External sources (e.g. ACS Green Chemistry Institute UNEP, UNIDO, U Sao Carlos (BR))
- A few Summer Schools (e.g. IUPAC, ACS Green Chemistry Institute, Leuphana U Lüneburg)
- Rarely extra occupational programs (U York, U Leuphana)

# publications on GCE and SCE (1998–January 2021, based on Clarivate Analytics 202153); topics: green chemistry education or sustainable chemistry education; *no differentiation between Green Chemistry (GC) and Sustainable Chemistry (SC)
Sustainable Transformation to Sustainability
- Sustainability as a cross-cutting topic

- **Interdisciplinarity – Transdisciplinarity**

- **Social basis of society**
  (learning // management // governance)

- **Physical basis of society**
  (biotic // abiotic) -> Chemistry

Methods and technologies to integrate the material, ecological, economical and social needs of a society, for sustainable development

- Inter- and Trans disciplinary Approach

- **A major in Sustainable Chemistry**
  - The realm of Sustainable Chemistry
  - Green Chemistry
  - Environmental chemistry
  - Computational chemistry
  - Analytical Chemistry
  - Benign by Design
  - (Eco)Toxicology
  - Resources
  - ...

At Leuphana University - Faculty of Sustainability
MSc Sustainability Science
https://www.leuphana.de/en/graduate-school/course-offerings/sustainability-science.html
Professional Master Sustainable Chemistry (MSc)
2 - Year Curriculum (90 ECTS)
German and European Accreditation; prerequisite: BSc or MSC in Chemistry

Small Format Certificates (20 ECTS)
- Benign by Design
- Sustainable Chemistry and Regulatory Affairs

- Unique extra occupational expert inter and trans disciplinary training
- Real world oriented content
- International teaching staff (academia, industry, administration)
- Blended learning, most online

- 25 November 2021: On-Line Information Day
- 10 December 2020: Application deadline
- March 2022: start next cohort
Take Home Message

1. GC and SC are on the rise, including education
2. Much more is needed
3. Enables a more sustainable contribution of chemistry to a more sustainable world
4. Sustainable Chemistry is the awarding inter- and transdisciplinary approach and systems thinking instead punctual solutions
Join a CAS SciFinder® Training on Sustainability

Learn How SciFinder® Can Support You To Make Science Sustainable

• Search Examples from Green or Sustainable Chemistry
• One hour webinar with experienced CAS experts including Q&A
• Pick from two options on Friday, September 10:


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Advancing Polymer Science with Organic Catalysts

Date: Wednesday, September 15, 2021 @ 2-3:30pm ET
Speakers: Andreea Dov, University of Birmingham, UK and Robert Waymouth, Stanford University
Moderator: Rachel Leteri, University of Virginia

What You Will Learn:
- Application of organic catalysts for stereo-controlled step growth polymerization.
- Development of high-temperature organic catalysts for polymerization and depolymerization.
- Using organic catalysts to selectively depolymerize plastic mixtures.
- New designs for ultralow organocatalyst polymerization reactors.
- Synergies between continuous flow chemistry and rapid organocatalyst polymerization reactions.
- New catalysts enabling the design of emerging functional materials for gene delivery.

Co-produced with: ACS Division of Polymer Chemistry

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Designing Around Structural Alerts in Drug Discovery

Date: Friday, September 17, 2021 @ 2-3:30pm ET
Speaker: Nick Heenan, AstraZeneca
Moderator: Deepti Solanki, Genentech Pharmaceuticals

What You Will Learn:
- The identity of structural alerts that have been associated with problems in drug discovery and development.
- The fundamental mechanistic organic chemistry underpinning structural alerts that are subject to bioactivation.
- Strategies and tactics to design around structural alerts.

Co-produced with: ACS Division of Medicinal Chemistry, American Association of Pharmaceutical Scientists, and ACS Publications

Service Dogs in Your Chemistry Lab

Date: Wednesday, September 22, 2021 @ 2-3pm ET
Speakers: Patricia Reardon, Saint Peter’s University (Joy Rana), Empower Mobility Consulting, LLC / Ashley Naylor, Independence Science
Moderator: Portia Bawa, Indiana University-Purdue University Indianapolis

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- What does the Americans with Disabilities Act cover regarding access rights for service dogs?
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