NATURE-INSPIRED CHEMICAL ENGINEERING, A TRANSFORMATIVE METHODOLOGY FOR INNOVATION

Marc-Olivier Coppens, Department of Chemical Engineering, and Centre for Nature Inspired Engineering (CNIE)
University College London (UCL), UK
m.coppens@ucl.ac.uk

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Some of our greatest challenges involve clean energy, water, the environment, dwindling resources, sustainable manufacturing, and healthy ageing. To approach them, chemical engineers are well equipped with the basic tools: balances, systems modeling, thermodynamics, kinetics and transport phenomena. Nevertheless, how these tools are employed in process and product design requires rethinking. Tackling Grand Challenges requires step-changes through transformative approaches and lateral thinking across disciplines, beyond incremental variations on traditional designs.

Nature is filled with well-integrated, “intensified” systems, optimized over the eons, to satisfy stringent constraints for survival by scalable processes with emergent properties. We propose to take nature as a source of inspiration, leveraging fundamental mechanisms underpinning desirable properties (like scalability, resilience or efficiency) and applying these to engineering designs, with suitable adaptations to satisfy the different contexts of technology and nature. We call this approach *Nature-Inspired Solutions for Engineering* (NISE), and its application to chemical engineering problems *Nature-Inspired Chemical Engineering* (NICE) [1].
The need to think about the context of technological applications, and the consistent use of fundamental scientific insights rather than superficial similarities, sets nature-inspired engineering apart from biomimetics or biomimicry. Examples from architecture and structural engineering will be given to illustrate this difference [2].
This lecture will introduce NICE as a systematic methodology [1] that is thematically structured around ubiquitous, fundamental mechanisms in nature, in particular: (T1) hierarchical transport networks, (T2) force balancing, (T3) dynamic self-organization, and (T4) control mechanisms in ecosystems, biological networks and modularity.

Thus, NICE looks at nature with the eyes of an engineer, employing scientific tools to derive nature-inspired concepts that are, subsequently, systematically used in the nature-inspired design of solutions to real problems, aided by mathematical and computational modeling and experimentation. In our examples, we will see how we learn from trees, lungs, kidneys, and dunes to intensify chemical and energy processes, and how we discover materials for biomedicine and the built environment, using the NICE methodology [1-6].

The NICE approach is powerful, because it allows us to merge creativity with rational design. Being thematic and systematic, once validated for one problem, NICE can be employed to solve various similar problems in other fields, e.g., from fluidized beds to fuel cells, and from catalysts to dental materials. Ultimately, the NICE methodology is a practical pathway for innovation and design.

References

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