# Beyond the Particle Ladder: Integrative Multiscale Modelling from Electrons to Digital Twins

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Multiscale modelling ladder in chemistry, materials science, and biosciences is often presented as a particle-based hierarchy, where electrons and nuclei are converted into atoms, atoms into molecules, molecules into coarse-grained beads, and beads into larger effective units. We will discuss a broader and more powerful view [**1**]. Once particles become too coarse for meaningful building blocks of matter, multiscale modelling must continue through fields, free-energy functionals, equations of state, hydrodynamics, pore networks, population balances, process models, digital twins, and data-driven inference [**2,3**]. We will here picture an integrative roadmap. connecting bottom-up molecular modelling with top-down experimental, thermodynamic, and engineering constraints, highlighting how methods from chemical engineering, applied mathematics, computer science, AI, inverse problem solving, and experimental characterization can be combined into a coherent modelling strategy [**4**]. The message is that modern multiscale modelling is not simply coarse-graining across length and time, but the systematic transfer of information across representations, observables and decisions.

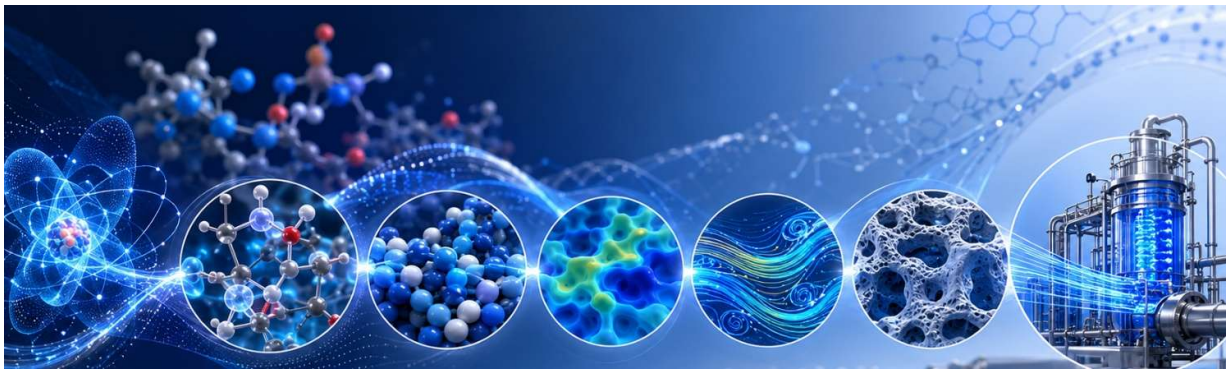

**Figure 1** - A generic multiscale scheme from electrons to industrial processes where information is passed from one scale to the next

## REFERENCES

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