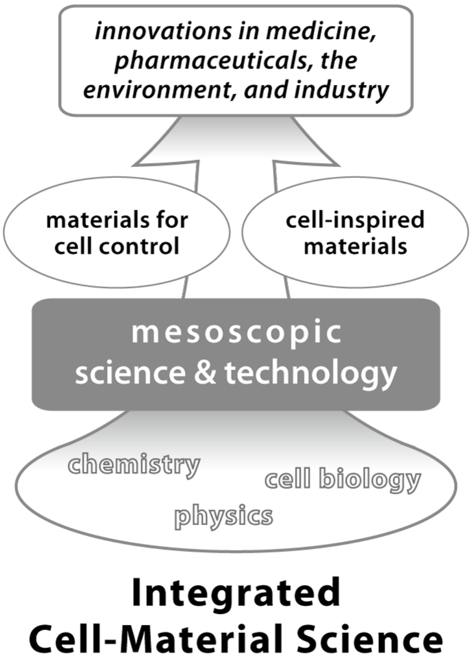
Vision Statement

Susumu Kitagawa
iCeMS Director-Designate

I. Vision for an Integrated Cell-Material Science

All cellular processes can ultimately be comprehended as chemical events, and such a chemical understanding of cells should allow us to mimic cellular processes using chemical materials. Our institute seeks to illuminate precisely such a *chemical basis of cells*, creating compounds to control processes in cells such as stem cells (*materials for cell control*) in addition to sparking cellular processes to create chemical materials (*cell-inspired materials*). Combining Kyoto University's established strength in cell biology, chemistry, and physics to delve deeply into the mesoscale world lying at the boundary of materials and life, we are making a concerted effort, through interdisciplinary research, to ultimately create a new research field of **integrated cell-material science**.



Efforts to explain cell functions using chemistry are not new. *Biochemistry*, for instance, uses proteins as a starting point in attempting this at a molecular level, and *molecular biology*, while also focused on molecules, takes a DNA-based approach. And in their own ways, both methods have yielded significant innovations in pharmaceuticals and biotechnology.

Meanwhile, *cell biology* has also seen substantial success by considering the cell as a whole, most notably in research related to embryonic stem (ES) cells and induced pluripotent stem (iPS) cells, in turn beginning to make an impact on the biomedical industry.

Our institute seeks a middle ground: between the large, whole-cell approach of cell biology, and the small, protein and DNA approaches of biochemistry and molecular biology. We call this the *mesoscopic* realm, lying between a few tens and a few hundreds of nanometers, on the border between materials and living matter. Investigating this boundary region, we strive to explain the material-chemical basis of cells' living functions, ultimately using materials to create facsimiles of these mechanisms.

A study of the melded boundary between cells and materials based on a fusion of cell biology, chemistry, and physics is our goal. We seek to be the best in the world, with the fruits of our international, interdisciplinary labors bringing nourishment and fresh ideas to research in industries as diverse as medicine and the environment.

Our efforts focus on examination of the following two questions.

(1) *Can we describe mesoscopic cellular processes in terms of chemistry?*

Cells sustain life through properties of self-assembly and cooperative interactions among nearly countless chemical materials, moving ceaselessly in space and time. Broadening our scope beyond the narrow confines of nanoscale molecular interactions, we find it necessary to take a wider, mesoscopic view of molecular complexes. To accomplish this, we are pursuing the development of advanced imaging technologies and modeling, and physical and chemical technologies to dissect complex cellular events. We plan to focus on the following three areas:

- **Gene Expression Control in Stem Cells**. Changes in the chromatin structure (essentially, the genetic code) of stem cells come about as a result of complex space-time movements of myriad proteins and nucleic acids. We strive to understand the chemical basis of this dynamic control.

- **Organized Functions on the Cell Membrane**. Not merely a boundary wall, the cell membrane serves as a host environment for the intricate assembly and cooperation of proteins, lipids, and glycans. We seek to explain the chemical basis of these organized functions.
- **Energy Storage in Cells**. As water is stored in dams, energy is stored in intricate structures within cells, via the ion density difference across the cell membrane and in meso-domains of concentrated proteins and lipids. This stored energy is in turn used to create compounds and deliver signals necessary to sustain life. We aim to decipher the chemical basis of these energy storage and conversion mechanisms.

(2) *Can we reproduce mesoscopic cellular structures with materials, and manipulate them?*

Renowned physicist Richard P. Feynman once wrote: “What I cannot create, I do not understand.” In other words, only in the process of creation can we achieve true understanding.

In this spirit, our institute aims to replicate mesoscopic cellular functions with designer materials. This should be possible once a full understanding of such cellular processes (as described above) has been achieved. We therefore simultaneously advance analysis and synthesis, applying the resulting higher level of knowledge to further research, such as in the proposed creation of chemical materials related to the three focal areas of study:

- with **Gene Expression Control in Stem Cells**, materials capable of manipulating gene expression resulting from cell reprogramming or differentiation;
- with **Organized Functions on the Cell Membrane**, compounds to mimic and replicate the complex, cooperative processes on and inside the cell membrane; and
- with **Energy Storage in Cells**, learning from the beauty of how living creatures store energy, materials capable of transporting and storing ions or molecules, or transforming carbon dioxide and nitrogen gas into energy-storage molecules.

II. Vision for the Institute’s Research and Management

(1) *Strengthening cell science*

In response to WPI Program Committee and Site Visit Working Group remarks questioning the strength of the institute’s cell science team, we are taking measures to strengthen the lineup of researchers, such as with the potential inclusion of world-renowned Kyoto University scientists **Ryoichiro Kageyama** (Institute for Virus Research) and **Mitinori Saitou** (Graduate School of Medicine).

(2) *Strengthening collaboration with CiRA*

Differences between iCeMS’ and CiRA’s scientific approaches and goals, often a point of discussion in years past, are now sufficiently clear: iCeMS incorporates iPS cells into its research combining cells and materials, while CiRA focuses on clinical applications of iPS cells. In this context, six CiRA scientists have iCeMS affiliations, performing basic and multidisciplinary research related to iPS cells in conjunction with iCeMS colleagues. Moreover, **Yasuhiro Yamada** (CiRA PI and iCeMS Professor) and **Takuya Yamamoto** (CiRA PI and iCeMS Kyoto Fellow) both engage in the management of this institute as participants in iCeMS Board of PIs meetings.

(3) *Strengthening institute management*

Director-designate Susumu Kitagawa is a specialist in materials science. Two deputy directors will be named to support his leadership, one to be a world-leading cell scientist, and the other to be iCeMS Professor **Motonari Uesugi**, a highly-regarded chemical biologist in the United States and Japan with a solid record of uniting cell-material research. The institute’s new leadership team, strong in both international and interdisciplinary contexts, will be well placed to lead iCeMS in this new phase of its unified study crossing the boundaries between cells and materials.

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