Chemoenzymatic synthesis and material design of structural and functional polypeptides

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Structural protein is one of the key factors to realize the unique properties and functions of natural tissues and organisms. However, use of structural proteins as structural materials in human life is still challenging. One of the major drawbacks of protein/polypeptide-based materials is their limited synthesis/process method. My research group has successfully synthesized various polypeptides, such as spider silk protein-like and elastin-like multiblock polypeptides, even with unnatural amino acids or nylon units, via chemoenzymatic polymerization. Those artificial polypeptides containing unnatural units achieve several properties that cannot be done by natural polypeptides. Thus, this enzyme-mediated polymerization of amino acid monomers provides a new insight for material design of polypeptide. Our research group also reported the new finding in spider silk spinning, which is essential to clear the hierarchical structure of spider silk. The scalable and sustainable synthesis method along the clarified structure-function relationship of natural proteins provides a new insight for structural and functional material design of amino acids-based polymers.

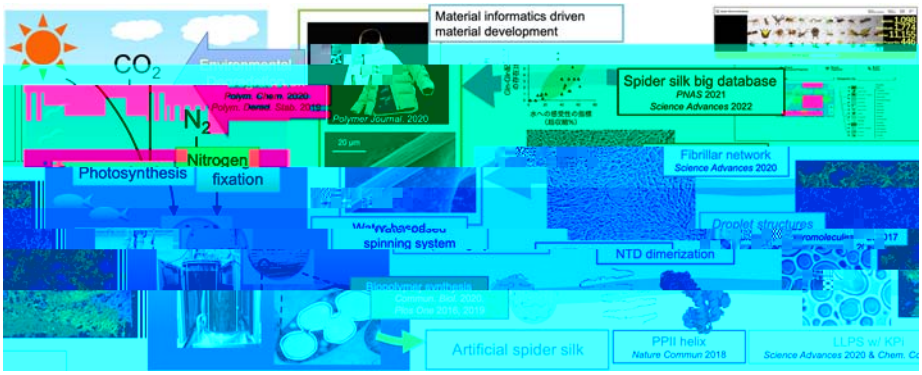

Figure 1. Sustainable design and biosynthesis of artificial spider silk.

Further, my research group is interested in marine purple photosynthetic bacteria as ideal organisms and platforms for production of useful materials to reduce production costs and to contribute sustainable society, because they can utilize sun energy, seawater and carbon dioxide and nitrogen gas in the air for their growth. My research group studies on the photosynthetic bacteria to produce spider silk-like polymers. To establish the fundamental platforms for photosynthetic bacterial technology, we are currently developing peptide-mediated transformation and protein introduction methods for alga and photosynthetic bacteria. These new methodologies will be able to support the high-throughput characterizations for biopolymer productions.

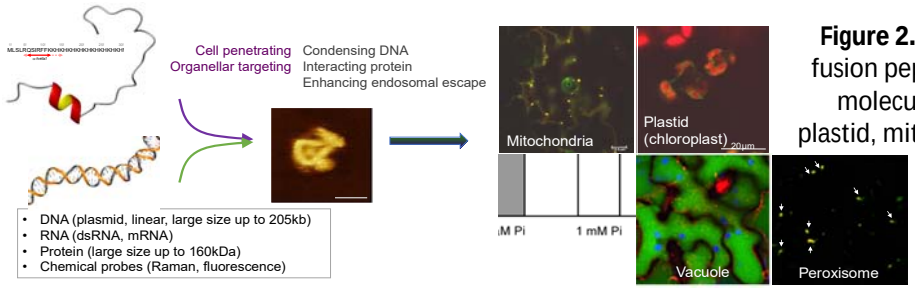

Figure 2. Schematic illustration of fusion peptide-mediated bioactive molecules delivery into nucleus, plastid, mitochondrion, peroxisome and vacuole.

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Curriculum Vitae

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Keiji Numata earned his Ph.D. (2007) with a thesis centered on enzymatic degradation and synthesis with hydrolases of biopolymers, especially poly(hydroxyalkanoate), under the supervision of Prof. Yoshiharu Doi, Tokyo Institute of Technology. His Ph.D. thesis includes works on enzymatic polymerization to synthesize branched biopolymers, which has been performed in Royal Institute of Technology (Sweden) under the supervisions of Prof. Ann-Christine Albertsson and Prof. Anna Finne-Wistrand. He worked as a JSPS Postdoctoral Fellow for Research Abroad at Tufts University (USA) where he studied biosynthesis of silk-based polymers via bacterial pathways as well as silk-based gene carriers in the laboratory of Stern Family Professor in Engineering David L. Kaplan. He moved to RIKEN as a Senior Scientist in 2010 to start up a laboratory to investigate biosynthesis and material design of structural proteins and poly(amino acid). He has been a Team Leader (PI) of the lab since 2012 and Research Director for JST-ERATO Numata Organelle Reaction Cluster Project (2016-2023), Research Director for JST-COI-NEXT (2022-), Research Director for MEXT Program: Data Creation and Utilization-Type Material Research and Development Project (2022-). In 2020, he moved to Department of Material Chemistry, Kyoto University, as a full professor. He received Nagase Prize from the frontier salon foundation (2022), the 2020 *ACS Macro Letters*/*Biomacromolecules*/*Macromolecules* Young Investigator Award (American Chemical Society, 2020), SPSJ Asahi Kasei Award (2019), Award for Encouragement of Research, Japanese Society for Plant Cell and Molecular Biology, Japan (2019), Bio-Environmental Polymer Society Outstanding Young Scientist Award, USA (2018), The Young Scientists' Prize for Minister of MEXT, Japan (2018), and so on. He was appointed as an associate editor of *Polymer Journal* (2018-2020) and is currently an associate editor of *ACS Biomaterials Science and Engineering*.