【Grant-in-Aid for Scientific Research (S)】

Visualization of intact metabolomes to understand the molecular mechanisms of cellular functions and properties expression

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Purpose and Background of the Research

●Outline of the Research

A certain group of compounds in a particular distribution and their state of existence: we believe that these are the prerequisite for the expression of biological functions and properties. Without establishing new analytical techniques based on such conditions, it is impossible to truly understand the expression of functions and properties of life. The purpose of this study is to **understand the nature of the characters and associated functions acquired by land plants during their evolution**. To this end, we will realize visualization, characterization, structural analysis, and analysis of the regulatory mechanisms of metabolites while maintaining their original (**intact**) state. We propose a new "cell" interpretation by visualizing the local functions and physical properties of intact metabolomes ranging from small molecules to macromolecules at the nanoscale (**Fig. 1**).

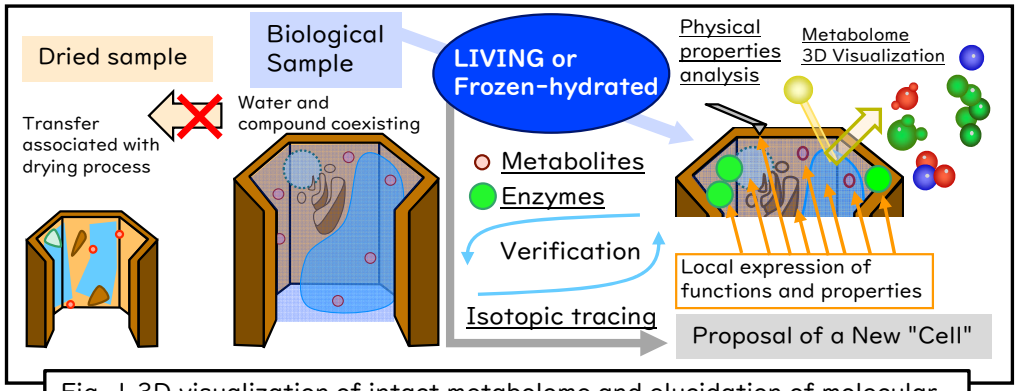

Fig. 1 3D visualization of intact metabolome and elucidation of molecular mechanisms for expression of cellular functions and properties.

●What is intact metabolome?

In the science of life phenomena, one of the ultimate goals is to reveal the full extent of the mechanisms by which cells are regulated. What are these tissues and cells doing? Where is this material made, how does it move, and where does it end up? In order to rationally explain the characters and associated functions acquired by land plants in the process of evolution from the viewpoint of environmental adaptation and survival strategies, it is necessary to visualize (understand with positional information) where and how the metabolism related to these characters develops and what functions and properties are expressed. In other words, it is necessary to visualize the molecular-level information in the cell as it is (**intact**).

Here, we name the entire picture of metabolites, including "where and with what" as the **intact metabolome**.

Expected Research Achievements

●What kind of metabolites are assembled and coordinated to establish cell functions and properties expression, and how are they regulated?

Cell walls have the most important functions for land plants, i.e., water impermeability, mechanical strength, and biological defense. Cell walls can be said to be the actual substance of woody biomass. An overview of one of the priority goals of this research [elucidation of the molecular mechanisms controlling plant cell differentiation, cell wall formation, and their physical properties] is shown in **Figure 2**.

The cells from the cambial zone to the xylem are at different stages of differentiation and growth. Therefore, wen can follow and evaluate their differences as time-related changes. The process from cell division in the cambial zone through lignification to programmed cell death and postmortem changes are integrated with the structure and properties of the cell wall and changes in the intact metabolome in the cell; and we try to find molecular mechanisms of expression of cellular functions and properties.

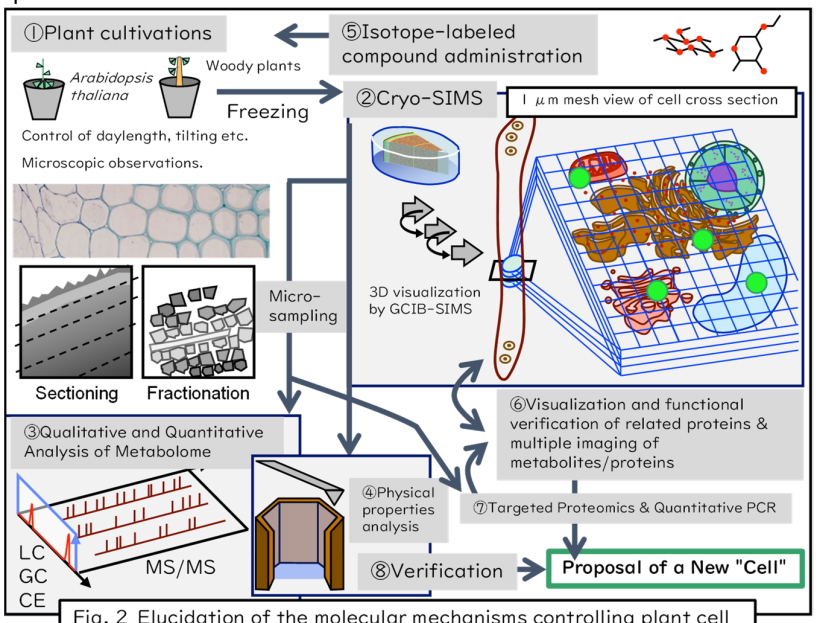

Fig. 2 Elucidation of the molecular mechanisms controlling plant cell differentiation, cell wall formation, and their physical properties

●We will extend our experiments to metabolites related to various plant characteristics, and aim to elucidate unresolved issues in plant science and wood science.

The discussion in this research starts from "where and what functions and properties are expressed". We aim to propose a new nanoscale cellular interpretation based on functions and properties expression. This is a major shift from the conventional intracellular description based on membrane structure. Studies at the individual, tissue, and cellular scales are essential for understanding the molecular mechanisms of concerted regulation of differentiation and expression of functions and properties in multicellular tissues. This will lead to a better understanding of cell wall differentiation and lignification of plants, which will also be an important milestone for research using natural trees.

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