【Grant-in-Aid for Transformative Research Areas（A）】

Organelle-Driven Sensors and Actuators Governing Plant Movement

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Project Information	Project Number : 26A304　　　Project Period (FY) : 2026-2030 Keywords : Plant movement, Environmental responses, Sensor, Actuator, Movement modeling

Purpose and Background of the Research

●Outline of the Research

Movement is an essential function for the survival of living organisms. While animals use muscles and nerves to move their bodies, plants rooted in the soil perform "movement" by moving organs such as roots and stems using mechanisms completely different from those of animals. Among the various movements uniquely evolved in plants, "tropism," which optimizes growth by bending organs in response to environmental stimuli such as light and gravity, has long been studied (Figure 1).

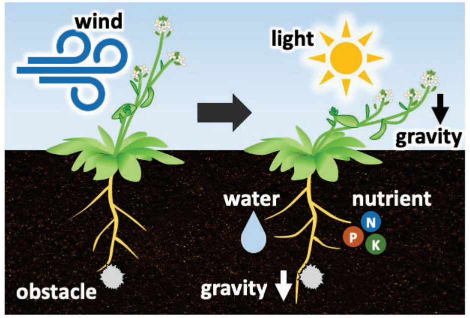

Figure 1. Plant tropisms to environmental stimuli

Organ bending has been explained by the asymmetric distribution of the plant hormone "auxin" (Figure 2). However, the core operating mechanisms—how cells perceive environmental stimuli, how this information is transmitted throughout the organ, and how organs connected by rigid cell walls can bend—remain unclear.

This research project focuses on gravitropism as a representative model and redefines it as a coordinated system between "sensors" driven by organelles and "cellular actuators" composed of organelles, the cytoskeleton, and the cell wall (Figure 3). Through close interdisciplinary collaboration with mathematical biology, biophysics, and mechanical engineering, we aim to elucidate the unique principles of plant movement and revolutionize the concept of movement by integrating different scales from molecules to organs.

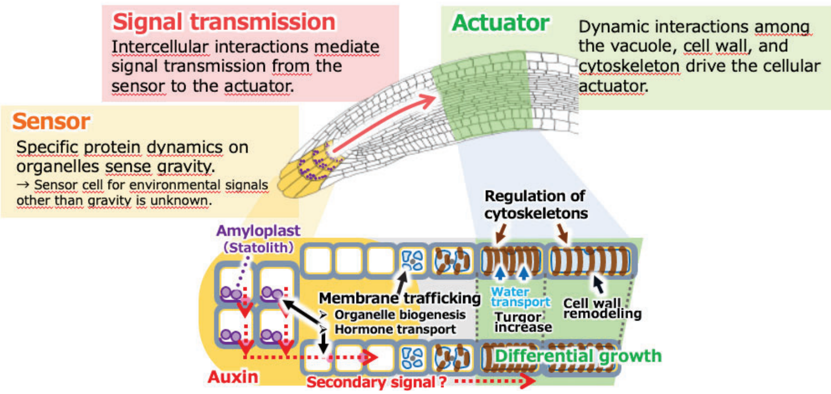

Figure 2. Overview of "gravitropism," a plant movement focused in this research project

Within the cellular actuator, which actually generates the bending force, the vacuole adjusts turgor pressure by taking in and releasing water, and the cytoskeleton regulates cell wall stiffness, leading to the deformation of cell shape. These processes are supported by the precise movements of countless molecules and organelles within cells. Furthermore, organ bending is thought to be controlled by physical forces generated in cells and tissues connected by cell walls. However, with conventional technologies, it has been difficult to precisely capture and integrate these processes simultaneously to understand organ movement. Therefore, this research project aims to elucidate these mechanisms, which have remained a "black box," by integrating cutting-edge imaging technologies, mathematical models, and robotics that manipulate cells with microscopic machines.

Expected Research Achievements

- **Analyzing the operating principles of sensors and actuators, and the integration mechanisms to understand plant organ movement.**

We will elucidate the sensors and actuators as well as their connections, from molecules to organs, using gravitropism as a model (Figure 3). To explore the diversity and common principles of plant movements, we will also investigate various tropisms, nastic movements, and spontaneous circumnutation. By focusing on the following points, we will elucidate the full scope of plant movements.

1. Sensors and signal transmission: Elucidate the mechanisms for sensing environmental stimuli and their signal transmission.
2. Driving mechanisms of cellular actuators: Identify the driving elements of how vacuoles, cell walls, and the cytoskeleton interact to change cell shape.
3. Mechanisms governing movement across scales: Integrate the data through theoretical research to reproduce and predict the process by which individual cell deformations converge to produce the bending of the entire organ.s

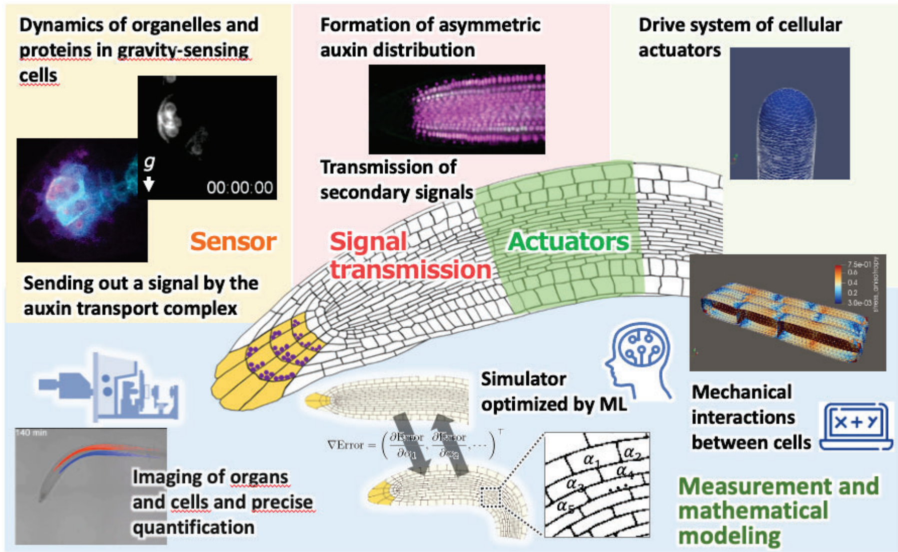

Figure 3. Elucidating cross-scale movement principles from molecules to organs

Website(s)	https://www.nibb.ac.jp/pmov/english/index.html