Summary of Doctoral Thesis

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Title	Scaling of shoot and root respiration rate, fresh mass, and surface area of *Fagus crenata* during ontogeny

This thesis investigates the scaling of respiration rate, fresh mass, and surface area of *Fagus crenata* throughout ontogeny and consists of two chapters.

Chapter 1. Seedlings with main leaves: rapid root development with decreasing respiratory carbon cost

As terrestrial plants are rooted in one place, their metabolism must be acclimatized to continuously changing environmental conditions. This process is influenced by different metabolic traits of plant organs during ontogeny. However, direct measurement of organ-specific metabolic rates is particularly scarce, and little is known about their roles in whole-plant metabolism. In this study, we investigated size scaling of respiration rate, fresh mass, and surface area of leaves, stems, and roots in 65 seedlings of *Fagus crenata* Blume (2 weeks to 16 months old).

With the increase in plant mass, a proportion of roots in whole plant increased from 20.8 to 87.3% in fresh mass and from 12.8 to 95.0% in surface area, while only from 15.6 to 60.2% in respiration rate. As a result, the fresh-mass- and surface-area-specific respiration rates in the roots decreased by 85% and 90%, respectively, and these decreases were significantly size-dependent. However, such a size-dependent decrease was not observed for the surface-area-specific respiration rate in the leaves and stems.

It is likely that this rapid root development is specific to the early growth stage after germination and would help plants acquire water and nutrients efficiently (i.e., at relatively low respiratory carbon costs). Overall, it is probable that the establishment of *F. crenata* forests and survival of *F. crenata* seedlings could be promoted by substantial root growth with a reduction in respiratory carbon cost.

Chapter 2. Germinating seeds to mature trees: scaling of shoot and root respiration rate, fresh mass, and surface area

Studies of terrestrial plant ecology and evolution have focused on the patterns of metabolic product allocation to roots and shoots in individual plants and the scaling of

whole-plant respiration. However, few empirical studies have investigated the root:shoot ratio by considering the scaling of whole-plant respiration at various sizes throughout ontogeny. Here, using 377 individuals of *Fagus crenata* from five different Japanese provenances, we measured the respiration rates, surface area, and fresh mass of the entire roots and shoots, from germinating seeds to mature trees.

We found that the relatively stable allometry of whole-plant respiration from seedlings to mature trees resulted from the integration of a convex upward curve of the root and a convex downward curve of the shoot to whole-plant fresh mass on the log-log coordinates. This suggests a gradual ontogenetic shift in allocation priority, from water uptake in seedlings to carbon gain in mature trees.

We propose that this size-related root and shoot shift is common in *F. crenata*, regardless of the environment or phylogeny. Rapid root growth in early growth stage may promote subsequent shoot growth, and approaching the saturation of root growth may cause a decline in shoot and whole-plant growth during the mature stage.

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