content in red leaves is much higher than that in green and yellow leaves, presenting a red-green mixture color; yellow leaves are due to a significant reduction in chlorophyll and the appearance of carotenoids, with very little anthocyanin accumulation, thus appearing yellow (Chen et al., 2019; Lu et al., 2020). In different red maple varieties, the degradation of chlorophyll and the large synthesis of anthocyanins together are the key to forming stable red leaves (Jie et al., 2019).

This phenomenon is also common in other maple trees and many other deciduous plants with distinct leaf colors. Generally speaking, the chlorophyll content in red-leaved varieties is usually lower than that in green-leaved or yellow-leaved varieties, while the contents of carotenoids and anthocyanins are higher. Among them, anthocyanins play an important role in the formation of leaf color (Chen et al., 2019; Zhang et al., 2022; Xie et al., 2023; Gong et al., 2025). Multi-gene studies on tree species such as red maple (*Acer rubrum*) have found that during the leaf color change process, the contents of chlorophyll and carotenoids gradually decrease, while some anthocyanins, such as anthocyanin-3, 5-diglucoside, increase continuously, eventually causing the leaf color to gradually change from green to red (Fan et al., 2024). Therefore, the different colors of maple leaves are actually related to the changes in the proportion of various pigment contents: when the chlorophyll content is high, the leaves usually appear green; when there is more carotenoids and less anthocyanins, the leaves are mostly yellow; when anthocyanins accumulate in large quantities, the leaves will turn red.

2.3 Seasonal changes and the formation of red leaves

The reddening of leaves is mainly due to changes in the quantities of several pigments within the leaves. As the seasons change and the leaves gradually age, chlorophyll gradually decreases, and the original green color becomes increasingly pale, eventually disappearing completely. As a result, the less obvious color of carotenoids becomes apparent. At the same time, many maple trees will produce more anthocyanins, or increase the existing anthocyanin content (Chen et al., 2019; Zhang et al., 2022). Studies on red maples and sugar maples have shown that in autumn, the chlorophyll in the leaves significantly decreases, and the content of carotenoids also changes, while anthocyanins accumulate continuously, especially in those leaves that change color earlier and have darker colors, this situation is more obvious (Mattila and Tyystjärvi, 2023). Transcriptome and metabolome studies have also found that during the process of leaf reddening, the expression of genes related to anthocyanin synthesis increases, thereby promoting the continuous accumulation of anthocyanins in the leaves (Fan et al., 2024; Gong et al., 2025).

The external environment can also affect the color changes of the leaves. Lower temperatures, larger diurnal temperature differences, and sufficient light all facilitate the breakdown of chlorophyll and promote the formation of anthocyanins. Therefore, the leaves on the outer part of the tree crown, or those that receive more sunlight, are usually more likely to turn red (Zhang et al., 2022; Mattila and Tyystjärvi, 2023; Xie et al., 2023). Additionally, if the branches of red maple trees are cut, the nutrient transportation within the branches will change, and the distribution of pigments in the leaves above the treated area will also change, so the leaves will turn red earlier (Yang et al., 2022). In summary, the red color of autumn maple leaves is the result of the combined effects of reduced chlorophyll, changes in carotenoids, and increased anthocyanins. These changes also form the common red-orange forest landscape seen in temperate regions during autumn.

3 Case Study: Maple Landscape in Arashiyama, Kyoto, Japan

3.1 Famous autumn foliage formed by extensive maple planting

Arashiyama, on the western edge of Kyoto, is renowned for its large expanses of Japanese maple (*Acer palmatum*) and other deciduous broadleaf trees, which form a celebrated autumn foliage landscape. Historical and planning studies describe Arashiyama and its suburban mountain area as a key scenic zone where maples, cherry trees, and pines are deliberately used as “constitution trees” of the landscape, shaping the visual character of the hillsides and river valley. The mixed forest mosaic on the slopes—dominated by deciduous broadleaf species—creates large, continuous patches of red, orange, and yellow that are visible from afar and attract millions of visitors annually (Figure 1).