

### 10.13.7. Underwater photosynthesis studies on a terrestrial species identify novel responses of gas exchange capacity and photosynthesis biochemistry to submergence

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Gas exchange is severely hampered when terrestrial plants are flooded. A straightforward way to reduce the shortages of oxygen and carbohydrates might be photosynthesis under water. Several terrestrial plants develop 'aquatic' leaves which show pronounced anatomical differences compared to the 'aerial' leaves. We investigated if this remarkable plasticity facilitates gas exchange capacity under water. The cuticle thickness of the flooding tolerant species *Rumex palustris* was reduced upon submergence, resulting in decreased diffusion resistance which greatly facilitated underwater photosynthesis. Furthermore, the photosynthetic machinery itself was affected by submergence. Rubisco contents were reduced upon acclimation to submergence, indicating a lower carboxylation capacity. Electron transport capacity was also reduced in these leaves, but not as strong as the change in Rubisco, indicating a substantial increase of the ratio between electron transport and carboxylation capacity upon submergence. This novel finding is striking since this ratio is believed to be very conservative.

### 10.14.1. Evolution in a community context: Multi-species selection on plant floral and defense traits

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As members of multi-species communities, plants simultaneously integrate direct and indirect interactions with herbivores, pollinators and other species. Thus, traits expressed by plants may be influenced by a variety of selective agents. This perspective is in stark contrast to studies that focus on pairwise interactions, i.e., how floral traits are acted on solely by pollinators and how defensive traits reflect selection from herbivores. Here, I describe experimental studies in which the community context of selection on plant floral and defense traits is explored. For example, costs of plant defenses against herbivores may affect the size and/or numbers of flowers produced, the amount of floral rewards, or the palatability of these rewards. In such cases, a defended plant may become more pollinator limited, and pollinator preferences may constrain the response to selection from herbivores for increased defenses. Similar indirect interactions with non-pollinator species may constrain the evolution of floral traits

### 10.14.2. Linking above and belowground multitrophic interactions: root herbivory affects aboveground herbivore, parasitoid and hyperparasitoid performance via changes in plant quality

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Plants and insects are part of a complex multitrophic environment, in which they closely interact. However, most of the studies have been focused mainly on bi-trophic aboveground subsystems. We studied whether root herbivory by *Delia radicum* can influence the development of the leaf feeder *Pieris brassicae*, its parasitoid *Cotesia glomerata* and its hyperparasitoid *Lysibia nana*, through changes in secondary plant compounds. In presence of root herbivory, the development time of the herbivore and the parasitoid significantly increased, and the adult size of the parasitoid and the hyperparasitoid were significantly reduced. Interestingly the effects were stronger at low root fly densities than at high levels of root herbivory. Higher glucosinolate (sinigrin) levels were recorded in plants exposed to belowground herbivory, suggesting that the reduced performance of the aboveground insects was via reduced plant quality. Our results show for the first time that root herbivory, via changes in plant quality, can reduce the performance of an aboveground three trophic level food chain.

### 10.14.3. Arabidopsis-a model for molecular approaches in plant volatile biology

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Volatile compounds are important mediators in plant environment interactions. We employ the genetic and genomic resources of *Arabidopsis thaliana* to study the molecular basis of biochemical and physiological processes as well as ecological functions of constitutive and inducible plant volatile emissions with particular focus on terpene volatiles. Arabidopsis flowers emit a complex mixture of monoterpene and sesquiterpene volatiles. In a reverse genetics approach, we have characterized all genes out of a large gene family of 32 terpene synthases (TPSs) that are responsible for the floral volatile emission. Analyses of gene expression and promoter activities revealed a highly restricted TPS activity in particular floral organs, the stigma and the intrafloral nectaries. Given the high vulnerability of these tissues to microbial infections, the active biosynthesis of terpenes at these sites suggests a primarily antimicrobial defense function for protection of reproductive organs. Studies with TPS knock out lines and different ecotypes under laboratory and field conditions will shed further light on the role of terpene volatiles in Arabidopsis flowers.

### 10.14.4. Phytochemical early warning systems: induced resistance to herbivores in ramet populations of clonal plants

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Plants are constantly exposed to the threat of herbivore damage. Many species have developed inducible defence mechanisms to deter feeding animals after an initial attack has happened. Such inducible resistance is considered beneficial in environments with spatio-temporally variable herbivore pressures as the production of costly defence chemicals is avoided whenever they are not needed. In many plants the defence induction signal (or the defensive phytochemical) can be transported throughout the plant, thereby conferring resistance to damaged and undamaged plant parts. This phenomenon, termed induced systemic resistance may be of particular importance to physically connected ramets of clonal plants because it allows for the internal transmission of phytochemical warning signals over considerable distances, thereby giving ramets of clonal plant species potential advantages over non-clonal neighbours in the case of imminent herbivore attacks. Our experiments provide clear evidence for ISR in ramet populations of the clonal herb *Trifolium repens*, and they show that the systemic transmission of early warning signals is constrained by phloem flows.

### 10.14.5. Signals from the deep. Root induction alters shoot-induced direct and indirect defences in wild Brassica oleracea

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Induced responses in plants are known to occur in both roots and shoots. In their natural environment, most plants will be attacked at both organs simultaneously. Because signaling hormones as well as induced defence products are transported systemically through the plant, root and shoot-induced responses may interact. Eventually, these interactions may constrain optimal defence induction. In wild *B. oleracea* we found that application of jasmonic acid (JA) to the roots yielded a significantly different glucosinolate profile in the shoots compared to shoot-application. Larvae of the specialist herbivore *Pieris rapae* performed significantly worse on root-induced plants. Similarly, plants pre-treated with JA at their roots before they were damaged and treated with *P. rapae* saliva, produced significantly different volatile profiles than plants pre-treated with JA to their shoots. Root induction thus affects both direct and indirect shoots defence levels. As a consequence, the presence of root feeders can have a significant effect on the aboveground multitrophic interactions associated with plants, and, eventually, plant fitness.

### 10.14.6. Variation in olfactory cues used by bees in flower selection

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While it is known that flowers attract pollinators through the display of visual and olfactory stimuli, our findings suggest that the relative importance of these cues to bees selecting flowers varies with the