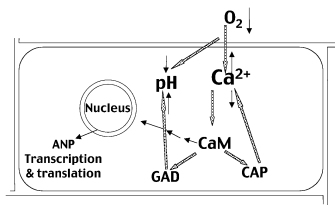




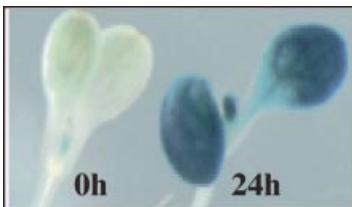
Functional dissection of the anaerobic response using microarrays

Successful manipulation of flooding tolerance requires a better understanding of the physiology and biochemistry of the anaerobic response. **Dolferus *et al.*** (pp. 111–117) use a combination of reversed genetics and microarrays to dissect functionally the anaerobic response and identify key metabolic and regulatory genes for future manipulation.



Calcium-mediation of responses to oxygen shortage

Subbaiah and Sachs (pp. 119–127) present an overview of their research on the role of calcium in the perception of oxygen deprivation stress in maize cells. They argue that rapid attainment of ionic homeostasis is as important as gene activation in cellular adaptation to stress.



Trapping low-oxygen-induced genes

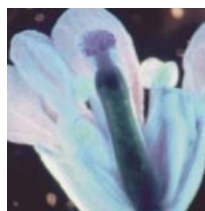
Low oxygen induces intricate cell- and tissue-specific patterns of gene expression. Using gene-trapping and enhancer-trapping, **Baxter-Burrell *et al.*** (pp. 129–141) characterize lines of

Arabidopsis with increased GUS reporter expression in response to low oxygen. By these means, genes that encode regulatory, enzymatic, structural and unknown proteins are identified. None of these genes are previously reported to be induced by oxygen deprivation.



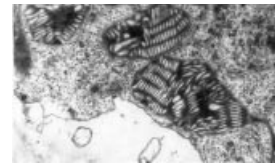
Rice germination under anoxia

Tolerance to low oxygen availability in cereals is the outcome of several interacting processes. One of these is the ability to degrade starch anaerobically, thereby avoiding cell death from sugar starvation. **Loreti *et al.*** (pp. 143–148) demonstrate that α -amylase production during the first days after imbibition results mostly from the activity of the *Ramy3D* gene. They also demonstrate that induction of *Ramy3D* transcription results from the low sugar content of anoxic grains.



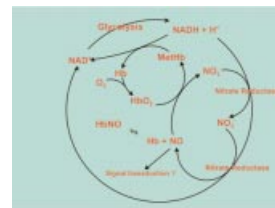
Anaerobic reporter gene expression in *Arabidopsis thaliana*

Reporter gene technology is an attractive approach to isolate signal transduction mutants. **Hänsch *et al.*** (pp. 149–154) show that the maize *GapC4* promoter drives anaerobic reporter gene expression in all tissues of *Arabidopsis thaliana*. Although anaerobic induction requires light and replacement of oxygen by carbon dioxide, these plants may be useful to isolate mutants with altered anaerobic gene expression.



Functional electron microscopy and anaerobiosis

Functional electron microscopy of mitochondria is used by **Vartapetian *et al.*** (pp. 155–172) to consolidate the concept of two principal strategies of plant adaptation ('true' and 'apparent') and to demonstrate a key role for energy metabolism in determining the extent of anoxia tolerance. Studies of physiological roles for anaerobic synthesis of lipids, for nitrate as a possible terminal electron acceptor under anoxia, and *in vitro* selection of tolerant cell lines and regenerated plants are also described. The possibility that these anaerobic responses support the notion of a general adaptation syndrome in plants is discussed.



Haemoglobins and hypoxia

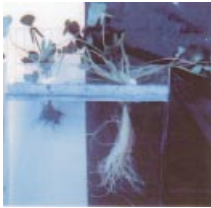
Class I haemoglobins are known to be induced by hypoxia. **Dordas *et al.*** (pp. 173–178) review the literature on this topic, including reports of studies that demonstrate nitric oxide formation in plants during hypoxia and its modulation by haemoglobin. A metabolic scheme for the interaction of NO and haemoglobins is proposed.

Continued overleaf



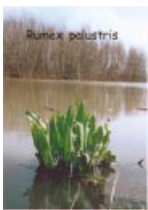
Antioxidants protect plants against damage caused by anoxia

Paradoxically, anoxia can lead to oxidative damage from reactive oxygen species (ROS). Sites of ROS formation and the mechanisms of lipid peroxidation as well as protection against this damage by antioxidants are discussed in this review by **Blokhina *et al.*** (pp. 179–194), in connection with anoxia-specific metabolic changes.



Protein induction and aerenchyma formation

There are two likely mechanisms for prolonged flooding tolerance of a resistant variety of underground clover. **Aschi-Smiti *et al.*** (pp. 195–204) show that one of these may be an induction of enzymes and haemoglobin protein that improves the energy status of adventitious but not primary roots. However, oxygen transport via aerenchyma is probably a more dominant mechanism.



Interactions between plant hormones regulate submergence-induced shoot elongation in *Rumex*

Rumex palustris has the capacity to respond to complete submergence with hyponastic (upward) growth and stimulated elongation of petioles. **Voesenek *et al.*** (pp. 205–211) show that ethylene, abscisic acid and gibberellins are

essential players in the signal-transduction pathway that leads to these responses.



Bog vs. forest

The interface between bog and forest is a struggle for territory between two different types of vegetation. **Crawford *et al.*** (pp. 213–216) examine the climatic history of northern Europe over the past century and its consequences for the position of the treeline. Contrary to some predictions, they suggest that instead of the forest advancing northwards with global warming there are areas where the treeline may be forced southwards due to increased bog growth.



Submergence tolerance in rice

Although complete submergence for only a few days can be highly damaging to rice, an inheritable tolerance trait has been identified in some lines. **Jackson and Ram** (pp. 227–241) review the physiology, biochemistry and molecular biology that underlie this difference in susceptibility, and assess the contribution that these studies are making to creating cultivars with superior tolerance to submergence in the field.



QTL analysis of submergence-tolerant trait in rice

Toojinda *et al.* (pp. 243–253) show that complete submergence is inherited from a

primitive Indian farmer variety of rice via a dominant locus on chromosome 9. Closely linked traits include a repression of underwater leaf elongation, and a slowing of leaf senescence. Secondary QTL affecting tolerance are to be found on six other chromosomes.



New submergence-tolerant Thai jasmine rice carries major QTL for submergence tolerance

A widely grown variety of Thai jasmine rice (KDML105) is highly susceptible to injury from submergence. Crossing and backcrossing with tolerant lines derived from the primitive Indian variety FR13A by **Siangliw *et al.*** (pp. 255–261) transferred tolerance to KDML105 in association with a critical region of chromosome 9. This was identified using DNA markers tightly linked to a major QTL for tolerance.



Submergence-induced shoot elongation in rice

Submergence-induced acceleration of shoot elongation by rice (*Oryza sativa* L.) makes it possible for the crop to be grown in areas prone to deep-water flooding.

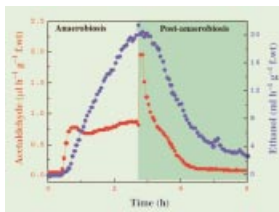
Vriezen *et al.* (pp. 263–270) discuss the regulation of underwater shoot extension in terms of molecular biology, metabolism, and interactions between the hormones ethylene, gibberellins and abscisic acid.

Continued overleaf



Coleoptile growth in anoxic rice seedlings

Few plant organs grow when anoxic; the rice coleoptile is a rare exception. The anaerobic elongation by the coleoptile establishes a 'snorkel' for rice sown in flooded fields. **Huang *et al.* (pp. 271–278)** show that anoxia inhibits K^+ translocation from the caryopses to the coleoptile much less than K^+ uptake from the medium, and that K^+ translocation is directed mainly towards the growing zone.



Rice response to anaerobiosis and submergence

Rice plants are severely damaged by complete submergence, which could be a result of tissue anoxia imposed by a reduced availability of oxygen. Using laser-based spectroscopy, **Boamfa *et al.* (pp. 270–290)** investigate this possibility by on-line monitoring of alcoholic fermentation products. They conclude that oxygen deprivation may not always determine the extent of damage caused by submergence under natural conditions.



Light/dark effects on PDC activity in submerged rice seedlings

Submergence tolerance of rice seedlings was assessed by **Mohanty and Ong (pp. 291–300)** under natural day/night conditions. Compared with pre-submergence values, the activities of pyruvate decarboxylase (PDC) extracted from roots during the night were higher than those extracted in the morning. Such increases were amplified in seedlings submerged in continuous darkness, demonstrating the incidence of tissue hypoxia or anoxia during submergence during each dark period.



Plasticity in root aeration in rice

Internal O_2 transport enables roots to grow in waterlogged soils. **Colmer (pp. 301–309)** shows that diverse rice ecotypes acclimate to waterlogging by increased aerenchyma and induction of a barrier to radial O_2 loss from roots. Plasticity in expression of these traits may enable rice to grow in soils that fluctuate between drained and flooded conditions.