Animal nerve signal is an innate plant stress signal

Plants respond to stress with a combination of chemical responses similar to those of animals, but using a separately evolved protein mechanism.

Communications published a paper “GABA signalling modulates plant growth by directly regulating the activity of plant-specific anion transporters” which reveals for the first time a mechanism by which GABA (gamma-aminobutyric acid) can act as an endogenous signal in plants. We have asked one of the authors of this research, A/Prof Matthew Gillham, to comment on this work.

The Study

In this study we found that there are proteins that sit on the membranes of plant cells that can bind GABA, and this modifies how plants transduce electrical signals, especially when plants encounter sub-optimal conditions. Although GABA has been long known as a key neurotransmitter, which calms down electrical activity in animal neurons, it was first described to science after its extraction from plant tissue over 60 years ago. We found that there is a family of ion transporter proteins in plants that have their activity directly regulated by GABA. These proteins share no similarity to animal GABA receptors other than in a tiny region that is associated with binding GABA. We modified this region and abolished GABA regulation of
these proteins but this did not affect other functions of these proteins. This information suggests that the ability for plants and animals to respond to GABA appeared to evolve separately in plants and animals rather than being present in a common ancestor.

The Difference Between Sleep and Anesthesia

Prof. Emery Brown of MIT on the rapid eye movement stage of sleep, electroencephalogram patterns, and the role of GABA receptors

We tried a number of plant-derived chemicals that are used in the medical area to interact with animal GABA receptors – some of these drugs are used to treat epilepsy or depression. These chemicals also regulated the plant GABA receptors. These findings call for a re-evaluate of what the natural role of these chemicals might be in nature, whether they have targets in plants or whether they are used by plants as a defense against animals. It also shows that it is likely to be further chemicals that can be found in nature that can be used as plants and animals seem to bind GABA in a similar way.

Plants, unlike animals, cannot move away from stress, they have to adapt to the stress or die – examples of how a plant can do this can be through a change in the way it grows or by altering how much energy it acquires through photosynthesis. Prior to our discovery of GABA regulation of these proteins, other researchers had identified some members of this protein family as having key roles in tolerance in
acidic soils and in the regulation of gas exchange in plants. The plant contains many members of this family, at least 9 in rice and 33 in soybean, with many individual members in different plant tissues. The identification of GABA-regulated proteins that modifies electrical activity across plant membranes provides another way that plants can use to respond, adapt and survive inhospitable conditions.

Background

GABA rapidly increases in concentration in plant tissues when a plant encounters environmental stress – i.e. drought, anoxia, acid soils, extreme temperatures, salinity and herbivory. For instance, an insect crawling on leaf can stimulate GABA to build up within seconds. It was also previously shown that GABA gradients could guide pollen tubes to the female tissue in flowers and this was important in proper fertilization. Coupled to the fact that GABA is known to be a key nerve signal in animals it was speculated that GABA could act as a signal in plants. However – since the publication of the first plant genome 15 years ago – it became apparent that there are no proteins that resemble animal GABA receptors in plants. Therefore, before now, there was no mechanism identified by which GABA could act as a signal in plants.

GABA is a key carbon and nitrogen containing metabolite in both plants and animals that can change concentration rapidly. This primes it as an ideal compound to signal changes in metabolic status. Plants do not have a nervous system but like all living organisms consist of cells that conduct electrical signals across their membranes. GABA in both plants and animals reduces membrane excitability, which can act as a signal. Despite the proteins that perform this role in plants and animals being quiet different it is fascinating that animals and plants have recruited the same signal to do this.

Future Direction

We explored the role of the GABA responsive proteins in wheat roots in response to acidic and alkaline soils. There are many different members of this protein family present in multiple tissues. We have projects exploring the role of these proteins in various tissues under stress. We are also exploring how the roles of GABA in metabolism and signaling are linked. When GABA was first proposed as a nerve signal in mammals the big debate was ‘how could it be a signal if the concentrations of GABA were so high in the tissue?’ The answer appears to be compartmentment of the signal, bulk concentration can be quite different from that
in local compartments of cells or tissues. The same question can legitimately be asked of plants and is one we are trying to answer.