Biological Sciences review

Unruly plants

Some plants have adaptations that allow them to function as parasites

Parasitic plants

From an early age we are taught that plants make food from sunlight. It is explained that plants have roots in the soil, which take up all the minerals and water they need. Later, we learn the critical role of the green pigment chlorophyll. Many textbooks lump all plants together when they cover photoautotrophs – self-feeding organisms that use light as their source of energy.

But some plants do not obey these rules. Some, like us, are chemoheterotrophs – relying on chemical reactions to provide their source of energy. Some lack roots. Some lack the ability to make chlorophyll. This is why a few informed textbook authors add the word 'green' to plants when considering energy transfer.

There are 4500 or so species of flowering plant classified as partial (hemi-) or complete (holo-) parasites (see Table 1), many of which are highly successful.

Table 1 Classification of parasitic plants

Type of parasite	Definition
Obligate	Cannot complete its life cycle without a host
Facultative	Can complete its life cycle independent of a host
Stem	Attaches to the host stem/branch
Root	A parasite of underground tissues – most attach to plant host roots
Hemi-	Retains some photosynthesis. It may obtain only water and mineral nutrients from the host plant or also gain organic nutrients from the host
Holo-	Derives all of its fixed carbon from the host plant and commonly lacks chlorophyll
Generalist	Capable of parasitising many species or even several species at once
Specialist	Parasitises only one or very few species

Mistletoe growing on a tree

Mistletoe

There are more than a thousand species of this obligate hemiparasite. They thrive on every continent except Antarctica. In Australia, there are sufficient plants producing berries throughout the year to allow the mistletoe bird to eat very little else.

A key enzyme called Complex I, previously thought to be essential for aerobic respiration in eukaryotes, is missing in European mistletoe (*Viscum album*). Complex I is usually embedded in the inner membrane of mitochondria. It is usually the first enzyme in the intramitochondrial respiratory chain, responsible for transferring electrons from reduced NAD to ubiquinone and generating a proton gradient.

European mistletoe has lost the genes responsible for this enzyme – a feature common to plant parasites, some of which have only 60% of the genes found in their non-parasitic relatives.

Plant parasites of fungi

One conifer, one bryophyte and around 400 species of flowering plant parasitise fungi. These mycoheterotrophs tap into mycorrhizal fungi, and so gain access to resources from a wide range of plants around them (see Biological Sciences Review Vol. 37, No. 4, pp. 12–15).

The ghost pipe is a memorable example when it emerges above ground to flower. This holoparasite has no chlorophyll, no leaves (only scales), and looks nothing like its more familiar relatives in the Ericaceae family, better known for its heathers, blueberries and rhododendrons. A mantle of fungal tissue forms on the surface of its roots, the outer cortical cells of which contain pegs of fungus and look similar to the transfer cells of phloem. The parasite is, thanks to the mycorrhizal fungi, supplied with photosynthate from the surrounding plants.

This plant features in some of the stories of the Cherokee of North America. Its other name, 'Indian pipe', refers to a legend about a group of chiefs quarrelling without resolution, while passing around a sacred pipe. The story holds that the Great Spirit turned the chiefs into the plant, because they should only have smoked the pipe after making peace with each other.

Ghost pipe (*Monotropa uniflora*), native to temperate regions of Asia, North America, and northern South America

Striga (witchweed) – a root parasite of cereals

A single plant of this ruinous hemiparasite can produce 500 000 seeds, which can remain viable in the soil for over 10 years. Germination is triggered by compounds called strigolactones – plant growth substances that attract mycorrhizal fungi, and are secreted by the host roots (see Figure 1). The host roots also secrete compounds involved in the synthesis of lignin, which (unfortunately for the host) act as pre-haustorium-inducing factors. A haustorium (a pad-like organ) forms, which then uses a combination of digestion and brute force to penetrate the host. Soon after the host xylem is penetrated, the parasite develops sieve tubes and attaches to the host phloem, ensuring a supply of water, minerals and photosynthates to fuel the growth of the parasite.

This parasite attacks economically important plants such as maize, sorghum, rice and sugarcane. It is one of the most destructive pathogens in Africa, affecting 40% of the continent's arable savanna region, which covers two thirds of the land area – approximately 40 million hectares of crops. This often causes 100% crop loss and financial losses of up to $13 billion each year. Most crops in Africa are grown by subsistence farmers who cannot afford control measures. The problem can be so severe that some farmers have to relocate every few years.

In some economically developed countries, 'suicidal germination' is one control measure. In fields not yet planted, *Striga* seeds in the soil can be induced to germinate by injecting ethylene gas. This mimics the physiological response tied to host recognition (see Figure 1) and since no hosts are available, the parasite seedlings die. However, this treatment is expensive.

Flowering stems of witchweed, *Striga elegans*, which has parasitised the underground tissues of the grass seen to the left of the image

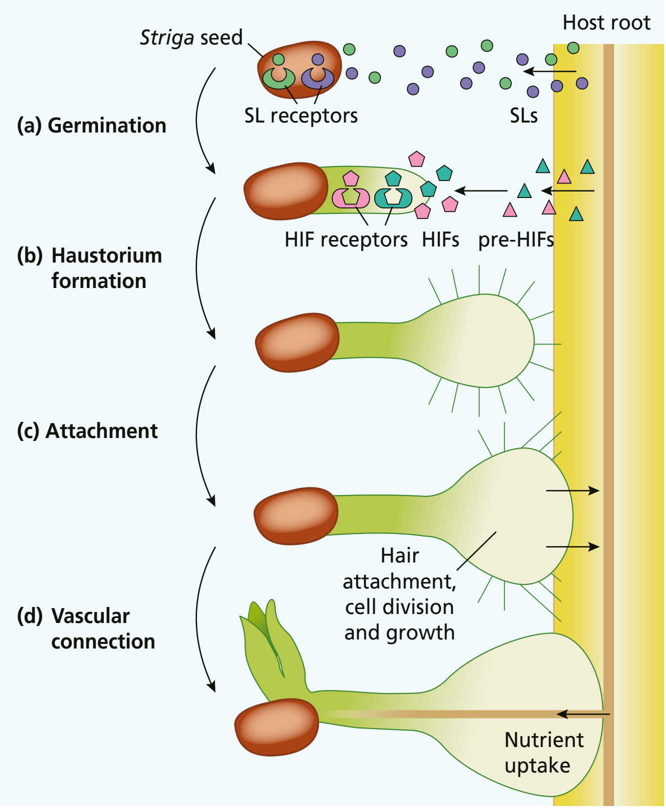

Figure 1 How witchweed invades its host. (a) Strigolactones (SLs), secreted by the host roots, are perceived by SL receptors in the parasite seed and trigger germination. (b) The host root releases pre-haustorium-inducing factors (pre-HIFs), which are perceived by HIF receptors, activating haustorium formation. (c) Haustorial hairs, cell division and growth allow the parasite to attach to the host root. (d) Further growth of the haustorium into the host creates a vascular connection

RESOURCES

An example of how one mistletoe species spreads:
https://tinyurl.com/parasite-in-poo

Mistletoe partnerships:
https://www.bbc.co.uk/programmes/p00crfc4

A biological superglue from mistletoe berries?
https://tinyurl.com/mistletoe-glue

Mistletoe mystery – something's missing from the kissing plant:
https://tinyurl.com/mistletoe-mystery

Ghost pipe – grief remedies and metaphors for the Anthropocene:
https://tinyurl.com/ghost-pipe

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