The common European mistletoe *Viscum album* growing on an oak tree in winter. The living evergreen mistletoe growths are most obvious.

The secret life of mistletoes

'Parasite!' We use the word as an insult, which perhaps betrays an attitude of disgust towards some of the 'smartest' creatures on earth.

In fact, the parasitic way of life is a common one, and highly successful. Many parasites deserve admiration for the way in which they have evolved to live and reproduce with minimal expenditure of their own energy. But they are not 'lazy' — they must make considerable effort to breach the defences of their hosts, as well as to overcome the other area of most difficulty for parasites — moving from one host to another. In general, they can't make that move themselves.

When we think of parasites we may imagine fleas, worms, or bacteria. But plants can also be successful parasites, and among the best known and most abundant of flowering-plant parasites are the mistletoes.

Strictly speaking, mistletoes are hemiparasites, because they do at least make their own food by the normal process of photosynthesis. (Some may not always make enough food and so may take some organic compounds from the host, while others may photosynthesise more efficiently than their hosts.) What they all take from their host is water and any minerals or other substances carried within it. Without this water supply they would die. Because they cannot develop their own root system, they are unable to be free-living.

Australia is rich in mistletoes, with about 90 species known. In terms of number of different species, mistletoes are most common in the tropics. But a walk in many other areas of the country will reveal mistletoes clinging to *Eucalyptus* or *Casuarina* species, their foliage often surprisingly similar to that of their host tree, in some cases almost indistinguishable.

We know that severely infested trees will die, but in a natural setting this is rare; after all, a good parasite should never kill its host, as it thereby kills itself. But before considering what can be done when mistletoes become a problem, we first need to know more about the plants themselves.

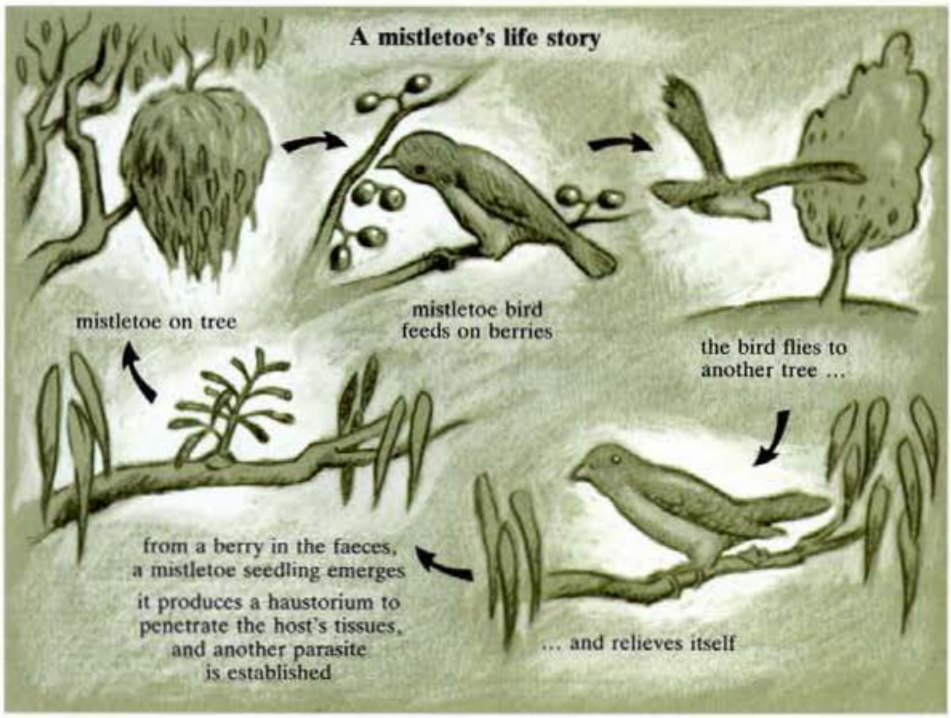
Unusual adaptations

We all know that mistletoes grow on the branches of trees, but how do they get there? To disperse their seeds, many rely on the unusual and aptly named mistletoe bird, while some are able to shoot their seeds away as their berries dry. The small mistletoe bird has a busy life, defaecating very frequently because of the laxative effect of the often brightly coloured mistletoe berries that, almost exclusively, make up its food.

The berry comprises a sweet outer layer, which the bird rapidly digests, and the seed, which is coated in a slimy substance termed viscin. This lubricates the passage of the seed through the bird's short intestine and allows its quick elimination in the faeces.

But there's the rub: for a mistletoe it would be a calamity if the seed dropped to the ground, because after germination it's unable to form a normal root and establish in the soil. It must land on its host. To ensure that it does, the obliging mistletoe bird twists sideways during the act of defaecation, and the seeds are deposited on the branch of a tree. And usually not just any tree — for the mistletoe bird is a fussy eater. It mainly eats mistletoe berries, and so is attracted only to trees that either carry mistletoe already (and thus must be suitable hosts), or sport foliage that looks like the mistletoe — and the host foliage often does, because many Australian mistletoes have evolved to mimic their hosts.

As the mistletoe bird is not a strong flier, the distribution of the parasites is often limited, and infection of trees tends to occur in 'clumps'. Large stretches of water represent a severe barrier. Mistletoes and their birds are absent from Tasmania



today, although they may have occurred there in the past when the Bass Strait was dry land.

Another adaptation to its mode of life is the production by the mistletoe seed of a haustorium instead of a root. This organ — probably by means of enzyme secretion — can penetrate the bark of the host. The haustorium also secretes host-like hormones that cause the tree's stem or branch to enlarge at the point of entry and induce the cells of the xylem (the water-conducting tissue) to proliferate.

This ensures the mistletoe a good water supply, which is what it really needs. The section of the host branch beyond the mistletoe eventually dies because of water lack, neatly preventing any shading of the parasite, which, of course, must still perform photosynthesis.

The fact that mistletoes as a group have no particular leaf shape, but rather emulate their hosts — those on casuarinas for example have long, needle-like leaves,

Many mistletoes rely on birds for their spread. The highly specialised mistletoe bird needs the parasite's berries for food.

while those on gums are quite different — has to be explained by supposing that this mimicry confers an advantage. One such, concerning dispersal by the mistletoe bird, we have already mentioned, but mistletoe biologists and aficionados — among them Dr Bryan Barlow, a botanist with the Australian National Herbarium at CSIRO's Division of Plant Industry — suspect the existence of other factors too.

It is possible that a mistletoe species' resemblance to its host's leaves represents a type of parallel evolution — that is, the adoption of similar characteristics because similar functions are required. However, the mistletoe leaves, although looking like their hosts', differ in construction, and mistletoes often lose much more water through their leaves by the process of transpiration than their hosts do.

Dr Barlow therefore argues that the mimicry in the leaf form is not merely a coincidence, nor a convergence of form brought about because the parasite and its host live in the same place. (See below for more detail on convergent evolution.) Rather, the scientist thinks that the mimicry may have evolved to provide some sort of protection from being eaten. In Australia, for example, possums enjoy mistletoe leaves; even if the animals have never tried them before, they soon develop a liking for them when given the opportunity.

The fact that mistletoes seemed to become more abundant in Australia earlier this century is possibly linked to the decrease in possum numbers that occurred with hunting and clearing. In New Zealand, mistletoes have become less common, and, at the same time, numbers of the introduced Australian possum have been increasing there. (See *Ecos* 26.)

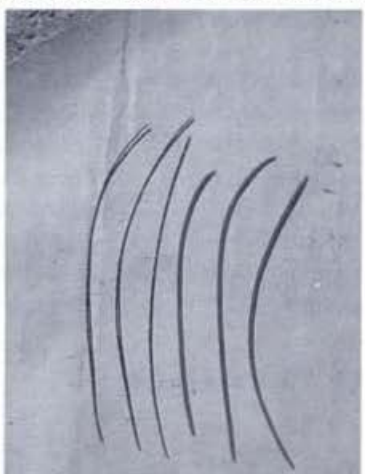
If possums are important mistletoe predators, then the mistletoe's similarity to its host enables the parasite to blend in on its tree and thus avoid being specifically chosen as food by the animals. Mistletoe leaves are often a slightly different shade of green from their hosts', but as possums have black and white vision and feed at night, only leaf shape would matter. The fossil record shows that leaf-eating arboreal animals such as possums have been common in Australian forests for several million years — plenty of time for a selection pressure to have 'shaped' the evolution of the mistletoe leaf.

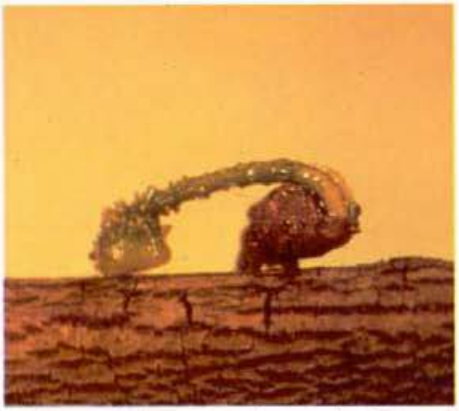
Mistletoes do have other unusual features, and an interesting aspect of their biology is that they may parasitise one another. Dr Barlow gives this convoluted example: in eastern Australia the mistletoe *Viscum articulatum* grows on the mistletoe *Notothixos subaureus*, which often grows on yet another mistletoe, *Amyema congener*, itself frequently found on the mistletoe *Muellerina eucalyptoides*, which, rather conventionally, just grows on gum trees. And of course mistletoes, like any other plant, can have fungal or viral parasites growing within them or on them!

Does living off another mistletoe provide any advantages? Dr Barlow thinks that it may. Firstly, the second parasite may benefit from sharing the dispersal vector of its mistletoe host.

A second line of reasoning runs like this: towards the edge of a host species' natural range its occurrence may become more sporadic. Because mistletoes are similar in

The mistletoe is a good mimic, regardless of the form of its host's leaves. Here it is shown with strap-like eucalypt leaves, with oval eucalypt leaves, and with the needle-like casuarina leaves. In all cases the mistletoe's leaves are on the right. They are often slightly paler than the hosts'.





Mistletoe starts life as a berry (left), which should germinate after being deposited on a branch of its host (centre) by the mistletoe bird. It soon penetrates the bark (right).

physiology and anatomy, they can parasitise one another more readily than they can adapt to new, different hosts. Thus a mistletoe may extend its natural range beyond that of its preferred host by using another mistletoe species as host.

Mistletoes and sex

Leaving aside for the moment the association of mistletoes with human fertility (see the box), what about their own reproduction? Many mistletoes today are dioecious, which means that they have separate male and female plants, the flowers only producing either pollen or eggs. By studying the chromosomes of many different species and populations of the large mistletoe genus *Viscum*, Dr Barlow came to some conclusions about the origin and significance of dioecy.

He found several monoecious species of *Viscum* — that is, with each plant carrying both male and female flowers — and suspects that dioecy was a later development. The obvious advantage of dioecy to the plant is that it promotes outbreeding and hence increases genetic diversity. Many plants achieve this without resorting to the complexities of separate sexes: common strategies are ripening of the pollen-producing anthers or the female pistil at different times of the day, or a biochemical self-incompatibility, which ensures that self-fertilisation, if it does take place, will be fruitless, and only pollen from another individual will develop on the stigma (the sticky area at the top of the pistil).

Many mistletoes are hermaphrodite and have such outbreeding mechanisms. However, if early mistletoes relied on small foraging insects for pollination, as many still do today, then their small range of movement would mean that even in self-incompatible plants sexual reproduction would still be difficult, as nearby insects would often be carrying pollen of the same genetic type and so a great deal of ineffective self-pollination would take place. Having separate male and female plants ensures that every cross will at least be able to develop and there can be no incestuous self-fertilisation.

To achieve this dioecious state requires some genetic re-modelling, just as it would for us dioecious humans if we were suddenly to become self-fertilising hermaphrodites. Dr Barlow has discovered that mistletoes in the genus *Viscum* show frequent occurrence of a genetic phenomenon called chromosomal translocation. In this, chromosomes break during the course of cell division and subsequently join up with segments from other chromosomes. Put simply, these translocations seem to have allowed genes for the two different sexes to be separated and to be passed on in the necessary way.

That dioecy is advantageous is demonstrated by the fact that groups of mistletoes with it show a much greater diversity and range of species in different habitats than do their monoecious cousins.

Mistletoes and Gondwanaland

Dr Barlow's studies of the chromosome numbers in existing mistletoes world-wide suggest that one family, the Loranthaceae, has an ancient history in the southern hemisphere. The most primitive mistletoes still living today are in cold habitats in Australia, New Zealand and Andean South America.

Now because mistletoes have such poor dispersal mechanisms across water barriers, it seems likely that they underwent their initial development when the southern lands were still united as the supercontinent of Gondwanaland. During these times the polar climate was mild and even Antarctica was covered by the rainforests in which the mistletoes probably first evolved. When Gondwanaland broke up into separate continents, the primitive mistletoes were already established, and gave rise to independent evolutionary lines in Africa,

The damage mistletoe can cause is seen here. The host branches beyond the parasitic clumps are mostly dead.

A mistletoe bird

Australasia and South America. The pattern of relationships in loranthaceous mistletoes thus tells us something of the vegetation history of the Gondwanan lands.

Mistletoes as a problem

In natural forests and woodlands, mistletoe-infested trees rarely die, and the balance between parasite and host is well maintained. Helping matters along is the fact that during dry spells the parasite will often die before its host because of the far higher rate of water loss from its leaves. Often the intensity of mistletoe infection in an area may vary in an almost cyclical fashion depending on rainfall patterns, and on the numbers and movements of mistletoe birds.

The occurrence of mistletoes as serious parasites causing tree death is certainly linked with human activity. Clearing the land means that any trees left standing will be targets for mistletoe infestation and may eventually become overloaded and die. These few remaining trees will receive more visits from the mistletoe birds and so be targetted even more. Also, clearing reduces the population of the mistletoes' possum predators.

The mistletoe *Amyema sanguineum* on its eucalypt host. The mistletoe boughs are ruddy-hued because of its reddish berries.

Death of relatively isolated trees in gardens and nature strips in towns is now quite serious, especially in South Australia. In dealing with it we cannot really view the mistletoes as troublesome weeds as they are native and belong with our trees. So far no effective treatment has emerged, apart from the obvious strategy of cutting off all the mistletoes on the affected trees. Apart from being time-consuming and expensive, this only gives temporary relief until the time when a mistletoe bird from a nearby area, possibly natural bushland, flies in with some more seeds. Various poisons can be injected into the host tree, and may kill the mistletoes — but the effect on the host is unpredictable and may be severe, often killing the tree. Again, infestations may recur. At the moment, we have no answer; only by understanding more about mistletoe physiology and ecology can we hope to manage them effectively.

Roger Beckmann

Mistletoe myths

Australians of Anglo-Celtic origin tend to associate mistletoes with Christmas festivities. In the British Isles and some other European countries the plant has figured prominently in mid-winter celebrations for centuries. It is striking in its ability to remain green on a deciduous tree in a bleak northern European winter, when everything seems dead.

For the Celts of pre-Roman Britain, whose animistic religion included tree worship, the 'mighty oak' was a spiritually significant plant: indeed, it's still a British symbol. The growth of mistletoes on oaks was rare then, as it is today, and considerably heightened the mistletoe's mystique when it occurred. People thought that the mistletoe must be keeping alive its deciduous host; so it was obviously the heart or spirit of the god that lived in the sacred tree, and it therefore became important in religious ceremonies. The Druids must also have known that the mistletoe fruits in winter and so possibly thought of the plant as a symbol of fertility — able to reproduce when all else was barren.

Christmas is a Christian compromise with an old winter solstice pagan festival that could not be banished. The winter rites were connected with assuring the return of spring, and the promise of fecundity in the following year's crops — hence the choice of evergreen plants for the celebrations: the conifer tree, the holly (also producing its red fruit in winter), and the mistletoe. These were reminders of the green of summer in a barren winter's landscape.

Certainly the tradition of kissing under the mistletoe comes from the old ideas of fertility that lay behind the winter festival. In Austria, an old tradition asserts that a piece of mistletoe should be hidden secretly in the bedroom of newlyweds to ensure the prompt arrival of children. Women in ancient Rome carried a piece of mistletoe to help with their fertility, and half a world away in Japan the Aino people believed that infertile women should eat mistletoe.

As Christianity was grafted onto existing beliefs, the magic of the mistletoe became transferred to the new religion. An old legend in Europe maintains that Christ's cross was made from the wood of the mistletoe and as a punishment the plant was banned from the goodness of the ground, having to make a living on other trees. The mistletoe was called 'Herbe de la Croix', and apparently still bears that name in some parts of Brittany.

Of course, a plant loaded with spiritual significance must have special powers, and so the mistletoe was well regarded in medicine. Mediaeval herbalists believed it was a cure for epilepsy, but it has also been cited as a palliative for virtually every ailment that afflicts people. Evidence exists that some mistletoes may have useful muscle-relaxing and narcotic properties, and may help control nervous spasms. However, large doses can cause convulsions. Many of the world's species of mistletoe have not yet been investigated for medicinal uses — so perhaps this 'magic' plant may yet surprise us.

More about the topic

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