# Successful cultivation of the golden chanterelle

Figure 1 **First cultivated fruit-body of the golden chanterelle (*C. cibarius*).**

The golden chanterelle (*Cantharellus cibarius*) and allied species are highly appreciated edible mushrooms. Large quantities of *Cantharellus* species are exported[1] from the northwestern coast of the United States to central Europe, where the *C. cibarius* population is declining[2]. There have been many efforts to cultivate this species[3–5], and here we report the first successful fruit-body formation in the greenhouse, hosted by pine seedlings only 16 months old.

Cultivation of the golden chanterelle has been hampered by the difficulty of obtaining pure mycelia, owing to contamination by other organisms in the fruit-body, especially *Pseudomonas* bacteria[6]. Also, unlike cultivated saprobic mushrooms that can utilize cellulose, *C. cibarius* obtains its carbohydrates from the ectomycorrhizal symbiosis it forms with trees. Common techniques for establishing mycorrhiza using fast-growing plant nursery fungi are not applicable to *Cantharellus*, so a routine method for *C. cibarius* mycorrhiza formation was not published until 1994 (ref. 7). However, by that time it was known from observations in nature that *C. cibarius* in Sweden was mostly found with trees older than 25 years.

In January 1995 we started an *in vitro* mycorrhiza synthesis procedure, using Swedish *C. cibarius* mycelia that we had isolated from fruit-body tissue in 1988. In March 1995, we transferred *Pinus* seedlings inoculated with *C. cibarius* into pots, from which we harvested plants during August 1995 to study mycorrhizal establishment. We returned a fraction of the plants to their pots and left them in the greenhouse for another seven months.

In April 1996 we found the first fruit-body, which we harvested later that month. It originated from a drain-hole in a plastic pot carrying *Pinus sylvestris* inoculated with Swedish *C. cibarius*. The size of the fruit-body was 3.5 cm, and its odour, trama and spore-forming hymenium were normal (see Fig. 1). We found fluorescent *Pseudomonas* in great quantities as in wild strains of *C. cibarius*. The fruit-body was not attached to roots or mycelial cords. Another pot contained a 0.5-cm fruit-body primordium and several contained large quantities of hyphal knots resembling young primordia. We found a third large fruit-body in June 1996. In November 1996 there was a second flush of three more fruit-bodies.

We found no obvious factors triggering fruit-body formation. The *Pinus* seedlings were 16 months old, demonstrating that *C. cibarius* is not dependent on old trees for reproduction. In addition, the fungal isolates used in this experiment had been in culture for eight years. It has been 112 years since Frank published the first observations on mycorrhiza[8], and only now can we control the life cycle of a mushroom that is an important symbiont to forest trees as well as a highly appreciated food item.

With greenhouse production, it would be possible to study, for example, the physiology of reproduction, genetics, and bacterial and insect symbiosis. Obviously, the life-cycle strategy of *C. cibarius* is different from inedible mycorrhizal model organisms such as *Laccaria*, which quickly colonizes roots via spores. The *Cantharellus* cultivation technique could be applied to other edible or endangered species such as *Tricholoma matsutake*. Its life cycle is similar to *Cantharellus*, and it is the most valuable mushroom in the world (US$100 per fruit-body). There are also potential commercial applications similar to the establishment of truffle (*Tuber melanosporum*) orchards by outplanting of inoculated seedlings[9].

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# Thalidomide's chirality

In her News article[1], Rubner wrote that "pharmaceutical products need to be tested separately for the effects of left- and right-handed molecules, following the tragedy in the early 1960s when women gave birth to children with malformed limbs after being given the sedative thalidomide, which had been contaminated with the wrong enantiomer". This statement about thalidomide relies on a report[2] demonstrating malformations in pups of rodents treated with *S*-thalidomide, whereas offspring of animals treated with the *R*-form developed normally. We point out here, however, that these data need to be interpreted with caution.

First, rodents are generally insensitive to the teratogenic effects of thalidomide[3]. Second, Fabro *et al.*[4] demonstrated that there is no difference in teratogenicity between the two enantiomers of thalidomide in New Zealand white rabbits, a species susceptible to the teratogenic effect of thalidomide. Third, and most important from our point of view, Eriksson *et al.*[5] have shown that there is a rapid interconversion between the two forms of thalidomide *in vitro* and *in vivo* in humans after application of either *S*- or *R*-thalidomide. The mean rate constants for *in vivo* inversion are between 0.12 and 0.17 $h^{-1}$, respectively, depending on whether the *S*-form or the *R*-form is applied. Therefore, about 8 h after application of the pure enantiomers, an equilibrium has been reached and both forms of the compound are present in the blood at similar concentrations. This leads to the conclusion that application of a pure enantiomer would not have prevented the tragedy of thalidomide-induced embryopathy.

Thalidomide has attracted new interest because of its immunomodulating activity[6], which is reflected in *in vitro* assays by an inhibition of the release of tumour necrosis factor (TNF)-α from activated mononuclear human blood cells. To find out whether this inhibitory effect is enantio-selective, we tested a set of configuration-stable thalidomide analogues as well as the enantiomers of thalidomide *in vitro*[7]. Surprisingly, we found a clear enantio-selectivity towards the *S*-form in all the analogues tested.

In the case of thalidomide, the *S*-form confers a slight, but statistically significant, increase in the degree of TNF-α inhibition compared with the *R*-form. It should be taken into account that the racemization is not complete during the first, most sensitive hours of this assay. Enantio-selectivity towards the *S*-form has also been observed with configuration-stable — or at least