IRISH NATIVE WOODLANDS AND THEIR ASSOCIATED FUNGI AND LICHENS

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Abstract

Irish native woodlands are under-recorded for both fungi and lichens. The relative permanence of lichens, as compared with fungi, has resulted in a more in depth lichen record. Records have been published on a 10km grid basis rather than by particular habitats. As most 10km squares that contain native woodland also contain planted woodland, it is not possible to list taxa of native woodland alone.

Fungi have been mostly recorded from woodlands and the woodlands most frequently recorded were planted in old demesnes. With few exceptions, fungal records have been carried out during one to two day visits, so only the species fruiting at that time were noted. More recent work has shown that such visits see less than one third of the macromycetes species that appear over the autumn/winter period.

About half of Irish native tree species form mycorrhizal associations with macromycetes; the fruit-bodies of these species tend to appear earlier in the autumn than those of true saprophytes. The timing of flushes of both mycorrhizal and saprophytic macromycetes is very weather dependant. The poor distinction (in terms of warmth and wetness) between summer, autumn and winter in Ireland causes great variability in timing of fruiting from year to year.

Oak woodlands of all types form the richest (and most recorded) native habitat for macromycetes in Ireland; willow and birch scrub woodlands may be as rich but have not been recorded to date. Ash woodlands are relatively poor in macromycetes.

Introduction

This review will first describe how fungi and lichens live and the different problems associated with recording lichens and macrofungi in the field. Examples will be taken from Derryclare Wood near Lough Inagh in Co Galway, from the Birch Grove near the summit of Howth, Co Dublin, and from broadleaf woodland in Co Meath. Since many of the macromycetes found in woodland are attached to mycorrhizal mycelia associated with about half of the Irish native tree species, the mycorrhizal status of Irish native woodland trees, where known, is discussed in the context of the comparison of macromycete biodiversity in different native woodland types. Finally recommendations are made about systematic recording in the field, record management and woodland management.

The biology of fungi and lichens in woodland

Fungi

Fungi are mostly microscopic, colourless, heterotrophic organisms, which permeate their substrate (soil, wood, dead or live plant tissues) by means of filamentous hyphae. The hyphae are between 2 and 15mm in diameter and function as feeding, storage and translocating structures. The hyphae of one individual can be

interconnected at one central point, or more commonly in a three-dimensional network. In some fungi, hyphae can form parallel aggregates, such as the white mycelial cords which are often seen connecting the reproductive structures in puffballs to the 'feeding' mycelium, or the black invasive rhizomorphs of the honey fungus, *Armillaria mellea.* These rhizomorphs can form a 'super-mycelium' which is very large (4 ha. has been claimed) and very old (10,000 yrs has been claimed). Most fungi are much smaller and have much shorter lives than the statistics for *A.mellea*; some are less than 500mm in width and will live for only a few weeks at normal soil temperatures.

After a period of vegetative growth, the length of which is determined as much by the species of fungus as by its environment, a mycelium goes into reproductive mode. Reproduction is almost universally by spores, which are usually produced on or in structures that are designed to disperse the spores away from the parent. Time-dispersed spores simply persist after their parent mycelium has decayed. Space dispersed spores are most commonly carried passively by moving air, water, or animals, but may display active mechanisms in order to become airborne. A few are motile (in water only).

Microscopic sporing structures take less time and material to organise, than massive fruitbodies, such as the brackets of *Ganoderma applanatum* or the giant puffball (*Calvatia gigantea*) both of which may weigh several kilogrammes and are capable of liberating billions of spores in their lifetime.

All heterotrophs eventually exhaust or destroy their habitat, so it has been assumed that the lifetime of an individual fungus mycelium is usually determined by the life of one or more limiting components of its substrate, in which the mycelium is embedded. Spores are the usual means of escape, and some reproductive structures, such as the time-dispersive 'resting' zygospores of the Zygomycotina, are only formed when the substrate is almost exhausted.

Fungi in woodlands, however, can be very long-lived by comparison with the moulds, such as *Penicillium* spp., which have been the subject of most laboratory experimentation. The woodland fungi that live in and on soil organic matter are presented with continually renewed substrate in the form of comminuted, partially decayed leaf and twigs, while those that decay wood inhabit extremely bulky and durable substrates in the form of stumps, trunks and major branches. Those fungi that cause disease, such as cankers in the woody part of their long-lived host, may have a niche that persists for decades, while those that are symbiotic with the roots of longlived tree species, such as *Quercus* spp. and *Taxus baccata* have a resource that lives for centuries, if not millennia.

It is not surprising, therefore, that woodlands support the richest diversity (of all ecosystems) of fungi with large reproductive structures, which are vernacularly called fruit-bodies, toadstools, mushrooms, brackets, conks, cups, stink horns, etc. In temperate and sub-Arctic woodlands, most of the reproductive structures attached to mycelia living in soil organic matter or with live roots, appear on the soil surface towards the end of the growing season, when temperatures are falling and more importantly when the soil has been recharged with water, but before the first frosts of winter. Most of the fungus fruit-bodies seen in Irish woodlands only survive for a few days before they are eaten by animals (ranging from fly maggots and slugs, to mammals, including people), or are rotted by bacteria and moulds. The fruit bodies which are formed on mycelia inhabiting wood live longer than those formed on soil; some live for a few weeks, many live for months, and some are perennial. Woodlands also support a great number of fungi that cause disease in all parts of the trees and of other woodland plants. Most of the disease fungi are microscopic, but have been well documented in a European context (Smith *et al*., 1988; Buczacki & Harris, 1981).

Lichens

Lichens are not single individuals, but a symbiosis between fungi and algae or photosynthetic bacteria. The fungal partner's mycelium, produces most of the bulk of the thallus and so determines the shape, pattern of growth and colour of the lichen. The fungal partner also produces spores in sexual reproductive structures, which are often a different colour from the rest of the thallus. The photosynthetic partner grows in small

pockets just under the densely woven surface (cortex) of the thallus, where it is at once protected from grazing and exposed to light. Both partners can survive drying and rewetting, and lichens are commonly found in exposed places where no other organisms can survive. As these exposed places, such as tree bark and stone surfaces, usually provide neither nutrients nor water, the lichen is dependent on rain, mist and cloud water for the supply of both necessities. In woodland, particularly if the canopy is dense as in commercial plantations, the upper third of the trees provides a good environment for lichens, if cover/abundance and diversity of taxa are used as criteria. In relatively open native woodlands and in mature parkland, where mature trees have spread their canopies wide, the whole tree provides a good environment for lichens.

Lichens are usually slow-growing, but can be extremely long-lived, unless they are eaten (by molluscs and by insect larvae), used for building materials by birds, become diseased (see Folan & Mitchell, 1970), or are poisoned by sulphur dioxide in polluted air.

Most lichens exhibit one of three growth-forms. Crustose species are more or less immersed in their substratum, but may still form a thin cortex which is a different colour from the substratum. The fungus fruitbodies appear as small spots or more complex shapes on the surface. This growth form is easily overlooked.

Foliose species form a 'leafy' thallus parallel to but separate from the substratum, to which it may be attached by specialised mycelial strands called rhizinae. The upper cortical surface of the thallus is always different from the lower medullary surface. Fungal fruiting bodies can be produced within or on the surface of the thallus.

Fruticose species form small bushy outgrowths or long beard-like structures emanating from a single point of attachment to the substratum. The branches are very often round in cross section, but where they are flattened, both sides are cortical. Fungal fruit bodies are produced on the surface of the branches.

Identification of fungi and lichens in the field

Fungi

It is possible to make a preliminary identification of most fruitbodies in the field, without recourse to a microscope, by using one or more of the various field guides (e.g. Phillips, 1981; Cortecuisse & Duheim, 1996), but some genera require microscopy of their spores to distinguish species with very similar fruitbodies from one another. Microscopic examination of cap surfaces, spores, and other details, provides valuable laboratory confirmation of field identifications. Preservation of specimens is not difficult with fresh field material; the best method is warm-air drying, using commercially available domestic mushroom dryers (available on the European mainland (Howard Fox, pers.comm.)). The laboratory 'environment' may also make it possible to use Internet resources, such as the library of photographs of named species.

As with most identification tasks, practice brings familiarity with common species making it easier to 'spot' new species in the field. Increasing familiarity with the field guide(s) makes it easier to find the correct section of the book quickly and to use their keys, where provided.

Lichens

Many lichens have obvious features and can be identified from these, using one or more of the standard guides (Duncan, 1959, Dobson, 1992). A hand lens is useful as some diagnostic features are less than 1mm across. There are three chemical reagents which produce useful colour reactions in cortex and/or medulla; they can be used in the field, provided that they can be carried safely. As with the fungi, further laboratory study is required to determine the names of some taxa, and is useful to confirm field identifications in many.

A comparison of the difficulties of recording macrofungi and lichens.

Most fungal mycelia are immersed in soil or in plant material, whereas lichen thalli need light and are therefore in conspicuous places.
Fungal mycelia are useless for identification (except by expensive, laborious and longwinded DNA typing methods), whereas lichen thalli have many useful characteristics for identification.

Fruitbodies of saprophytic and mycorrhizal fungi do not need light, and may be inconspicuous. However most need access to free air in order to disperse spores; fungi with animal-dispersed spores may be totally cryptic, as in the truffles (*Tuber* and *Choiromyces* spp.). Fruitbodies of lichens are borne on the thallus and are usually very obvious.

Most fungal fruitbodies are fleshy and soft and are short-lived in nature, whereas lichen fruitbodies are persistent. It is best not to postpone the identification of fleshy fruitbodies, but lichen identification can be postponed, provided that the specimens are dried.

A fungal species list of a woodland can only be reasonably complete after repeated collections each year over several years. A lichen taxa list can probably be established in one collection per decade, provided that the upper parts of the trees are thoroughly explored.

Records of lichens and fungi found in Ireland

Fungi and lichens are under- recorded in Irish native woodlands. The key reference for lichens is Seaward & Hitch (1982) and those for fungi are Muskett & Malone (1978, 1980, 1983, 1985). Adams & Pethybridge (1910) published a *Census catalogue of Irish Fungi* almost a century ago.

The Lichen Atlas (Seaward & Hitch, 1982) is a set of distribution maps of individual species on a 10km grid basis in Great Britain and Ireland. As most 10km squares that contain native woodland also contain planted woodland, it is not possible to list taxa of native woodland alone, though each map has a commentary which discusses the substrates and habitats of that species. Less than half the Irish 10km squares had been recorded by 1982; the fullest coverage is in the south east (Wicklow, Wexford, Carlow Kilkenny), and in the south west (West Cork and Kerry). Most of the midlands of Ireland have not been explored for lichens.

Muskett & Malone (1978) list the Gasteromycete (puffballs) species found in Ireland in alphabetical order, followed by a list of dates and sites. Each record is given a citation number from the complete Irish mycological bibliography (Muskett, 1976). The site descriptions are often too brief to even identify which woodland was surveyed. The separate listing of the original references adds a further stage to the connection of record and place.

Muskett and Malone (1980 and 1983) used the same pattern when compiling the lists of Hymenomycetes (mushrooms and toadstools) and Ascomycotina respectively. Their last list (Muskett & Malone, 1985) is of micro-fungi, which are outside the scope of this review.

All three publications, Muskett & Malone (1978, 1980 & 1983) also list 72 of the 'Demenses, estates, woodlands, etc, frequently searched for fungi' together with their Vice-county code and grid reference. A quarter of these sites (18) are in or near Dublin (Dublin 9, Wicklow 6, Meath 2, Kildare 1); a further third are near Belfast (Down 14, Antrim 9). This skewed distribution towards the eastern counties in the island reflects the location of professional mycologists in universities and Government agencies. A further six sites are in or near the 'honeypot' of Killarney, and were surveyed by the British Mycological Society forays of 1885 and 1935. Muskett and Malone (1980) also refer to an intensive mycological survey of Clare Island (Rea & Hawley, 1912), which not only involved the island, but notable woodlands in West Mayo (7 sites).

Thus the majority (54 out of 72) of the most recorded places are either on the east coast or in two areas that were last intensively studied many decades ago. Many of the woodlands for which fungal lists have been published have changed in the decades since. There are important native woodlands for which no records exist, particularly from the west (Donegal, Sligo, Galway, Clare and Limerick), the south (Waterford, Wexford, Carlow-Kilkenny), and from the midlands of Ireland.
With the exception of the south eastern counties in the case of lichens, and of Mayo in the case of fungi, the deficits in fungal and lichen records match quite well

An example of this type of omission is Derryclare Wood, by Lough Inagh in Galway (grid. ref .L 840 500). This wood was not mentioned in any of Muskett and Malone's (1978, 1980, 1983) site lists, even though the nearby Ballinahinch estate (planted) wood was listed. Derryclare was identified as a scientific site of 'national importance' by An Foras Forbartha (1981) and consisted at that time of 'semi-natural oakwood with rich communities of lichens and invertebrates, which have been partly studied'.

Derryclare wood is 300km from Dublin and 95km from Galway and is even too remote from local habitation for significant harvesting of dead wood for firewood (Folan & Mitchell, 1970). It is dominated by *Quercus petraea*, with some emergent *Betula pubescens* and *Sorbus aucuparia*, and *Corylus avellana, Ilex aquifolium* and *Crataegus monogyna* in the shrub layer. Folan & Mitchell (1970) catalogued the lichens of the wood, finding 98 taxa, adding 32 new taxa to the 576 already listed for Vice County H16 (West Galway) and three that were new to Ireland. West Galway then contained 42% of the known lichen flora of Britain and Ireland. The apparent richness of this single vice-county was not only due to the favourable unpolluted climate of the area, but to the diligence and hard work, over several decades, of the second and senior author of the paper.

The authors also identified seven microfungi which were parasitic on lichens; six of these were new to Ireland. They are the only fungi listed for Derryclare Wood.

Records of fungi are also patchy in both time and space as exemplified by those of two unmistakable taxa in Muskett & Malone (1980); there are seven records of *Daedalea quercina* (Maze gill). This fungus forms a conspicuous and unmistakable hard (and therefore persistent over many months) creamy coloured bracket up to 15cm across, and is 'virtually restricted to oak' (Phillips, 1981). There are no records for West Galway, one from Brackloon Wood in Mayo (1910-11) and one from Kerry (Cromaglouin Wood in 1856). The other five records are from Wicklow (3) and Down (2) and none is more recent than 1948. There are two records of *Clavariadelphus fistulosus*, one from Cranmore, County Antrim, in 1840 and the other from the 1910/11 Clare Island Survey. This fungus forms slim tapering wands between 10 and 30cm high, growing from half buried twigs 'of frondose and coniferous trees, especially beech' (Phillips, 1981), and can be easily overlooked, as fruit bodies only last about two weeks and appear 'late' (October-February). This species appeared in the author's 17 year old planted ash wood in 2000 and has just (20/11/2004) appeared in his 12 year old planted birch-oak wood. It has to be more common and widespread than the text books opine and than the Irish records indicate.

Results from medium and long-term studies of particular woodlands in Ireland

Birch Grove, Howth Castle Demesne, October-December 1995.

This small patch of naturally regenerating birch is sited above the planted mixed broadleaf/coniferous woodlands of the old demesne. Local pollen studies (Cooney, 1994) showed that birch scrub had been present in the locality since C15th, but that fires were frequent up until 1970. In 1995 fifteen 10m x10m 'permanent' quadrats were studied by Roche (1996) from October to February 1996. On each of 25 visits he recorded the numbers and identity of macromycetes fruiting on the ground in each quadrat. He also collected soil samples from each quadrat and carried out a variety of laboratory tests on these soil samples. In general the soils consisted of a thin acid peaty A/B horizon over sandy parent material.

Thirty five macromycete species were identified over the five month period, but no new species appeared after the turn of the year. The species numbers recorded on each visit (Figure 1) showed three peaks (late October (12), mid November (11) and early December (10)). So, a single visit on the best day, would only have recorded 37% of the species appearing over the whole study period. The median number of taxa found on each visit was 8, just under 25% of the total list.

Peak numbers of fruitbodies were found in mid October (78), early November (140) and in late November (62) (Figure 2). Large numbers of fruitbodies did not coincide with the largest number of species; indeed, on 8/11/95 less than twenty fruitbodies, belonging to 11 species, were recorded.

Roche (1996) assigned the fungi he named into two groups; mycorrhizal and saprophytic. The mycorrhizal species were less numerous, less frequent and fruited earlier than the saprophytic species (Table 1). The most widespread of the mycorrhizal species were *Paxillus involutus* (in 11/15 quadrats), *Amanita muscaria* and *Russula ochroleuca* (each in 4/15 quadrats). The first two species are particularly associated with birch (Phillips, 1981). The most widespread saprophytic species were *Collybia dryophila* (in 10/15 quadrats), *C.butyracea* (in 7/15 quadrats) and *Mycena epipterygia* (in 9/15 quadrats).

Table 1. *The numbers of mycorrhizal and saprophytic fungal species, their peak frequencies, and the date on which the peak occurred in the Birch Grove, Howth Castle Demesne, Co. Dublin in 1995.*

	Saprophytic species	**Mycorrhizal species**
Number of species	19	16
Peak numbers (caps/sq.m)	0.3	0.11
Date of peak	Nov.3	Oct 4

Mixed woodland on neutral gley soil at Jealoustown, Dunshaughlin, Co Meath, surveyed continuously1974-2004.

The oldest part of this woodland forms part of a C19th estate as well as a parish boundary, and is marked as a woodland strip on the 1840 six inch Ordnance Survey. In 1974 it consisted of *Ulmus campestris*, *Fraxinus excelsior, Crataegus monogyna, Acer psuedoplatanus, Fagus sylvatica* and *Quercus robur.* All the elms (which died during the next 5 years) were ca 30-35 y.o, meaning that the woodland had grown up since the 1940s.

The younger parts of the woodland were planted by the author; *Salix caprea x viminalis* (1974), *Populus nigra* (1978), *Fraxinus excelsior, Alnus glutinosa, Salix* spp and *Corylus avellana* (1983-1990), *Betula pubescens, Quercus robur, Fraxinus excesior* and minor spp. (1992).

As these woodlands are all within 100m of the author's home, they have been under frequent, if not regular, surveillance since 1974. Any new species of macromycete has been identified and recorded. The list for the entire 2ha. now numbers over 100, but includes those from meadow and garden (ca 38 spp). The mycoflora of the youngest wood is expanding faster than that of the older woods, but new species are still appearing in the oldest woodland.

A few species have appeared once only in the thirty years, all in the oldest wood; *Verpa conica, Mutinus caninus* and *Calvatia gigantea* each appeared as single fruitbodies sometime in the 1990s. *Leotia lubrica, Boletus porosporus* and *Pluteus salicinus* appeared for the first time in 2004, and may well recur next year.

Nineteen species have appeared every year since 1974, but a further 35 species have appeared every year since they first arrived after 1974. Eight of these 'constant' species (all on dead wood of various dimensions) can be found at any time of year, but the rest are seasonal.

The biggest number of species found on one day was 26 on 6/9/04, ca 42% of the 63 species ever found over the last thirty years, which is bigger than the 31% found by Roche (1995) on one day, within his quadrats.

However, the 26 include the eight perennial xylophagous species, such as *Ganoderma applanatum* and *Diatrype disciformis,* and the 63 includes species that have appeared sporadically over the thirty years. A more comparable fraction with that of Roche (1996) would be restricted to fruitbodies of constant species occurring on the ground and would be 18/46 or 39%, which is not significantly different from Roche's 37%.

Another indication of the sporadic nature of fruiting, is the behaviour of *Armillaria mellea,* which has appeared twice (on a hawthorn stump in 1980, and on a poplar stump ca 10m from the first sighting, in 1996). This pathogenic fungus has also killed four ornamental shrubs and conifers in the same general area over the 24 years from its first appearance. It is more likely that the mycelium has persisted in a vegetative state than that six new infections gave rise to the fruitbodies and killed the four ornamentals.

Some conclusions from these two studies are as follows:

1 Any woodland will yield a small number (10 - 20) of xylophagous species at any time of year.
2 A single visit in one year will yield at most 40% of the species occurring at that site, but most visits will yield much less than 40%.
3 Repeated annual single visits will extend the list of fungi for a particular site, but because of the great year-to-year variability in fruiting times, a number of species which are in fact constant, may be recorded sporadically (present one year but absent the next).

Mycorrhizal associates and macromycete diversity

Roche (1995) in his study, distinguished between mycorrhizal and saprophytic species. All Irish native trees are mycorrhizal. However, only about half of them form ecto-mycorrhizas (ECM) with fungi, classified in the Ascomycotina and in the Basidiomycotina, that are macromycetes and form visible fruitbodies on the surface of the ground under their tree associates. The twelve native trees which associate with macromycetes are *Alnus glutinosa, Betula* spp., *Corylus avellana, Populus tremula, Quercus* spp., and *Salix* spp.

ECM partnerships are not absolutely specific, as each tree species associates with several fungal species, and some fungal species associate with more than one tree species. For instance, *Betula* spp. associate with *Amanita muscaria* and *Paxillus involutus and Leccinum versipelle* on acid sandy soils, as in the Birch grove on Howth, with *Lactarius vietus, L. torminosus, Leccinum scabrum* and *Cortinarius betularum* on heavier neutral soils as near Dunshaughlin, and with *Leccinum holopus* in *Sphagnum* as in the birch woods on All saint's Bog and Clara Bog in Offaly.

It is worth noting here that willows (there are five native species) also host several ECM macromycetes, and are more abundant and widely distributed in Ireland than most other tree species. However, willow scrub and wet willow woods are particularly impenetrable because of their low stature compounded by their tendency to fall over and reroot, and because the ground underfoot is frequently uneven and very wet in places. There are very few records of fungi from willow woodland in Ireland.

The other fifteen native tree species (*Crataegus monogyna, Frangula alnus, Fraxinus excelsior, Ilex aquifolium, Malus sylvestris, Prunus* spp., *Sorbus* spp., *Taxus baccata,* and *Ulmus glabra*) have different mycorrhizal systems (vesicular-arbuscular, VAM), in which the associates are microfungi in the taxonomically difficult family Endogonaceae. These fungi never form macroscopic fruitbodies, are very difficult to isolate into pure culture, and are rarely identified even to genus. However they are the predominant form of mycorrhizal association, infecting over 90% of vascular plant species in Ireland and worldwide.

It follows that woodlands which are dominated by tree species with ECM associates should have a richer macromycete flora, and that woodlands that contain several different ECM host trees, such as oak with birch and willow, will be richer than woodlands that only have one ECM host tree species. Woodlands that are poor in ECM host trees, such as those dominated by *Fraxinus excelsior* are poor in macromycete species, not only because of the VAM associate, but also because the dead ash leaves never have a chance to build up a humus

layer. The dead leaves are rapidly buried by *Lumbricus terrestris* and other earthworms within two months of falling. Half buried fallen twigs yield several species of small macromycetes, such as *Xylaria hypoxylon, Sarcoscypha coccinea, Clavariadelphus fistulosus* and *Cyathus striatus*, but most of the larger pieces of wood are removed for firewood before they decay.

Recommendations for management of woodlands for fungi and lichens.

Some of the general recommendations for native woodland management, such as the preservation of both standing and fallen dead wood, the elimination of domestic grazing animals, and the creation of gaps and glades, have obvious beneficial effects on both fungi and lichens.

Dead wood is the habitat of at least thirty macromycete species in Ireland, and of many microfungi as well. Some of these fungi are essential for specific insect associates. There are several lichens that are also dead wood specialists.

Sheep and cattle eat and trample fungal fruitbodies; cattle in particular will congregate in woodland (if allowed to) during wet weather, in hot, sunny weather and in windy weather. During those periods they enrich the woodland soil with excreta, disturb the organic soil horizons and eat dead twigs and rotting wood. Their faeces produce an alien fungal flora, more typical of grazed grassland.

Gaps and glades allow light to reach the sides of trees, which encourages the colonisation of the lower branches and trunks by lichens. Generous spacing of mature specimens by carefully controlled thinning would have a similar effect.

Recommendations for information management

A national fungal recording centre should be established. As long as fungi are regarded as being more like plants than anything else, the National Herbarium at Glasnevin, Dublin, would seem to be a better location for this centre than the universities. The latter institutes will soon lose their Botany Departments if they have not lost them already, as 'Life Sciences' take over. There is no room in modern 'Life Science' for field biology or for the recording of non economic organisms. Things that have no price (like wilderness, and clean air) have no value.

During the next few years, while professional mycologists are still employed in or attached to the Universities, they should be encouraged to record and to educate non-professionals as well as students to make and submit their own records. Most of the fungal records that do exist in Ireland were compiled by groups of 'amateurs' under the supervision of a professional during the golden years of 'Natural History' in the late C19th and early C20th. We should repeat the exercise before it is too late.

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