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# FUNGI IN AUSTRALIA

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J. Hubregtse

## Part 1

### Introduction



© Jurrie Hubregtse

Mt Field National Park, Tasmania



Est. 1880

# FUNGI IN AUSTRALIA

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## Part 1

### Introduction

Revision 2.2

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*“We don’t have to engage in grand, heroic actions  
to participate in the process of change.  
Small acts, when multiplied by millions of people,  
can transform the world.”*

**Howard Zinn** 1922 — 2010

Historian; Teacher; Playwright; Social Activist

## Foreword

One of the greatest pleasures that a naturalist can experience is wandering through forests and woodlands during the wetter months of the year and observing the myriad fungal forms that appear, as if by magic, from the soil, litter, logs and trees. After the heavy rains in Gippsland before Easter 2011, the forests and woodlands around Genoa erupted into a fungal “bloom” of great diversity of form and colour, reminiscent of the desert blooming after the drought breaks. Faced with such incredible numbers and diversity it can be very difficult to put names to them all.

In fact, it can be difficult to identify fungi under normal circumstances. Simple morphological attributes are not always sufficient to identify species. Microscopic examination and DNA analysis may also be required. As with most living things subjected to closer examination, the degree of our ignorance becomes more evident and the taxonomy therefore more complicated.

Nevertheless, naturalists working in the field need to be able to identify fungi with some degree of confidence. They cannot take a fully equipped laboratory with them, but a small hand-held electronic device is another matter altogether. This e-book, *Fungi In Australia* can be uploaded into such devices and easily carried into the field. *Fungi In Australia* is not intended to be a complete treatise on all fungi but an aid to the identification of some fungi encountered in our native forests. It is predominantly based on Victorian fungi observed, collected and identified during the many fungal forays undertaken by the Fungi Group of the FNCV. It follows on from “The Fungi CD”, also a much valued resource. This long-awaited e-book field guide has the facility to be regularly and easily updated as new data become available.

A picture is worth a thousand words and this guide makes good use of that assertion with hundreds of high resolution images of fungi in situ as well as additional, anatomical views to aid identification. It has a logical, hierarchical structure that is easily navigated and will be useful to both amateur and professional alike. It is also an excellent introduction to Fungi.

*Fungi In Australia* is another valued addition to the many field guides and natural history publications produced by the members of the FNCV since it began in 1880.

Maxwell Campbell  
President FNCV  
2016

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## Preface

The *question* is the cornerstone of all investigation, and the beginning of a journey.

The genesis of the e-book *Fungi in Australia* dates back to when The Field Naturalists Club of Victoria (FNCV) Fungi Group was formed on 28 September 2004. When the Fungi Group started, there was a lack of readily available information on Australian fungi, making it very difficult for amateurs like ourselves to make accurate identifications of fungi in the field. To help remedy this lack of information the Fungi Group started to publish images of fungi along with their names in a CD ROM format. This was later followed with the production of a CD ROM titled *The Fungi CD*, 1<sup>st</sup> edition in 2008, 2<sup>nd</sup> edition in 2009 and the 3<sup>rd</sup> edition, sub-titled *Fungi In Australia*, in 2012, featuring 300 species. *The Fungi CD* allowed you to search for species of fungi by shape as well as by name. For each species there were up to 5 images accompanied by a detailed description with references. The major drawback of the CD ROM format was that it needed a computer to run it, and therefore it could not readily be taken into the field.

In the intervening years, new technology has brought us the e-book with the small lightweight eReaders about the size of an A5 book. To take advantage of this new environment *The Fungi CD: Fungi In Australia* CD ROM has been converted into a PDF e-book with an emphasis on assisting with identification of fungi in the field.



## Acknowledgements

This publication *Fungi in Australia* could not have been produced without the contribution, assistance and encouragement from a number of people. The person I would like to acknowledge most is my wife Virgil, who introduced me to the Kingdom Fungi and who also proofread all of my text and turned it into English. It was through her encouragement and many helpful suggestions that I was able to persevere with the production of this publication. I would also like to acknowledge the rest of my family for their patience in having to put up with parents who have an obsession about fungi.

I am also very grateful to the many specialists and mycologists who have helped me in various ways. The willingness of members of the mycological community to give freely of their valuable time has assisted me enormously in my study of fungi; I sincerely thank them all.

The people who have made my involvement with fungi most enjoyable are the members of the FNCV Fungi Group. With their assistance, on numerous forays, many of the interesting fungi in this publication were found. This Group's aggregate knowledge about our natural environment is broad and astonishing, and their comradeship has made the large number of forays I have been on (sometimes in inhospitable conditions) enjoyable and educational. I sincerely thank them all and hope to be with them on many more forays yet to come.

Jurrie Hubregtse  
26/01/2016

## CHAPTER 1

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# INTRODUCTION TO *FUNGI IN AUSTRALIA*

*To explain all nature is too difficult a task  
for any one man or even for any one age.*

*'Tis much better to do a little with certainty,  
and leave the rest for others that come after you,  
than to explain all things by conjecture.*

**Isaac Newton**, Preface to *Opticks*, 1704

This e-book is intended to serve as a resource to assist in the identification of some fungi that may be encountered in our native forests. It does not contain a comprehensive list of Australian fungi, but only a small cross-section of fungi that we have been able to identify to a reasonable degree of accuracy and for which references can be supplied for further study.

The fungi described in this e-book have been observed during the many forays that have been undertaken by the FNCV Fungi Group. The majority of the fungi illustrated have been found in native bushland in national parks and reserves in Victoria.

This e-book is a living document: it is our intention to continually correct, update and add new species as more identifications become available.

Information about the edibility of fungi is not provided.

No fungi should be collected from public land without a permit from the the appropriate government department.

## 1.1 Organisation of *Fungi In Australia*

It used to be easy to define a book as a collection of printed pages bound inside a cover that you could place on a shelf in your library. Then along came the e-book (electronic-book) consisting of a digital file that requires an electronic device (such as a computer, tablet, or a dedicated e-book reader) to make it readable. This e-book, *Fungi In Australia*, expands on the e-book concept:

instead of having a single readable file, multiple files are used to deliver the content.

*Fungi In Australia* consists of 7 parts, each of which is a PDF file that may be treated as a free-standing e-book. The reasoning behind this multiple part concept is: (1) to keep each part as small as possible so the PDF files will still be responsive in hand-held devices; (2) to function effectively as a field guide, where the separate parts are used to act as pictorial guides to assist in the identification of fungi in the field; and (3) to facilitate access to the required section, so that only the relevant part needs to be loaded at any one time.

- **Part 1** comprises the Introduction to *Fungi In Australia*.
- **Part 2**, “Ascomycota: Pezizomycotina”, contains the ascomycetes.
- **Part 3**, “Basidiomycota: Agaricomycotina – I”, contains only the order Agaricales, which is the largest order in Agaricomycotina with approximately 63% of the species.
- **Part 4**, “Basidiomycota: Agaricomycotina – II”, contains the remaining orders in Agaricomycotina.
- **Part 5**, “A Photographic Guide to Ascomycetes”, in which species are grouped according to their morphology (e.g. disc, cup, club, etc.).
- **Part 6**, “A Photographic Guide to Gilled Fungi”, in which species are grouped according to their spore print colour.
- **Part 7**, “A Photographic Guide to Non-Gilled Fungi”, in which species are grouped according to their morphology (e.g. bolete, puffball, earth-star, coral, etc.).

**Parts 2 to 4** contain species descriptions, each accompanied by two images plus references.

**Parts 5 to 7** are photographic guides, in which each page is dedicated to a single species, with up to 6 photos of each species.

This arrangement allows the user to make an identification using one of the photographic guides, then access more detailed information in **Parts 2, 3** or **4**.

## 1.2 Methodology used

Most of the fungi described have been collected during forays conducted by the FNCV Fungi Group. Interstate collections are also made when members attend fungi-related conferences.

When a fungus is collected it is photographed and documented in the field. If the fruit-bodies encountered are of sufficient number and quality, a herbarium collection is made, otherwise one or two fruit-bodies are collected for identification purposes.

## 1.3 Species Arrangement

In Parts 2, 3, and 4, which contain the taxonomic descriptions, the Orders are arranged alphabetically, not taxonomically. Families within each Order are arranged alphabetically, as are genera within each family and the species within each genus. In the remaining books the species are arranged alphabetically for each morphology type.

## 1.4 The Challenge of Identification

*The beginning of wisdom  
is to call things by their proper name*

**Confucius** ca. 500 BC

There are some species of fungi that are sufficiently unique to make their identification relatively straightforward, but these seem to be in the minority. Fungi are living organisms, and as with any living organism their condition will vary in accordance with their environment. Depending on how favourable the growing season, they may grow larger or smaller than described. Their colour and surface condition will vary with the amount of rain. Rain will often bleach fruit-bodies, or wash off scales, while a lack of rain may cause what should have been a smooth sticky surface to be dry and scaly. If this does not make the identification of fungi difficult enough, these endearing organisms

make it a whole lot more complex by producing different species that look similar.

Although the macro characteristics of a fungus are important in its identification, it is also necessary to rely on the microscopic characteristics. The microscopic characteristics of most fungi do not vary greatly with different environmental conditions or the age of the fungus, and therefore can be used to identify the fungus in question. For this reason the text for each fungus includes a description of the microscopic features.

The final identification process is where the observed characteristics are matched with those that are published in peer reviewed literature. This is where the problem of species identification becomes most problematic. Taxonomic descriptions are published in an extremely diverse group of journals, some of which are inaccessible even with the aid of a university library. Once a fungus has been identified, the next problem is to find its current taxonomic name. There is a very good reason why the current taxonomic (Latin binomial) name needs to be known. The taxonomic name given to an organism indicates its rank in a taxonomic hierarchy, which represents its position in the *tree of life*. Knowing an organism's rank (name) informs us about its relationship with other species.

In this era of rapid taxonomic revision there is no official central depository with oversight of fungal species names. An approximation to this is *Species Fungorum* WEB site, which is used as the reference for most species names used in *Fungi In Australia*. The acceptance of new species names that appear in *Species Fungorum* is left to the mycological community; names are picked up by some mycologists and appear in the literature, or may be simply ignored. When it comes to fungi there is a laissez-faire system in place for the publication and acceptance of new species names, which makes it extremely difficult to obtain an up-to-date taxonomic name for a species.

## 1.5 Microscopy

Many species are not readily identifiable in the field from their macroscopic features. To obtain extra information to assist in their identification it is necessary to examine and measure some of their microscopic characteristics. To do this, a calibrated optical microscope with achromatic objectives with magnifications 4 $\times$ , 10 $\times$ , 40 $\times$ , and 100 $\times$  (oil immersion) is required.

Where possible, fresh specimens are examined; dried material when used is rehydrated using 5% KOH solution. Initially a small fragment of the fruit-body is examined using a crush-mount in 5% KOH solution or Congo Red with 5% ammonia.

Measurements and descriptions of microscopic features such as spores, basidia and asci are included in the species descriptions because these are the most useful in assisting with the identification.

## 1.6 Spore Measurement

The spore size and shape are relatively constant characters for a given species, and have been used as a diagnostic in mycology since the advent of the microscope. Spore size is relatively easy to measure and small sample measurements will usually allow differentiation between species of fungi. Although the spore size within a species is relatively constant, nevertheless there is a distribution of spore sizes within each specimen. To minimise the spore size distribution it is preferable to measure mature spores, which can be obtained from a spore print. This is our preferred method, but if it is not possible to obtain a spore print a squashed tissue sample is used.

The measurement method used for this publication is to photograph a number of spores using a compound microscope with a  $100\times$  oil immersion lens, and with an attached camera. The camera is connected to a computer via a USB cable and the microscope is focused using live-view before the photograph is taken, ensuring the best possible focus. The microscope-camera set-up is calibrated using an objective micrometer with  $10\text{ }\mu\text{m}$  divisions. This calibrated set-up is used in a public domain program called ImageJ to measure the length and width of each spore. Normally 20 to 30 spores are randomly selected from the photographs and measurements are taken only of spores in side-on view and in focus. Their lengths and widths are measured in ImageJ and these measurements are imported into an Excel Spreadsheet that calculates the mean and standard deviation for the width, length and Q (the spore aspect ratio  $L/W$ ).

## 1.7 Photography

A high quality image, showing diagnostic features, is a most helpful aid when trying to identify a fungus. The fungi images reproduced here were all taken with a digital camera. The majority of the images were made with a variety of DSLR cameras with a macro lens with a magnification range up to 1:1, but some minute fungi were photographed using a super macro lens with a magnification range up to 1:5. The images that were not taken with a DSLR were made using high quality point and shoot digital cameras, all with a macro setting option. Apart from a few minute fungi that were moved to a more appropriate position for macro photography, the fungi were photographed in the field in their natural environment.

Unlike plants, fungi don't need light in order to grow. As a general rule they prefer moist, shady regions, such as on the undersides of logs, or in dense undergrowth. This presents the photographer with the problem of suitable lighting. The quality of light found on the forest floor after it has diffused through the tree canopy is low, with unsuitable colour casts making accurate colour recording almost impossible even though all digital cameras have automatic colour correction software built into them. Through experience the best and most reliable results have been obtained using on- or off-camera diffused flash lighting or off-camera daylight-corrected LED light panels.

The majority of the images were taken with the camera on its aperture-priority setting. The camera aperture was set to guarantee that there is an adequate depth of field. For the DSLRs the aperture was usually set at F/16.

In most cases post processing of images was limited to cropping and resizing. All the diagnostic images reproduced here have a 4:3 or 3:4 aspect ratio, with the height of the image being set to 1000 pixels.

## Open Nomenclature — levels of uncertainty

*‘When I name a fungus,’  
Humpty Dumpty said in rather a scornful tone,  
‘it means just what I choose it to mean— neither more  
nor less.’*

My apologies to **Lewis Carroll**, from “*THROUGH THE LOOKING-GLASS: and what Alice found there*”

Generally, fungi are cryptic fruit-body producers. Many of the morphological features used to identify a fungal species are modified by its environment. This means that mycologists employ a lot of subjectivity in determining which features define and segregate species. Then we, as amateur field mycologists or even professional mycologists, try to reconcile the features observed on a fruit-body with those in the literature, and then form an opinion about the identification. This is a very error-prone methodology, especially if you are not highly familiar with the species you are trying to identify.

Nevertheless, many of us behave like Humpty Dumpty: we seem to give an impression of certainty when identifying a fungus. In the literature one can find many foray species lists, but they never seem to include any levels of uncertainty attributed to the identifications. For instance, one would assume when reading such a list that the level of certainty in the identification of a well-known species such as *Amanita muscaria* is the same as that of a not so well-known species such as *Galerina neocalyptata*, which is one of many morphologically similar species of small moss-inhabiting fungi.

Uncertainty is an ever-present ingredient of science, and is manifested in all phases of conducting research and drawing conclusions. In many other scientific fields, levels of uncertainty in conclusions are given, and are usually displayed as error bars. When producing foray lists, it may be useful to attach a level of certainty to the identification of each species.

The uncertainty or the provisional status of an identification can be expressed by the application of a set of terms and abbreviations known as Open Nomenclature qualifiers. This approach is applied widely across a number of biological disciplines, but unfortunately there has been no consensus about the use and meaning of Open Nomenclature qualifiers. Since the biological sciences



have not been able to come to a consensus on how to integrate uncertainty into their species determinations, or to define a set of accepted Open Nomenclature qualifiers, in this publication Open Nomenclature qualifiers proposed by Bengtson (1988) and Sigovini *et al.* (2016) are used.

The following subset of Open Nomenclature qualifiers are:-

**“field name”** A “field name” is a short descriptor of a recognisable but unknown species. For example, *Clitocybula* sp. “streaky yellow” is either an undescribed species, or a species for which a description has not been found. The “field name” qualifier has the same level of uncertainty as “sp.”

***affinis***, abbreviation **aff.** = affinity with a known species, from the Latin for ‘has affinity with’. This qualifier indicates that the specimen is most likely a new, undescribed species which has some affinity to a known species but it is not identical to it. The specimen differs clearly from the holotype species description, but it may fall within the variability limits. The **aff.** qualifier indicates that the specimen belongs to a potentially new undescribed species. The **aff.** qualifier has a slightly higher level of certainty than **sp.**

***confer***, abbreviation **cf.** = to compare, or to be compared with, from the Latin confero, infinitive conferre: ‘to bring together’. This qualifier indicates that most of the diagnostic characters correspond to those of a given species, but some characters are unclear. The identification is provisional but is likely to be definitive after comparing with reference material or consulting a specialist on the taxon. The **cf.** qualifier generally implies a higher degree of certainty than **aff.**

**Species complex**, abbreviation **complex**. A species complex is generally understood to be a group of related species characterised by unclear boundaries, often still waiting for a critical revision to clarify the taxa involved. Identifying a species as belonging to a complex can be done with relative certainty, but there is a high degree of uncertainty in identifying each individual species within the complex. A species complex is referred to by the type species name, followed by **complex**.

***Incertae sedis***, from Latin *incertae* (“of uncertainty”) + *sedis* (“seat”). This term is not an ‘Open Nomenclature’ qualifier but is part of ‘The International Code of Nomenclature for algae, fungi, and plants’. In taxonomy ***Incertae sedis*** means ‘of uncertain taxonomic position’. It is often used when conducting a formal phylogenetic analysis, where the placement of a particular taxon may remain uncertain because insufficient closely related species have been used in the analysis. In this case, the uncertain taxon is labelled ‘*Incertae sedis*’. For example, the species *Ductifera sucina* is readily identifiable, but there is uncertainty about the family it belongs to, therefore at present the family name for *D. sucina* is substituted with ‘*Incertae sedis*’.

It is always important to minimise the level of uncertainty when identifying a fungal species. This can be achieved by carefully studying the species of interest, making sure that the fruit-body is in good condition, making microscopic examinations if necessary, comparing your findings with multiple taxonomic descriptions, and if possible consulting with an expert. The process of reducing uncertainty in your fungal identifications can be a rewarding and satisfying achievement.

## References

- Bengtson P (1988) “Open Nomenclature. Palaeontology”. *Palaeontology* **Vol. 31(1)**, pp. 223–227
- Sigovini M, Keppel E and Tagliapietra D (2016) “REVIEW: Open Nomenclature in the biodiversity era”. *Methods in Ecology and Evolution* **Vol. 7**, pp. 1217–1225

## CHAPTER 2

### INTRODUCTION TO *THE KINGDOM FUNGI*

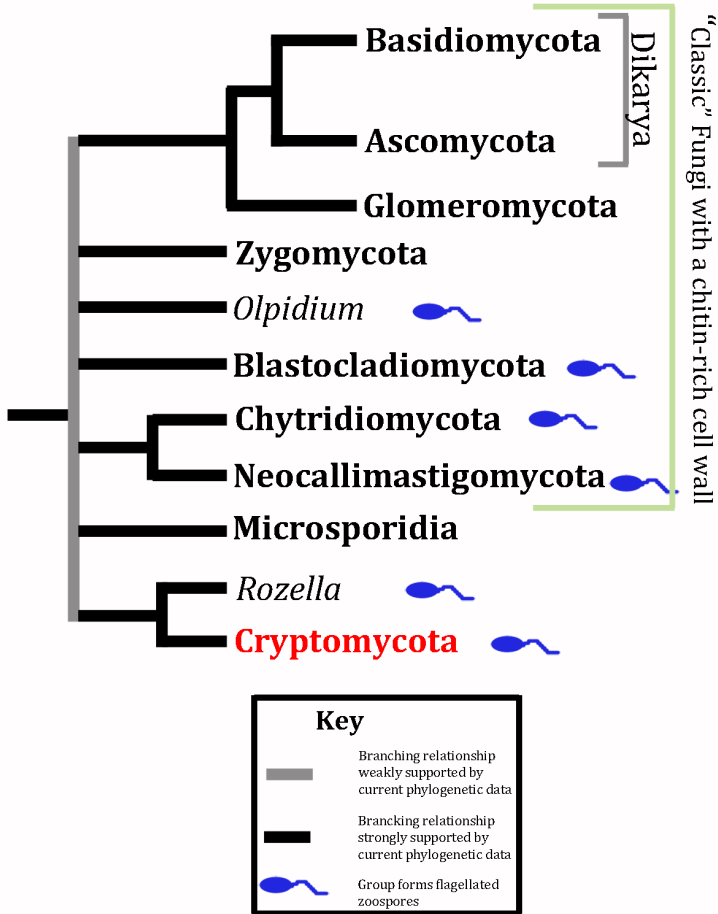


Figure 2.1: The Kingdom Fungi

The classification of living organisms is a challenging task, especially with such cryptic organisms as fungi. Traditionally, the study of fungi (mycology) has been a subdiscipline of botany and hence fungi were originally classified as

part of the Kingdom Plantae. In 1969, RH Whittaker began the processes of placing organisms in phylogenetic groups and, as a result, fungi were taken out of the Kingdom Plantae and placed into their own kingdom, the Kingdom Fungi (Whittaker 1969).

Since the late 1990s our knowledge of the systematics and evolution of fungi has gone through a revolutionary change. This change has been driven by the surge in molecular phylogenetic data and analysis, aided by the cost reduction of molecular sequencing. Worldwide research projects such as AFTOL (Assembling the Fungal Tree of Life) (Lutzoni *et al.* 2004, <http://tolweb.org/Fungi/2377>) and “Deep Hypha” (see “Deep Hypha” issue of *Mycologia* Vol. 98, 2007) have provided a new phylogenetic view of the Kingdom Fungi. Hibbett *et al.* (2007) published a comprehensive classification of the Kingdom Fungi, the result of collaboration between many fungal taxonomists. However, the classification of fungi is still undergoing major changes as more DNA based evidence is collected and examined.

Traditionally the investigation of fungal diversity was done by collecting specimens, but now, due to further advances in DNA analysis, it is possible to collect environmental soil samples and test them for fungi that reside within them. Using this soil sampling technique Meredith DM Jones obtained an environmental sequence from a pond at the University of Exeter, UK, where she worked, with surprising results (Jones *et al.* 2011a; 2011b). What she and her co-workers discovered was an unknown major branch (phylum) belonging to the “Fungal Tree of Life”, which they named Cryptomycota, or “hidden fungi”. It is most likely that this new phylum represents the link between the Kingdom Fungi and its sister kingdom, Kingdom Animalia, greatly increasing our understanding of fungal evolution.

The revised classification of the Kingdom Fungi has potentially 8 phyla, as shown in Figure 2.1. Seven phyla comprise the classical fungi group, which has chitin-rich cell walls. These are: Basidiomycota and Ascomycota (which belong to the subkingdom Dikarya), Glomeromycota, Zygomycota, Blastocladiomycota, Chitridiomycota and Neocallimastigomycota. Then there is another group which represents fungi that do not have chitin-rich cell walls, namely the phylum Cryptomycota, plus Microsporidia and Rozella.

Phylogenetic analysis of fungi is ongoing. At present approximately 100,000 species of fungi have been identified, and out of those approximately 10,000 species are *incertae sedis* (of uncertain taxonomic position) (Kirk *et al.* 2008). It has been estimated that there are possibly 1.5–5.1 million species of fungi

(Hawksworth 1991; Blackwell 2011), indicating that only a very small percentage of the overall population has been studied, and a significant percentage of those have an uncertain taxonomic position.

We are entering a new era in the study of fungi. These initial studies are already having a major impact on our understanding of these organisms, and there is no doubt that there is much new information about the systematics and evolution of fungi still to come.

## 2.1 Phylum Ascomycota

The defining feature of fungi in the phylum Ascomycota (Figure 2.2) is that the sexual reproductive structure is an ascus (pl. asci), which is shaped like a sac and contains ascospores. This phylum is the largest group in the Kingdom Fungi and it contains approximately 6500 genera and 65,000 described species (Kirk *et al.* 2008 ) in three subphyla: Taphrinomycotina, Saccharomycotina, and Pezizomycotina.

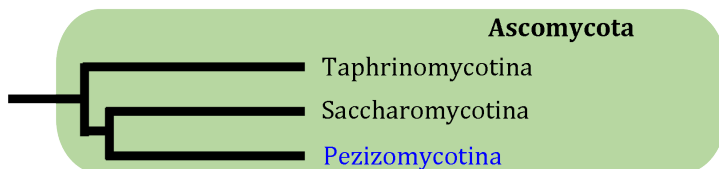


Figure 2.2: The Phylum Ascomycota

Fungi in the subphylum **Taphrinomycotina**, which contains approximately 140 described species (Kirk *et al.* 2008 ), are largely plant parasites with both a yeast state and a filamentous (hyphal) state. Characteristically they infect leaves, catkins and branches, but not roots.

Fungi in the subphylum **Saccharomycotina**, which contains approximately 1500 described species (Kirk *et al.* 2008), are predominantly yeasts, most of which live as saprotrophs in association with plants and animals.

The subphylum **Pezizomycotina** consists of hyphal (filamentous) fungi with differentiated tissues, and is the largest group in the phylum, with more than 63,000 described species (Kirk *et al.* 2008) that occupy a wide range

of ecological niches, occurring as saprotrophs, parasites and mutualists with plants, animals and other fungi.

## 2.2 Phylum Basidiomycota

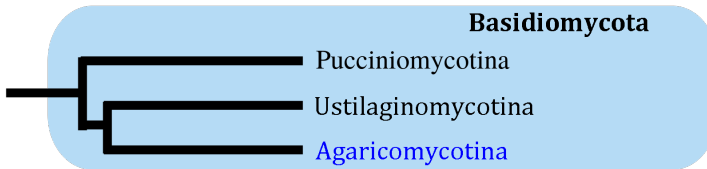


Figure 2.3: The Phylum Basidiomycota

The phylum Basidiomycota (see Figure 2.3) forms the second largest group in the Kingdom Fungi and contains approximately 1600 genera and 32,000 described species (Kirk *et al.* 2008 ). The defining feature of fungi in the Basidiomycota is that their sexual reproductive structure is a basidium (pl. basidia) (Figure 2.4), which is usually a club-shaped cell with four small protrusions called sterigmata (sing. sterigma). The sterigmata produce one spore each and at maturity the spores are actively discharged.

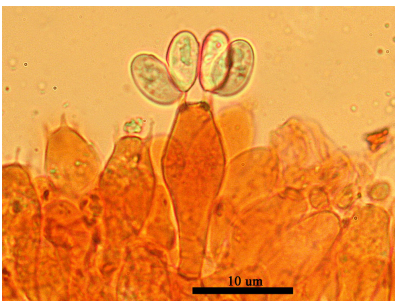


Figure 2.4: Basidium  
(*Volvopluteus gloiocephalus*)

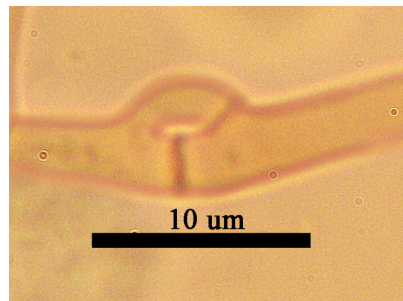


Figure 2.5: Clamp connection  
(*Oudemansiella gigaspora*)

Another feature that is also unique to some fungi in this phylum is the presence of clamp connections (Figure 2.5 ) which form during hyphal cell growth (Alexopoulos 1996).

Basidiomycota (Figure 2.3) contains three subphyla: Pucciniomycotina, Ustilaginomycotina, and Agaricomycotina (Hibbett *et al.* 2007).

**Pucciniomycotina** is the second largest subphylum in the Basidiomycota and contains about one-third of the described species (approximately 8500) with about 90% belonging to a single order, Pucciniales. The fungi in this subphylum are predominantly parasitic rusts and smuts. Some species are responsible for diseases in crops, animals and humans, while other species have been used for biological control of invasive plants and pathogenic fungi (Aime *et al.* 2006).

**Ustilaginomycotina** contains about 1500 described species, all of which are plant parasites. During their life cycle they have a saprobic yeast phase followed by a parasitic hyphal phase. Amongst the parasitic fungi these have been the most studied (Begerow *et al.* 2006).

**Agaricomycotina** is the largest subphylum in Basidiomycota, containing about 21,000 described species, including all the fungi with large fleshy fruit-bodies that we recognise as belonging to this subphylum (Hibbett 2006).

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