State of LA Fungi

March 28, 2023

Chlorophyllum rhacodes

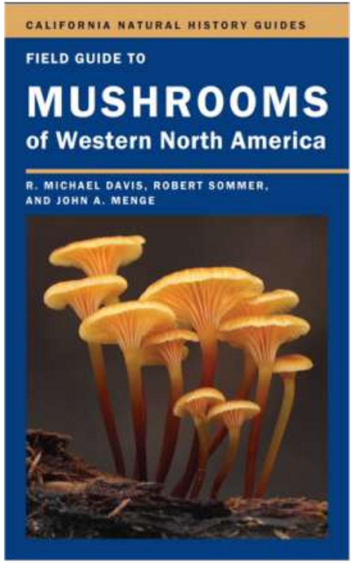
Los Angeles Mycological Society

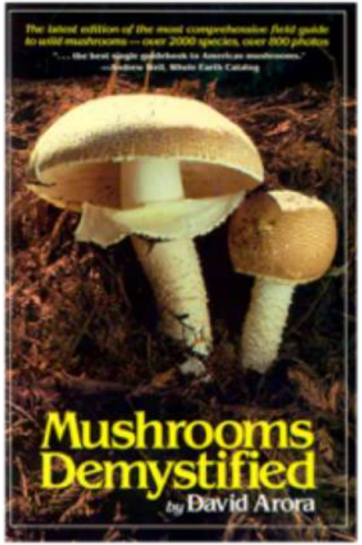
I. Look back on March

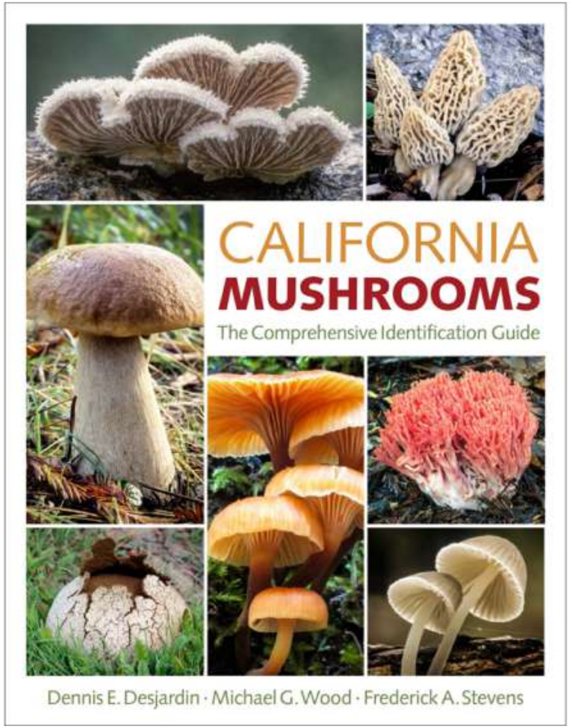
II. Reproduction and mating types in Basidiomycota

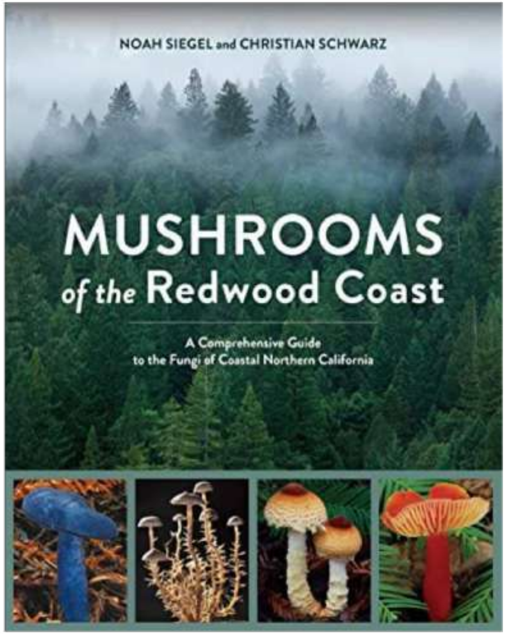
III. Mushrooms in the chaparral

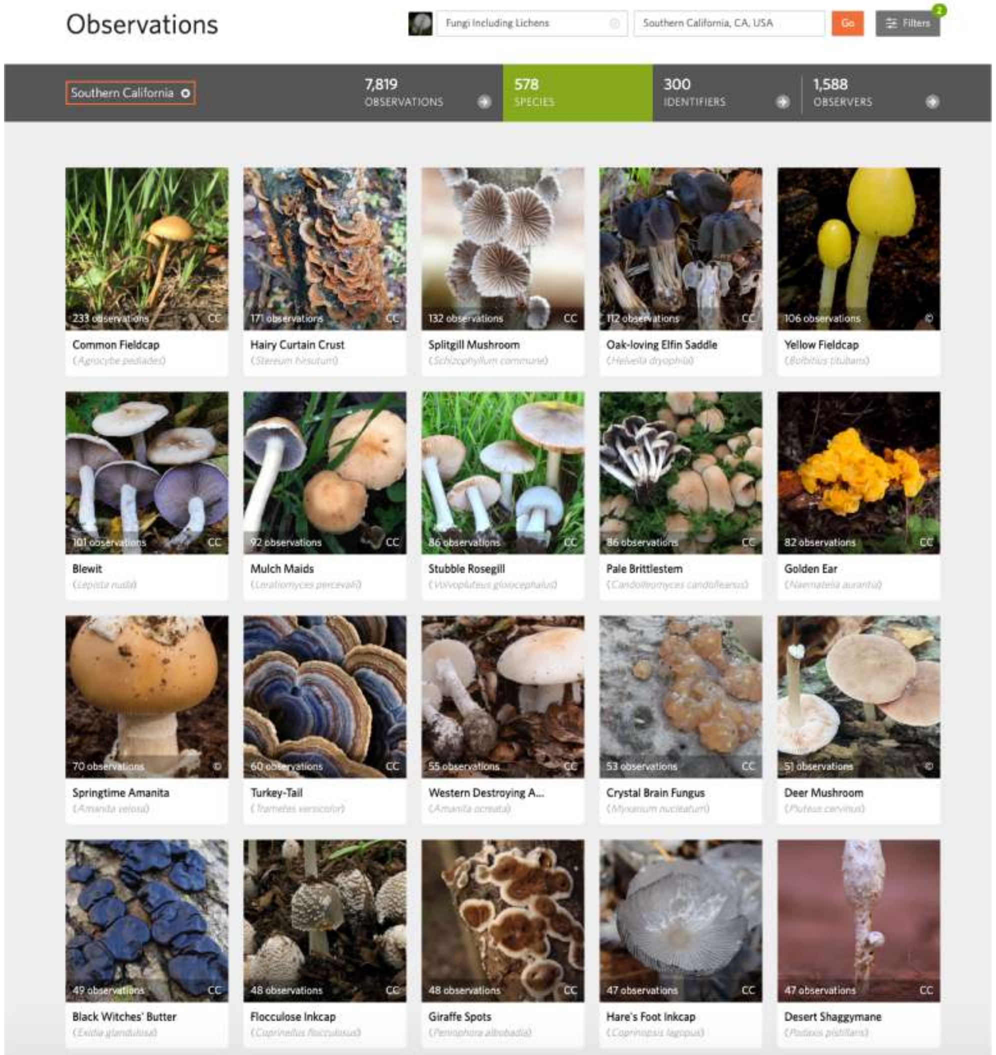
IV. Evolution and ecology of psilocybin in nature


CALIFORNIA NATURAL HISTORY GUIDES
FIELD GUIDE TO
MUSHROOMS
of Western North America
R. MICHAEL DAVIS, ROBERT SOMMER,
AND JOHN A. MENGE


Mushrooms Demystified
by David Arora

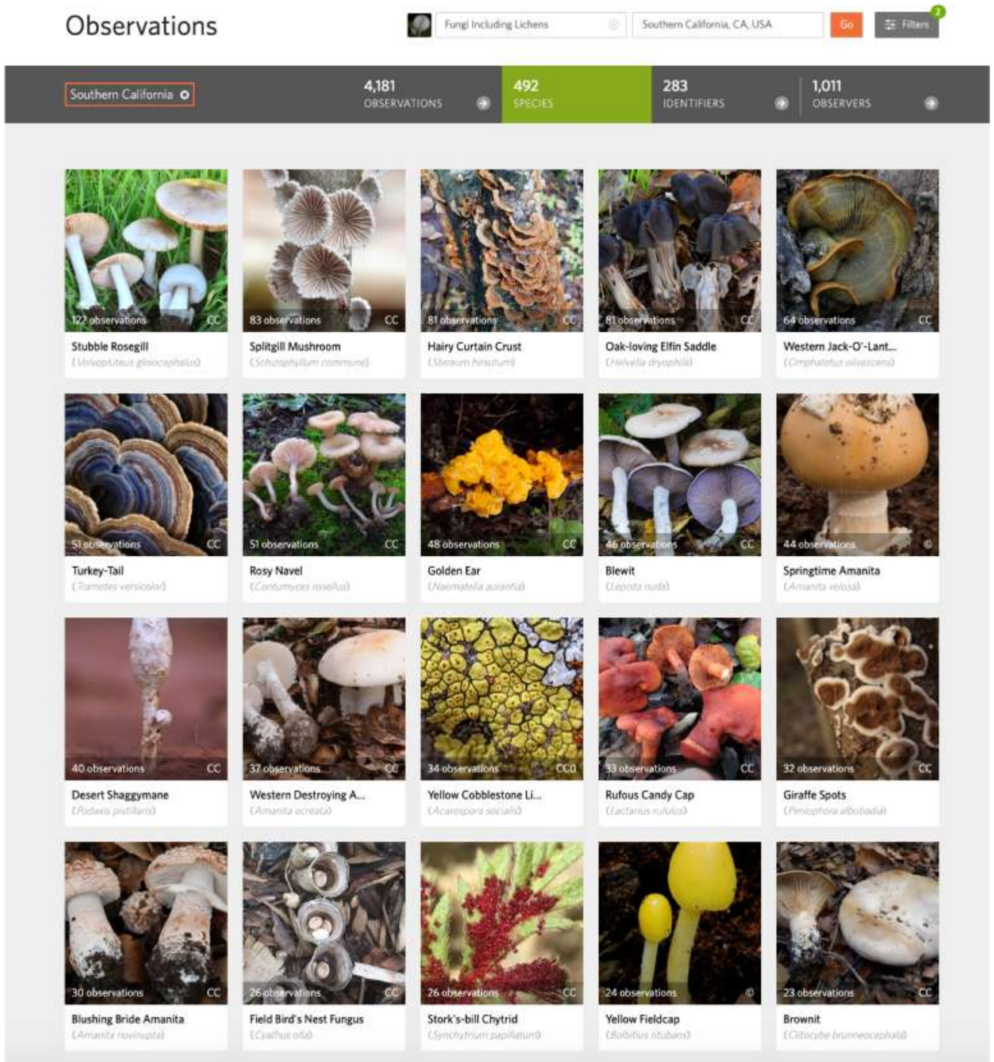

CALIFORNIA
MUSHROOMS
The Comprehensive Identification Guide
Dennis E. Desjardin · Michael G. Wood · Frederick A. Stevens


NOAH SIEGEL and CHRISTIAN SCHWARZ
MUSHROOMS
of the Redwood Coast
A Comprehensive Guide
to the Fungi of Coastal Northern California



https://www.inaturalist.org/observations?d1=2023-03-01&d2=2023-03-28&place_id=51727&taxon_id=47170&view=species

iNaturalist: Most Common Fungal Species in SoCal, March 2023



https://www.inaturalist.org/observations?d1=2023-03-01&d2=2023-03-28&place_id=51727&taxon_id=47170&view=species

iNaturalist: Most Common Fungal Species in SoCal, February 2023

Fungal reproduction.

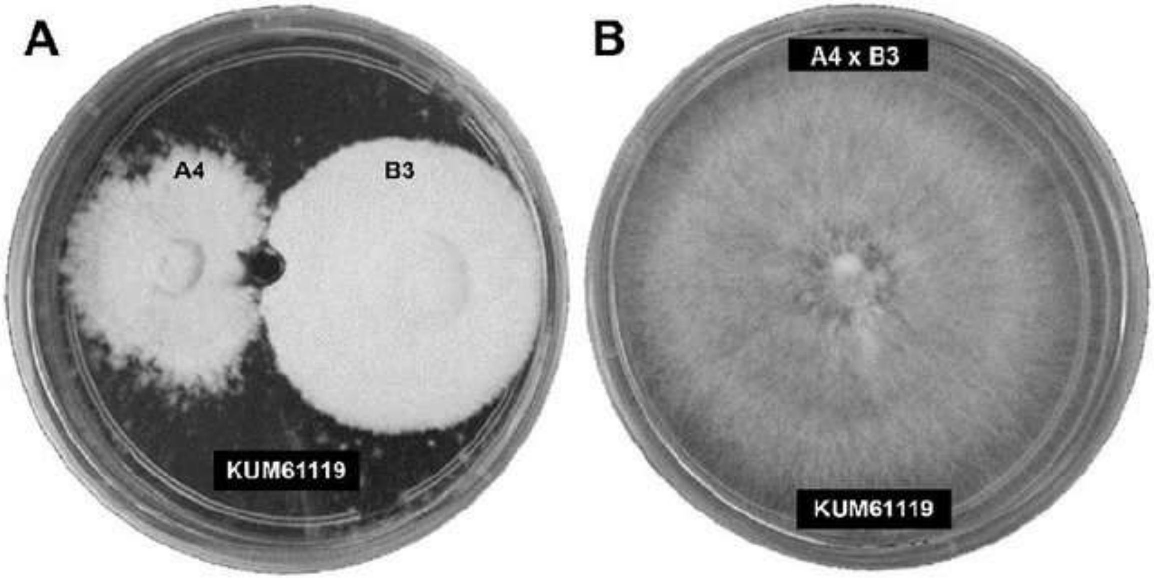


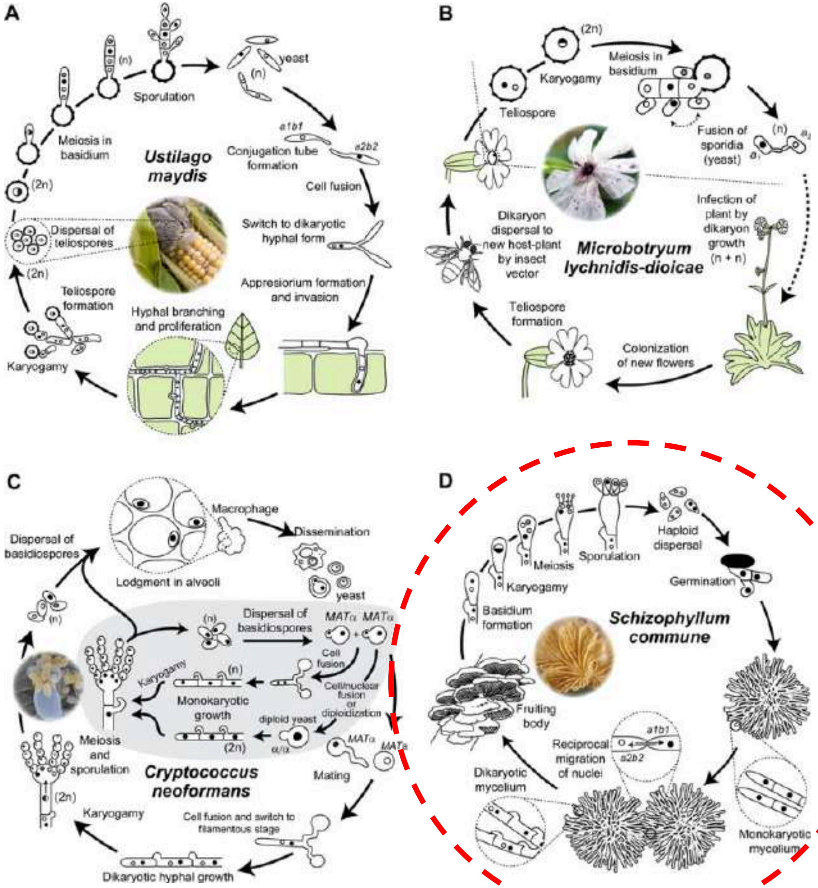
Fig. 1: Cross compatibility test. (A) A compatible mating between two selected monokaryotic isolates of A4 and B3 (obtained from KUM61119 strain). (B) Successfully crossed strain (dikaryotic). Avin et al., 2014.

https://www.online.lincoln.edu.my/uploadedfiles/emp_rch/8ea78471-a54d-4c2c-9b13-f3a21ad9a458DNA%20PEDIGREE%20TRACKING%20TO%20IDENTIFY%20COMPATIBLE%20MATING%20PARTNERS%20OF.pdf

Diversity in mating system complexity *just* in Basidiomycota

https://en.wikipedia.org/wiki/Basidiomycota

Mating in other fungal lineages:
https://en.wikipedia.org/wiki/Mating_in_fungi

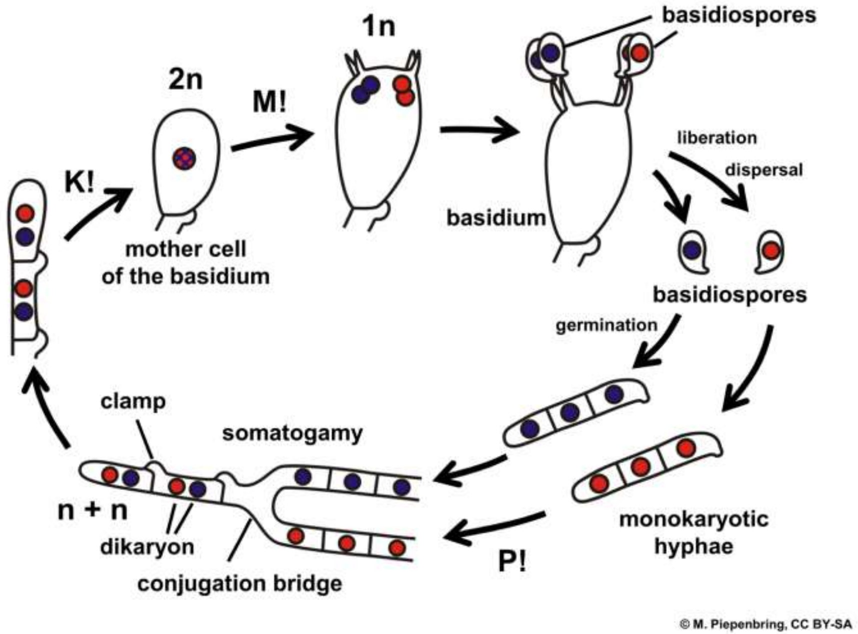


Most common system in mushroom-forming fungi.

Figure: Coelho MA, Bakkeren G, Sun S, Hood ME, Giraud T. Fungal Sex: The Basidiomycota. Microbiol Spectr. 2017 Jun;5(3):10.
https://journals.asm.org/doi/10.1128/microbiolspec.FUNK-0046-2016

Basidiomycete Mating Types

David Bermudes



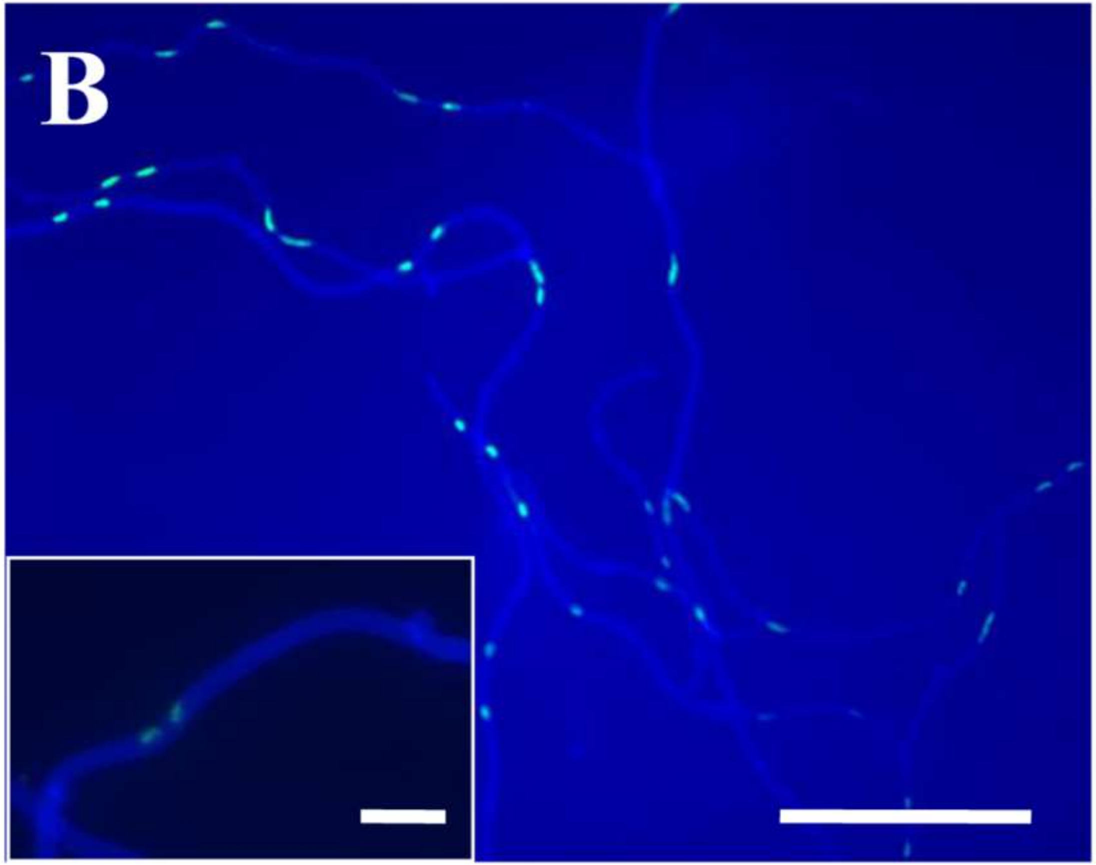
Omphalotus olivascens

https://bio.libretexts.org/Bookshelves/Botany/A_Photographic_Atlas_for_Botany_%28Morrow%29/03%3A_Fungi_and_Lichens/3.06%3A_Basidiomycota_%28Club_Fungi%29/3.6.03%3A_Life_Cycles_of_Basidiomycetes

Kwoniella mangrovensis

Haploid nuclei – alone but together.

The mycelium of a mushroom that has mated spends its life with two haploid nuclei that are paired within the same septal division (genetically referred to as haploid dikaryotic or n + n)



Guerreiro et al., 2013
Eukaryotic Cell
12: 5 746-760

How does a basidiomycete go from haploid to haploid dikaryotic?

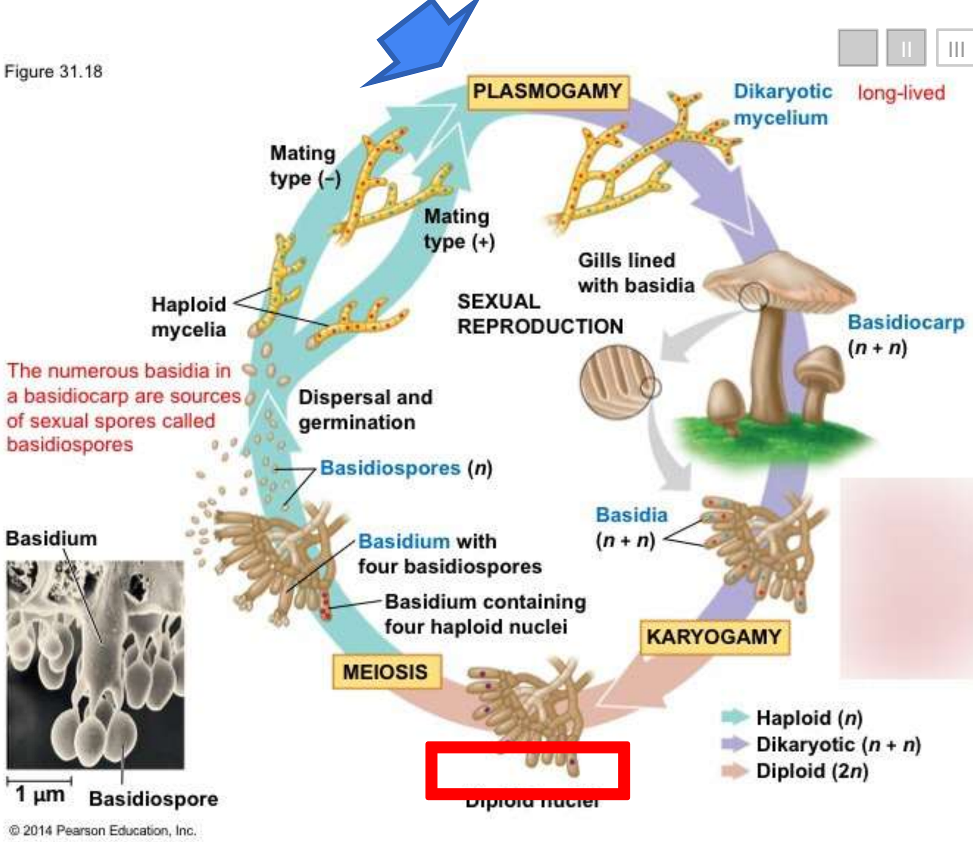
Several functions need to be performed to become a dikaryon:

Haploids need to sense each other and grow toward each other (pheromone production and pheromone receptors)

Cell wall dissolution at the tips needs to occur followed by cell fusion (plasmogamy)

Nuclei of each haploid need to migrate to the opposing cell

Clamp connections (many but not all basidiomycetes) need to form that are also involved with septal dissolution and nuclear migration

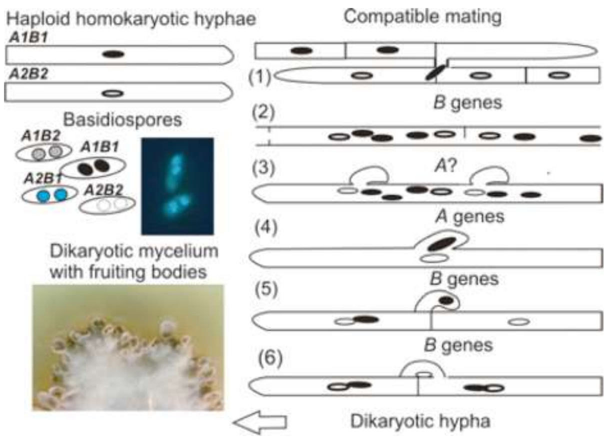


https://quizlet.com/287338501/basidiomycete-mushroom-forming-life-cycle-diagram/

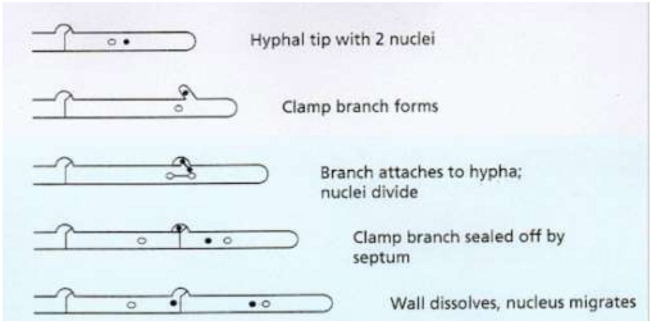
DB

Ascomycetes and Basidiomycetes (The Dikarya)

- 90% are heterothallic
- Many are tetrapolar, having two unlinked mating loci
  - *E.g., A1 A2, B1 B2*
- Mating compatibility requires different specificities in the functions relating to the process of dikaryonization
- Dikaryonization requires the entire set (A1 B1 A2 B2) which the individual haploids don't have.
- This is a process of complementation that results in a complete set of genes required for the process. The loci are often referred to as "opposite", but complementary is more accurate
  - E.g., two haploids that are complementarity are *A1 B1 and A2 B2*
    - Thought to promote outcrossing
  - "A" genes are involved in clamp initiation and "B" genes are involved in the completion of clamp connections. Some of the "A" genes are signal transduction factors.
  - "B" genes are involved in the initial recognition through pheromones and pheromone receptors. "B" genes regulate the reciprocal nuclear migration, illustrated by movement of a nucleus via a hyphal fusion through broken septa from one haploid hypha into the other.



Eukaryot Cell. 2010 Jun; 9(6): 847–859.

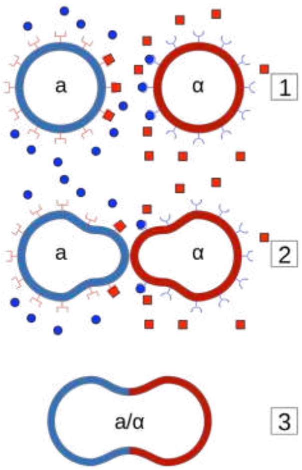


http://archive.bio.ed.ac.uk/jdeacon/microbes/basidio.htm
https://www.youtube.com/watch?v=FTtQtYZFBow

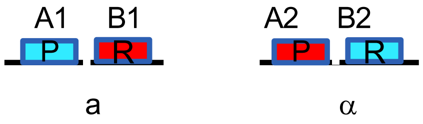
DB

Hormonal (Pheromone) Control of Mating

- Mating (cell fusion) is dictated by mating types that are controlled by:
- 1) Cell surface receptors
- 2) Pheromones
- 3) Transcription factors
- Cells must be of compatible (sometimes referred to as opposite) mating types
    - E.g., a and α
        - (arbitrary designations)



What does this look like genetically?

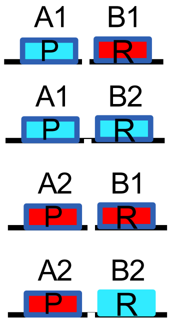


The two different cells have two different sets of mating type genes on two different chromosomes

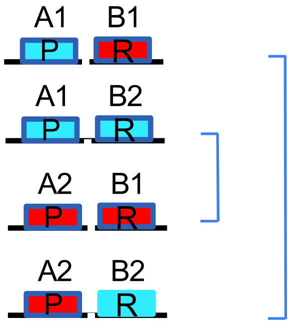
In yeast, type a produces a pheromone that is specific for the receptor on α type. Type α produces a pheromone that is specific for the receptor on a type. There are also two different receptor types and that are specific for the pheromones.

https://www.youtube.com/watch?v=Qy2HPA3W9JM

What are all the possibilities from spore production in basidia?



Which ones are compatible?



Each one is only compatible with 1 out of 4?

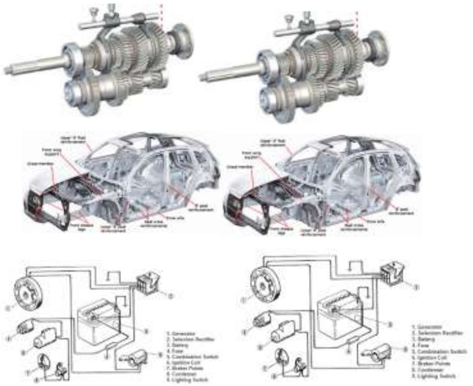
Why Are “Opposite” (Complementary) Loci Required?

Analogy: Working Together to Build a Car

- Requirements include:
  - List 1 – List 2
    - Wheels • Transmission
    - Engine • Chassis
    - Fuel • Electrical

Two people with the same list 1

Two people with the same list 2

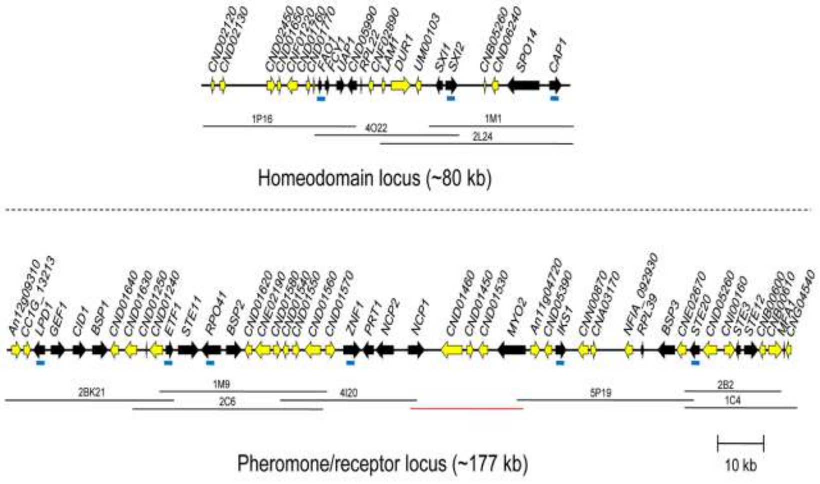


Two people with List 1 and 2

This one is the only functional one

Control of Mating in Fungi is Governed by the MAT Loci Homeodomain (A) and The Pheromone/Receptor Locus (B)

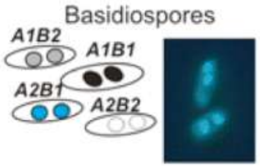
- Mating is controlled by MAT loci
  - Complex multi-gene regions of the chromosome
- The MAT loci contain numerous genes related to mating and maintenance of dikaryotic cells
  - Pheromone
  - Pheromone receptor
  - Signal transduction
  - Clamp connections and septation
  - Nuclear migration
  - Others
- Cells must be of compatible/complementary (opposite) mating types
  - E.g., a and α
    - (arbitrary designations)



Because these loci have entirely different compositions, they are referred to as idiomorphs rather than alleles

MAT Loci Control of Mating in Fungi: Effects Observable at the Macroscopic and Microscopic Levels

- The roles of combined (complementary) A and B genes
- Hyphae may fuse, but the process of creating a dikaryon is incomplete
- This can be observed on a petri plate and with a microscope



Pairing of strains with:	Events observed
Different A, different B idiomorphs (**dikaryon**) Fertile	1. Septal dissolution 2. Nuclear migration 3. Clamp branches arise and fuse with hypha
Common A, different B idiomorphs Flat	1. Septa dissolve 2. Nuclei migrate
Common B, different A idiomorphs Barrage	1. Septa remain intact 2. No nuclear migration 3. Clamp branches arise but do not fuse
Overlap Common A, common B idiomorphs	1. No septal dissolution 2. No nuclear migration 3. No clamp connections

Deacon 2006, Fungal Biology, Table 5.2.

Observations on *Omphalotus olivascens*

Arbitrarily: A1 B1 x A2 B2

This picture shows a progression of a mating between Omphalotus olivascens that produced clamp connections and septa. Mycelial contact zone was robust. Initially only the colony on the left was pigmented, but after enough growth both sides turned out to be highly pigmented. Pictures taken about two weeks apart

Photo courtesy of Brenda Whitney, BIOL437/L/492V Spring 2016

Observations on *Omphalotus olivascens*

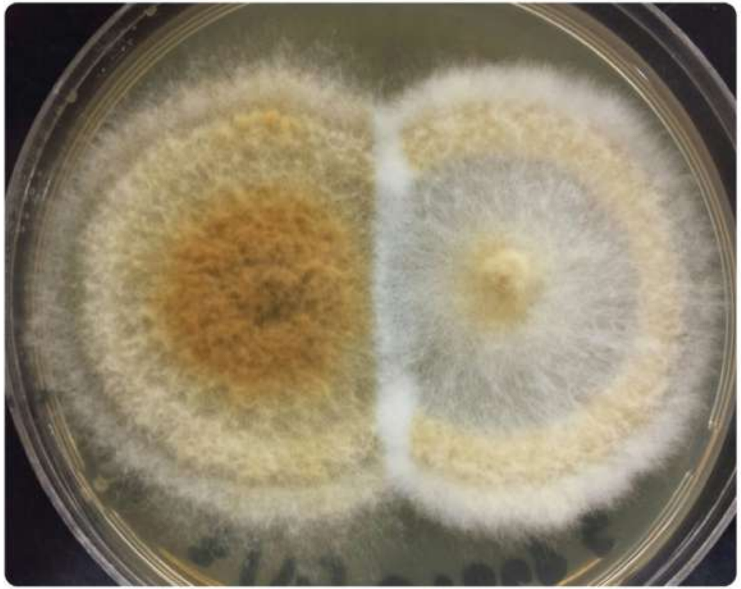
A1 B1 x A1 B2

(same A different B)

Two weeks progression of mating type growth that produced a flat reaction.

Photo courtesy of Brenda Whitney, BIOL437/L/492V Spring 2016

Observations on *Omphalotus olivascens*



Microscopy shows false clamps

A1 B1 x A2 B1 (same B)

This photo shows a two week progression between mating types which produced false clamps. Mycelial contact zone is barrage.

Photo courtesy of Brenda Whitney, BIOL437/L/492V Spring 2016

Observations on *Omphalotus olivascens*

A1 B1 x A1 B1 (same A same B)
”Overlap”
No clamp connections
No septal dilution
No nuclear migration

Mating type growth between same mating types, two week progress

Photo courtesy of Brenda Whitney, BIOL437/L/492V Spring 2016

I II III IV

ELSEVIER

FEMS Microbiology Reviews 18 (1996) 65–87

FEMS MICROBIOLOGY REVIEWS

Tetrapolar fungal mating types: Sexes by the thousands

Erika Kothe *

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Received 28 August 1995; accepted 16 January 1996

THE MAGAZINE SHOP DISCOVER LOGIN REGISTER STAY CURIOUS

THE SCIENCES | MIND | TECHNOLOGY | HEALTH | ENVIRONMENT | PLANET EARTH

PLANET EARTH

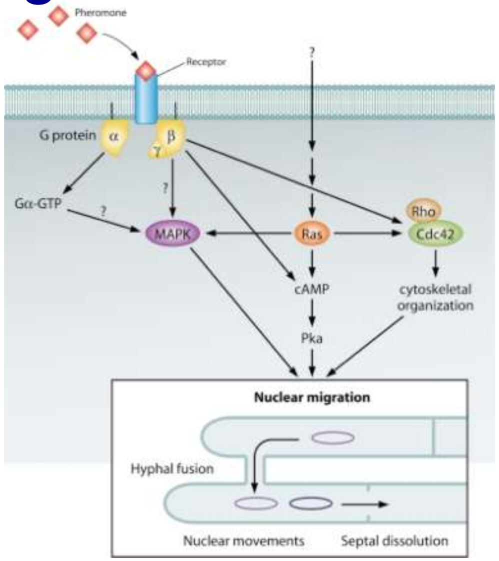
Why This Fungus Has Over 20,000 Sexes

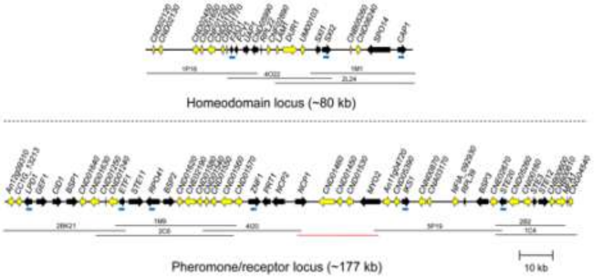
D-brief | By Nathaniel Scharping | Nov 6, 2017 1:23 PM

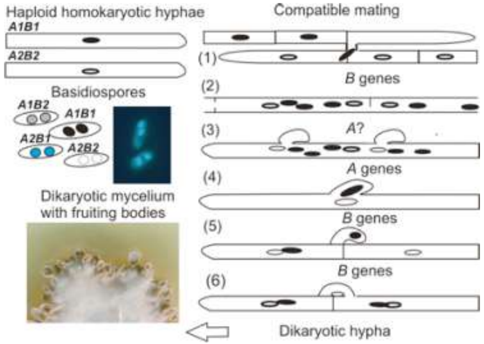
DB

Mating loci contain multiple linked genes

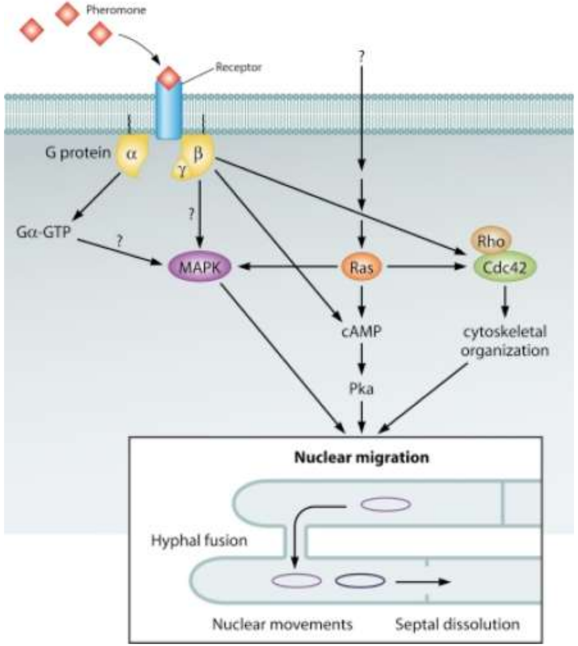
- *Different A genes (combination)*
  - Pheromones
    - Short peptides
  - Pheromone receptors
    - Cell membrane G protein
- *Different B genes (combination)*
  - Transcription factors respond to G protein coupled signals
    - Clamp connections
    - Nuclear migration
    - Septation







Higher numbers of mating types is due to variations in some of the individual genes. Example, Y and Z signal transduction proteins



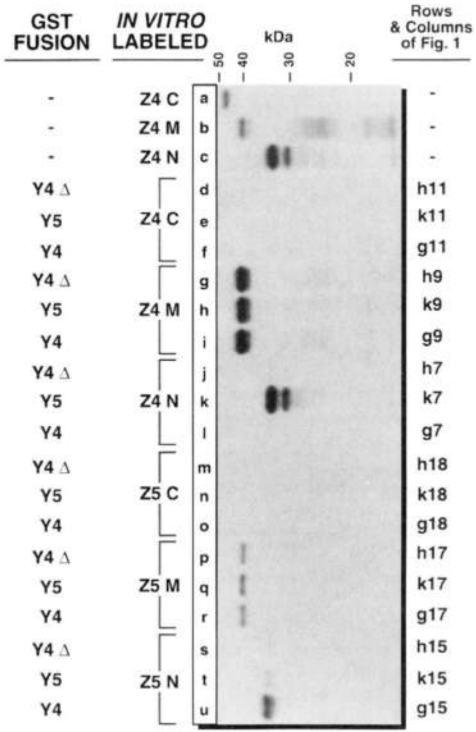


FIGURE 3.—Autoradiogram of electrophoretic gels displaying the results of protein affinity assays between full-length GST-fusion proteins Y4, Y5 and $Y4_{\Delta FL\ 1\text{-}9,\ 81\text{-}928}$ and *in vitro* translated proteins: Z5N, N-terminal amino acids 1–289; Z5M, mid-region amino acids 288–494; Z5C, C-terminal amino acids 493–755; Z4N, N-terminal amino acids 1–271; Z4M, mid-region amino acids 270–544; Z4C, C-terminal amino acids 543–930. Procedures as described for Figure 2.

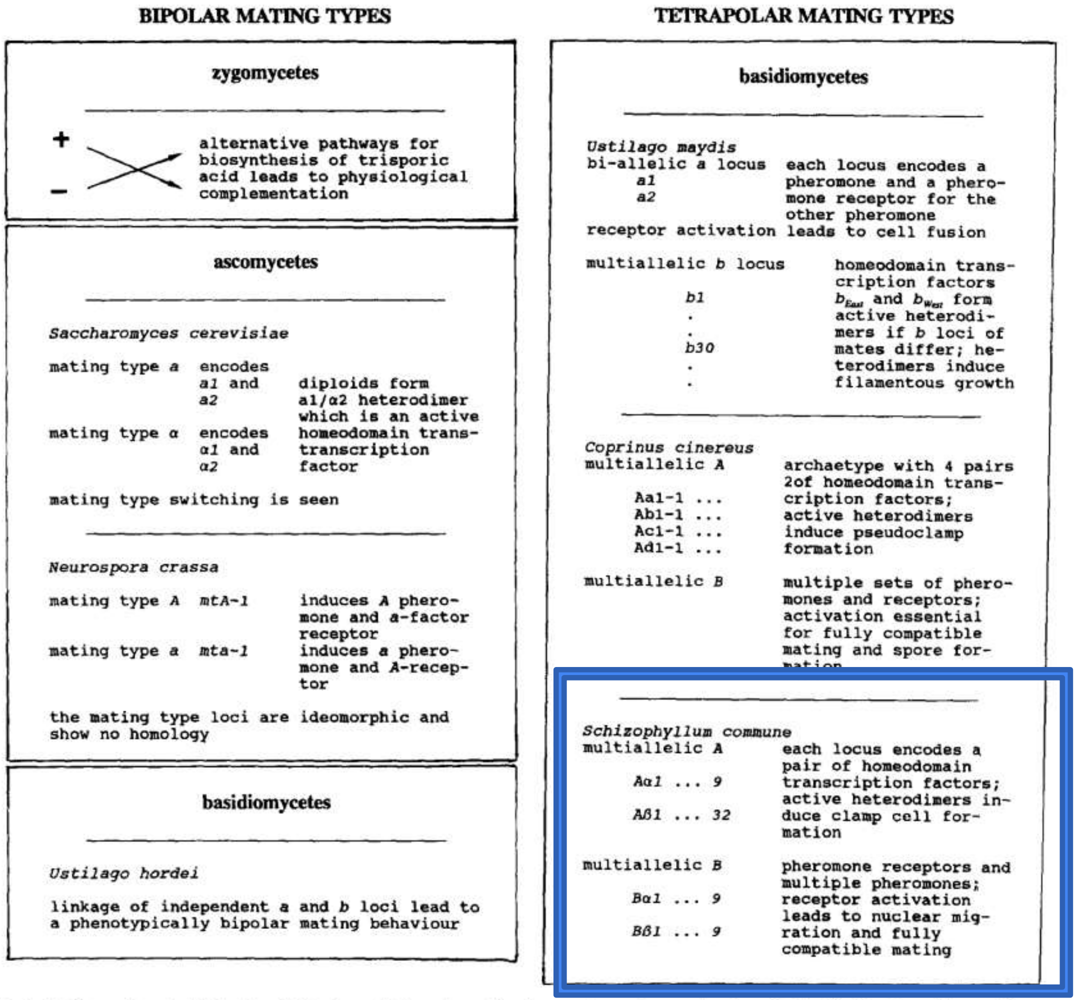


Fig. 1. Mating systems in higher fungi. Bipolar and tetrapolar mating type systems of some fungi are listed. The function of the mating type genes is indicated.

Based on the subvariants, there are a large number of theoretical sexes. Some of the variations such as having multiple pheromones and multiple pheromone receptors expand compatibility, while others such as incompatible within signal transduction factors such as Y and Z diminish compatibility.

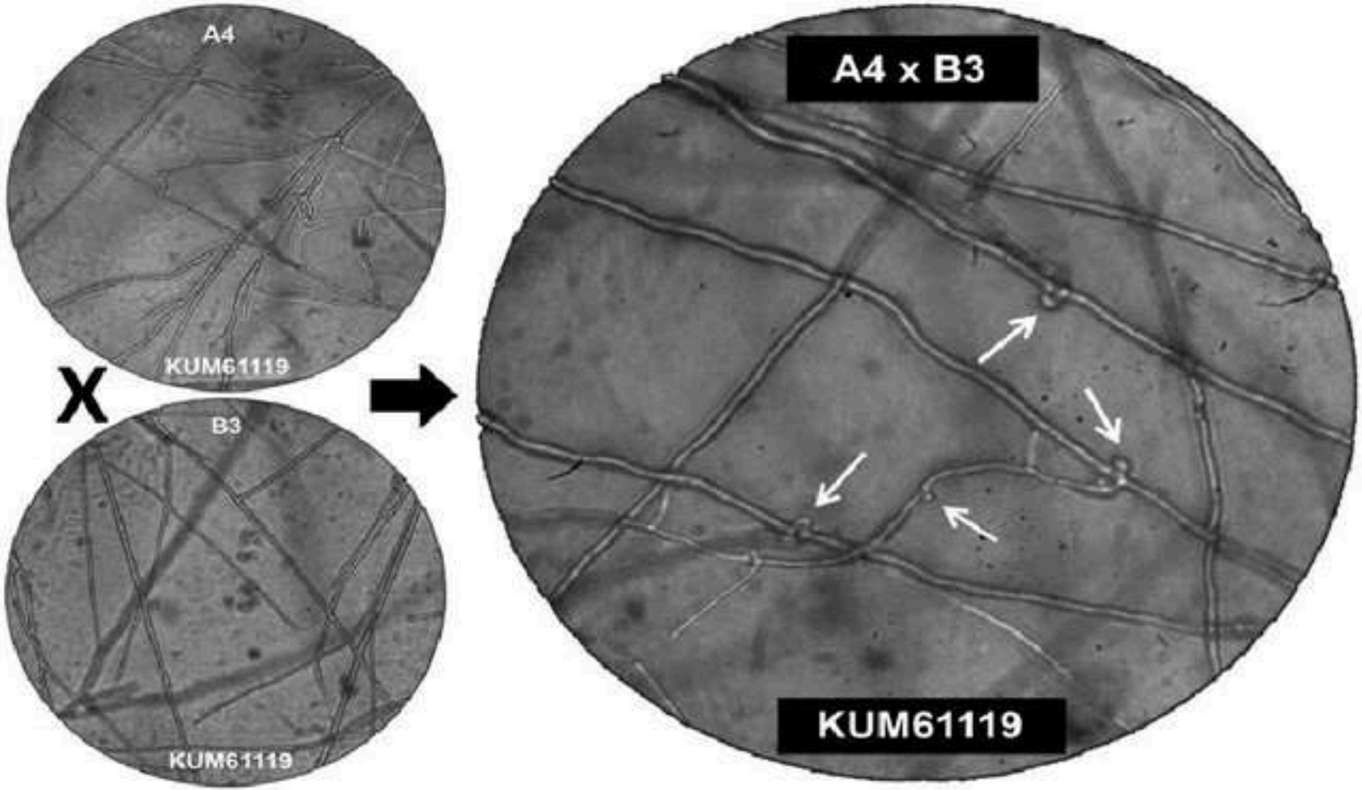


Fig. 2: Detection of compatibility by mating test. The crosses were scored as compatible if clamp connections observed. Avin et al., 2014.

https://www.online.lincoln.edu.my/uploadedfiles/emp_rch/8ea78471-a54d-4c2c-9b13-f3a21ad9a458DNA%20PEDIGREE%20TRACKING%20TO%20IDENTIFY%20COMPATIBLE%20MATING%20PARTNERS%20OF.pdf

Evolutionary forces in mating type multiplicity:

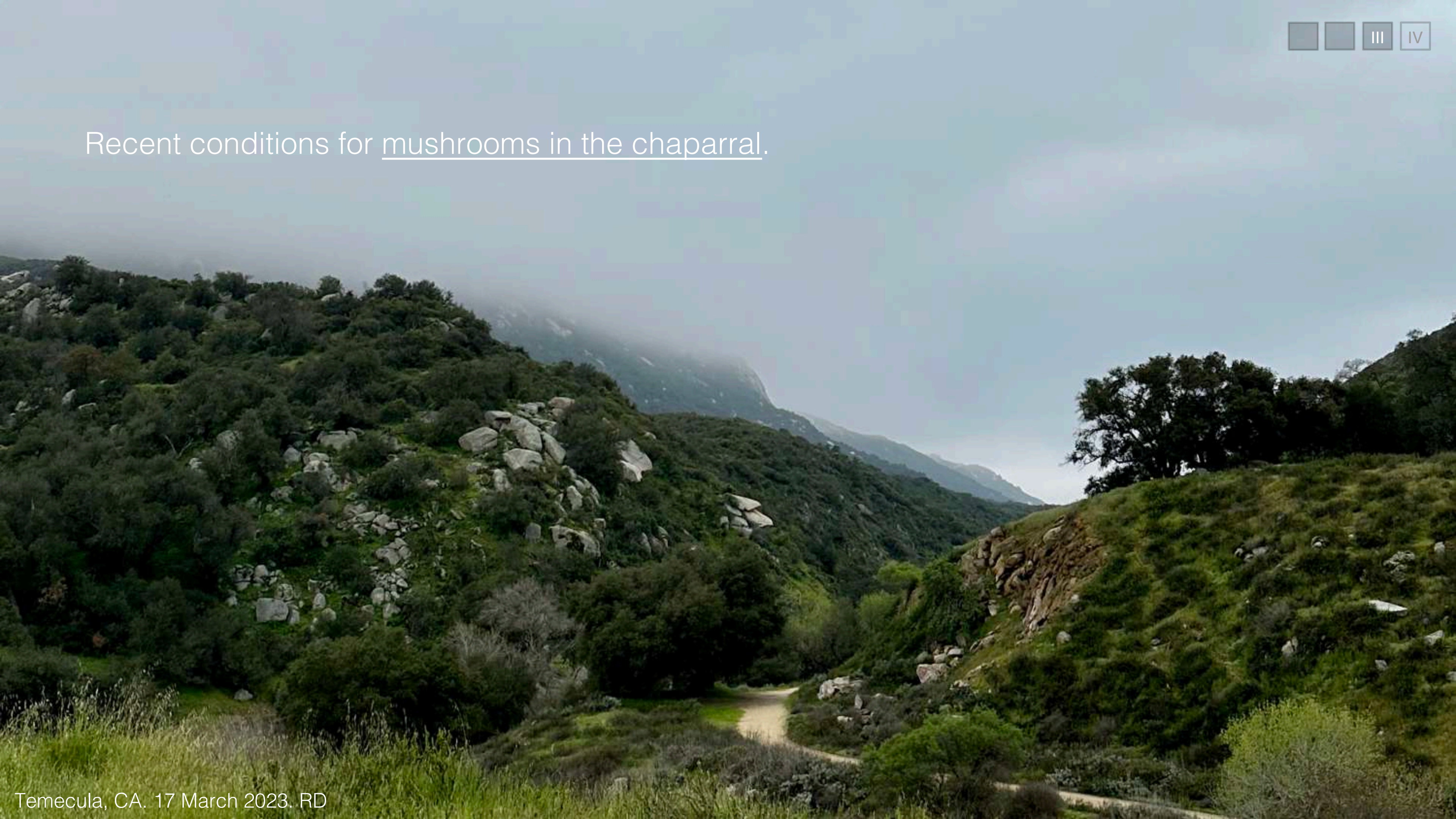
Gene duplication – Sequence divergence – Chromosome rearrangements

Functional integration

How could it be the case?

- Fungi have an extreme capacity for tolerating internal and external (genetic and environmental) disturbance
- After it has appeared, redundant genetic features could become linked with novel genetic variation that fulfills important life history and ecological functions.

Recent conditions for mushrooms in the chaparral.



Temecula, CA. 17 March 2023. RD


Arrhenia chlorocyanea
Hygrophoraceae, Agaricales
III IV
https://www.inaturalist.org/observations/151448320 Temecula, CA. March 2023 SP

Common moss mushroom look-alikes.

San Gabriel Mts. March 2023. SP https://www.inaturalist.org/observations/150748901

Murrieta, CA. March 2023. RD https://www.inaturalist.org/observations/149713015

Temecula, CA. 17 March 2023 SP

Pleuroflammula

Crepidotaceae, Agaricales

On wood of *Artemisia*.

https://www.inaturalist.org/observations/152092833 San Gabriel Mts. SP

Calocybe onychia
Lyophyllaceae, Agaricales

https://www.inaturalist.org/observations/149300379 20 FEB 2023. Pine Valley. acorncap

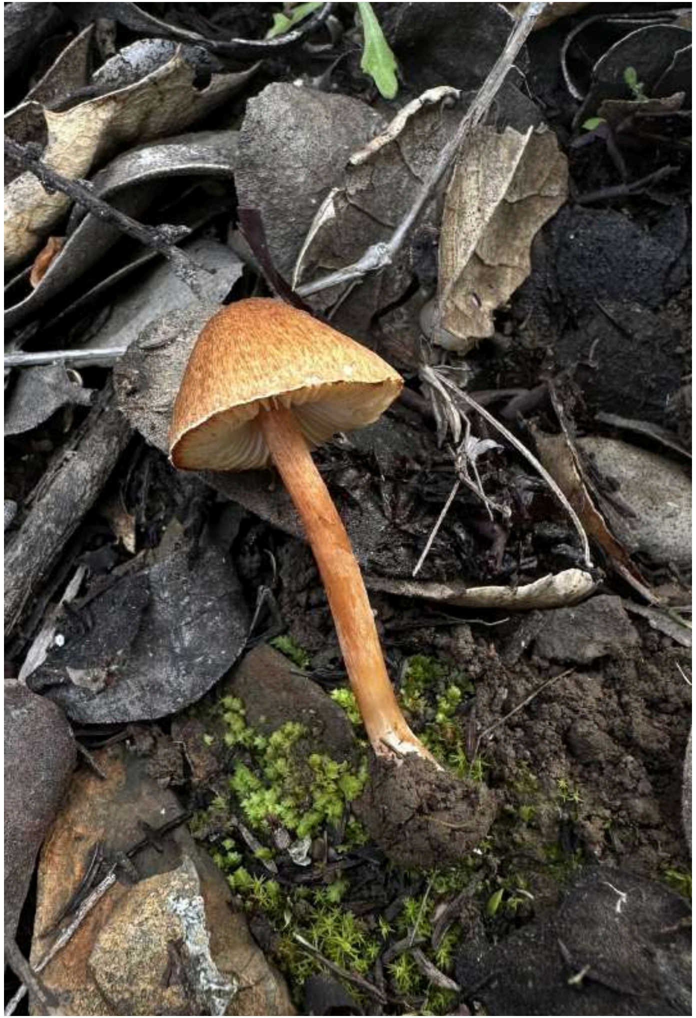
***Entoloma* subg. Cyanula**
Entolomataceae, Agaricales

Temecula, CA. 17 March 2023. RD https://www.inaturalist.org/observations/151466408

Riverside County. March 2023. SP https://www.inaturalist.org/observations/152212249

***Cystolepiota* sp.**
Verrucosporaceae, Agaricales

Under *Eriogonum fasciculatum*.

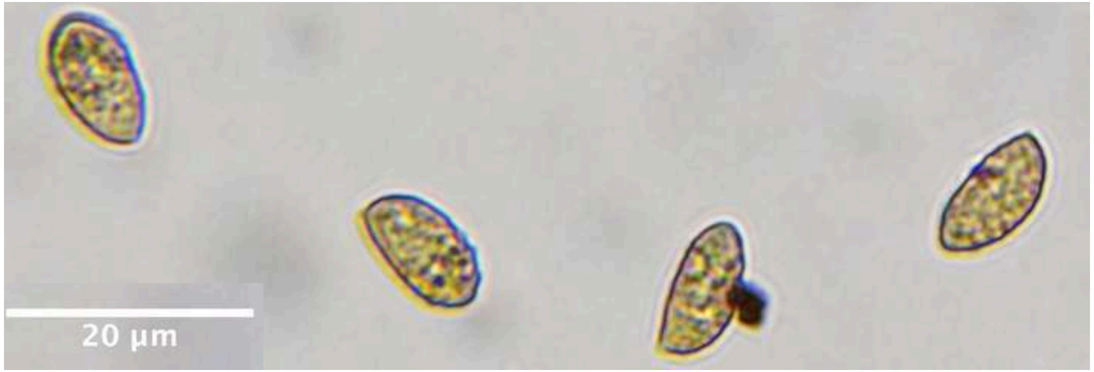


Lepiota cf. _boudieri_
Verrucosporaceae, Agaricales

Chiquito Basin. 18 March 2023. RD https://www.inaturalist.org/observations/151656946

Cortinarius (Telamonia)
Cortinariaceae, Agaricales

Under *Adenostoma fasciculatum* (chamise).



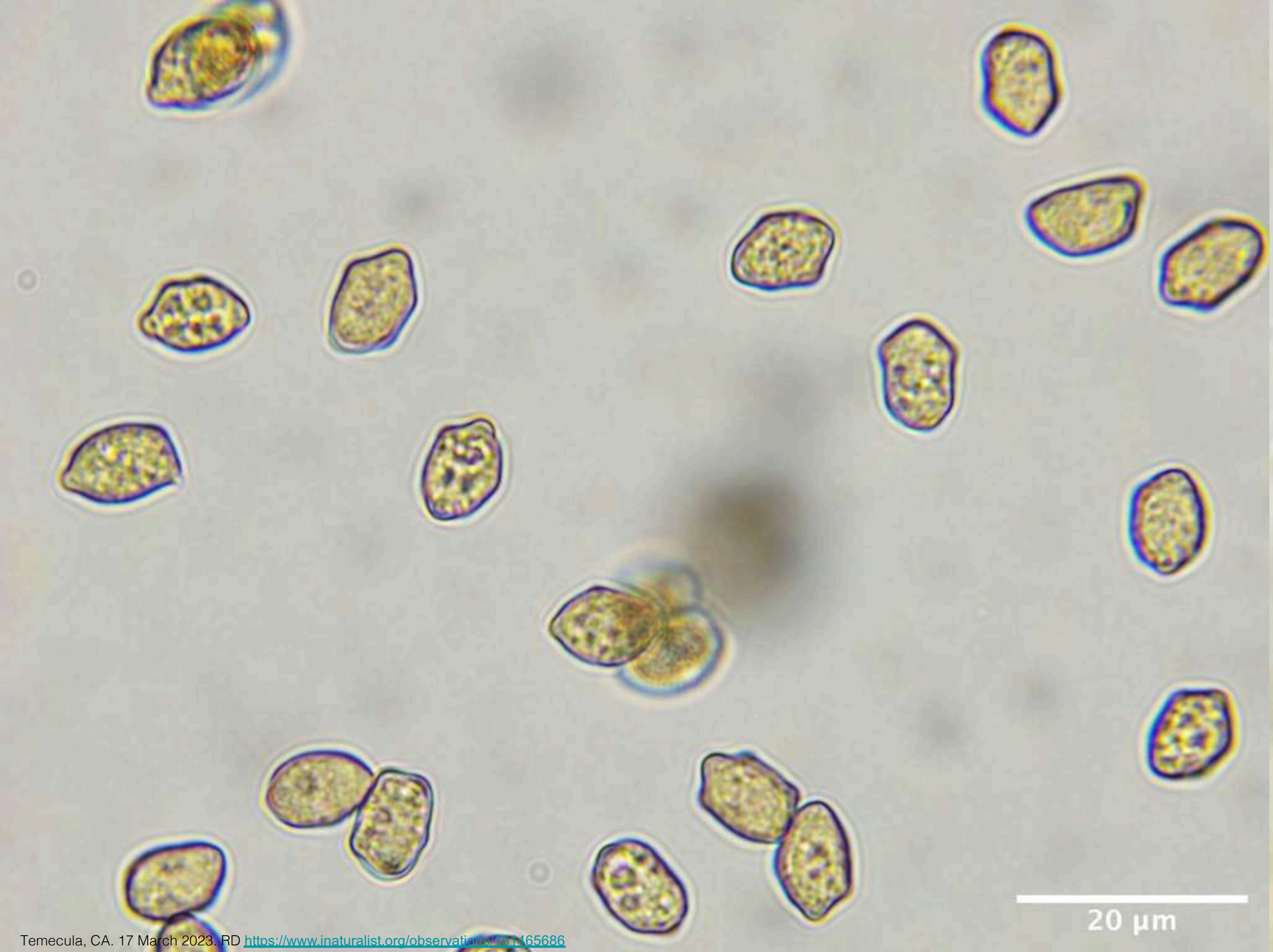
Temecula, CA. 17 March 2023. RD https://www.inaturalist.org/observations/151465563

Inocybe sp.

Inocybaceae, Agaricales

Under scrub oak.

Temecula, CA. 17 March 2023. RD https://www.inaturalist.org/observations/151465686



Temecula, CA. 17 March 2023. RD https://www.inaturalist.org/observations/151465686

***Balsamia* sp.**
Helvellaceae, Pezizales

Under scrub oak.

Santa Monica Mts. Feb. 2023. SP https://www.inaturalist.org/observations/148562000

***Melanogaster* sp.**
Melanogastraceae, Boletales

Santa Gabriel Mts. March 2023.
SP https://www.inaturalist.org/observations/150748987

NOT POOP.

***Melanogaster* sp.**
Melanogastraceae, Boletales

Under scrub oak.


III
IV
Synchytrium papillatum
Chytridiomycota
Parasite on Erodium.
Chalon Boesel https://www.inaturalist.org/observations/151256102

Psilocybin-producing fungi

Psilocybe spp.

Psilocybe species diversity. Basidiomata of **(A)** *Psilocybe serbica* (jonagruska, CC-BY-SA 3.0), **(B)** *P. mescalenroensis* (Alan Rockefeller, CC BY-SA 4.0), **(C)** *P. cubensis* (Ricardo Arredondo, CC BY-NC), **(D)** *P. ovoideocystidiata* (Shroomydan, CC-BY-SA 3.0), **(E)** *P. allenii* (Alan Rockefeller, CC-BY-SA 3.0), **(F)** *P. azurescens* (Shroom360, CC BY-SA 3.0), **(G)** *P. cyanescens* (Alan Rockefeller, CC BY-SA 3.0), **(H)** *P. subaeruginosa* (ericos_bob, CC BY-SA 3.0), **(I)** *P. angulospora* (Inski, CC BY-NC-SA), **(J)** *P. baeocystis* (Caleb Brown, CC-BY-SA 3.0), **(K)** *P. pelliculosa* (Scottdarbey, CC-BY-SA 3.0), **(L)** *P. semilanceata* (Alan Rockefeller, CC-BY-SA 3.0), **(M)** *P. hoogshagenii* (Brayan Coral Jaramillo, CC BY-SA 3.0), **(N)** *P. mexicana* (Alan Rockefeller, CC BY-SA 4.0), **(O)** *P. neoxalapensis* (David Morales, CC-BY-NC 4.0), **(P)** *P. zapotecorum* (Alan Rockefeller, CC-BY-SA 3.0).

https://doi.org/10.1016/j.funbio.2022.01.003

Panaeolus cinctulus, RD

Gymnopilus spp. https://en.wikipedia.org/wiki/Gymnopilus_luteofolius

Pluteus americanus https://en.wikipedia.org/wiki/Pluteus_americanus#/media/File:Pluteus_americanus.jpg

Inocybe corydalina
Alan Rockefeller https://www.inaturalist.org/observations/4675516

Massospora spp.
https://www.sciencedirect.com/science/article/pii/S1754504819300352

Genera with psilocybin-producing species

Genus	Family	Lifestyle	Morphology	Sclerotia
Panaeolus	Bolbitiaceae	Saprobic	Agaricoid, Secotioid	Variable
Pholiotina	Bolbitiaceae	Saprobic	Agaricoid	No
Gymnopilus	Hymenogastraceae	Saprobic	Agaricoid	No
Psilocybe	Hymenogastraceae	Saprobic	Agaricoid, Secotioid	Variable
Pluteus	Pluteaceae	Saprobic	Agaricoid	Variable
Inocybe	Inocybaceae	Ectomycorrhizal	Agaricoid	Variable
Massospora	Entomophthoraceae	Insect Pathogenic	Abdominal Spore Mass	No

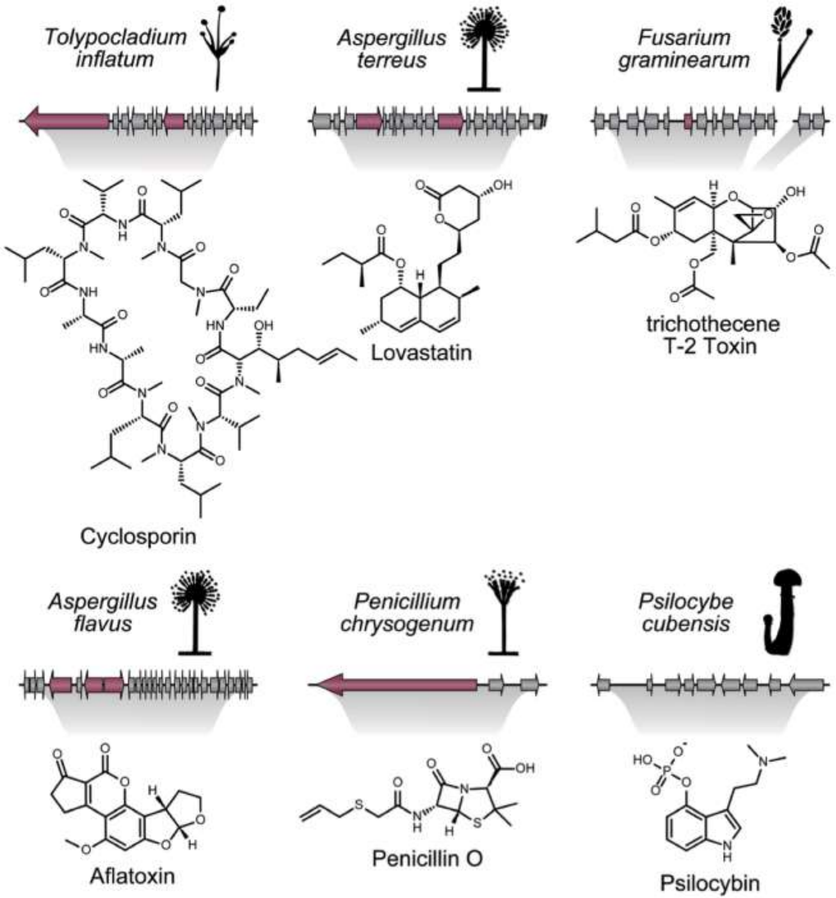
Table 1, Meyer & Slot 2023: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4384673

“**Secondary metabolites (SMs)** are generally defined as small organic molecules produced by an organism that are not essential* for their growth, development and reproduction.”

From: Biotechnology and Biology of Trichoderma, 2014

* i.e., a molecule *in addition* to the standard toolkit shared by most branches of the tree of life.

Psilocybe ovoideocystidiata – West LA, Sept. 2022. RD



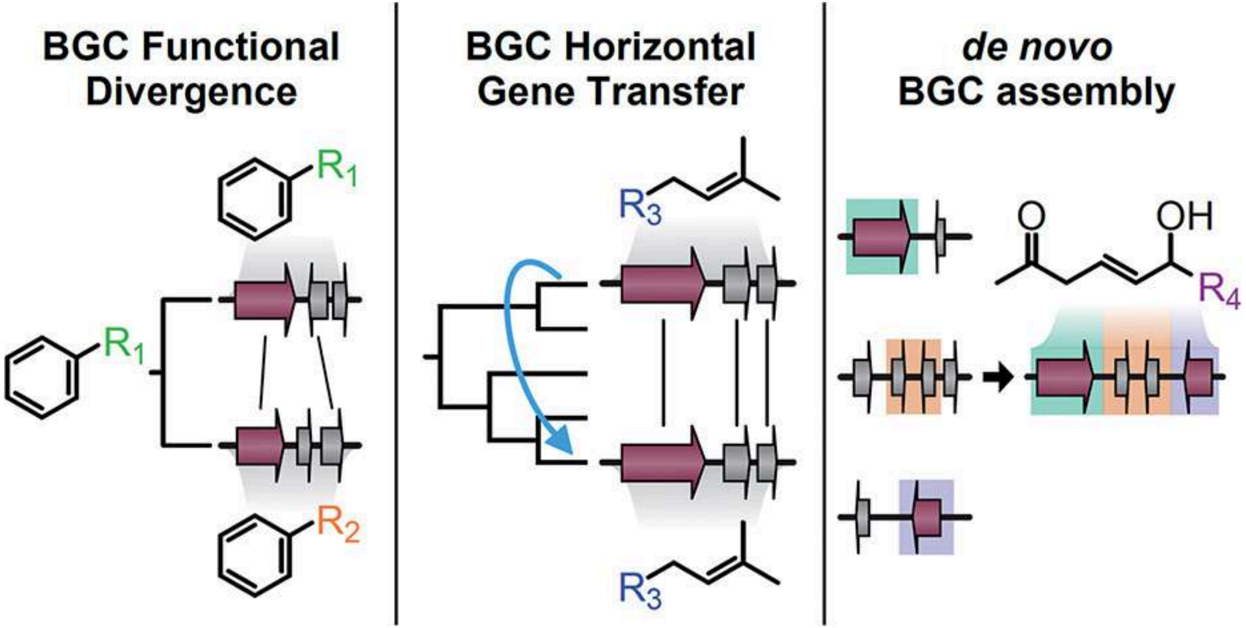
Secondary metabolites are end products in a careful process of construction and modification, encoded genetically in groups of genes called biosynthetic gene clusters (BGCs).

These genes encode different proteins with different functions in the constructive process.

They include enzymes, transporters, and transcription factors, as well as enzymes that confer resistance to the final metabolite.

Rokas, A., Mead, M. E., Steenwyk, J. L., Raja, H. A. & Oberlies, N. H. Biosynthetic gene clusters and the evolution of fungal chemodiversity. *Nat. Prod. Rep.* **37**, 868–878 (2020)
https://www.sciencedirect.com/org/science/article/abs/pii/S0265056822005864

Mechanisms for the evolution of BGCs and fungal chemodiversity:



Rokas, A., Mead, M. E., Steenwyk, J. L., Raja, H. A. & Oberlies, N. H. Biosynthetic gene clusters and the evolution of fungal chemodiversity. *Nat. Prod. Rep.* **37**, 868–878 (2020)
https://www.sciencedirect.com/org/science/article/abs/pii/S0265056822005864

Horizontal gene cluster transfer increased hallucinogenic mushroom diversity

Hannah T. Reynolds,[1,2,*] Vinod Vijayakumar,[1,*] Emile Gluck-Thaler,[1,*] Hailee Brynn Korotkin,[3]
Patrick Brandon Matheny,[3] and Jason C. Slot[1,4] 2018

Abstract

Secondary metabolites are a heterogeneous class of chemicals that often mediate interactions between species. The tryptophan-derived secondary metabolite, psilocin, is a serotonin receptor agonist that induces altered states of consciousness. A phylogenetically disjunct group of mushroom-forming fungi in the Agaricales produce the psilocin prodrug, psilocybin. Spotty phylogenetic distributions of fungal compounds are sometimes explained by horizontal transfer of metabolic gene clusters among unrelated fungi with overlapping niches. We report the discovery of a psilocybin gene cluster in three hallucinogenic mushroom genomes, and evidence for its horizontal transfer between fungal lineages. Patterns of gene distribution and transmission suggest that synthesis of psilocybin may have provided a fitness advantage in the dung and late wood-decay fungal niches, which may serve as reservoirs of fungal indole-based metabolites that alter behavior of mycophagous and wood-eating invertebrates. These hallucinogenic mushroom genomes will serve as models in neurochemical ecology, advancing the (bio)prospecting and synthetic biology of novel neuropharmaceuticals.

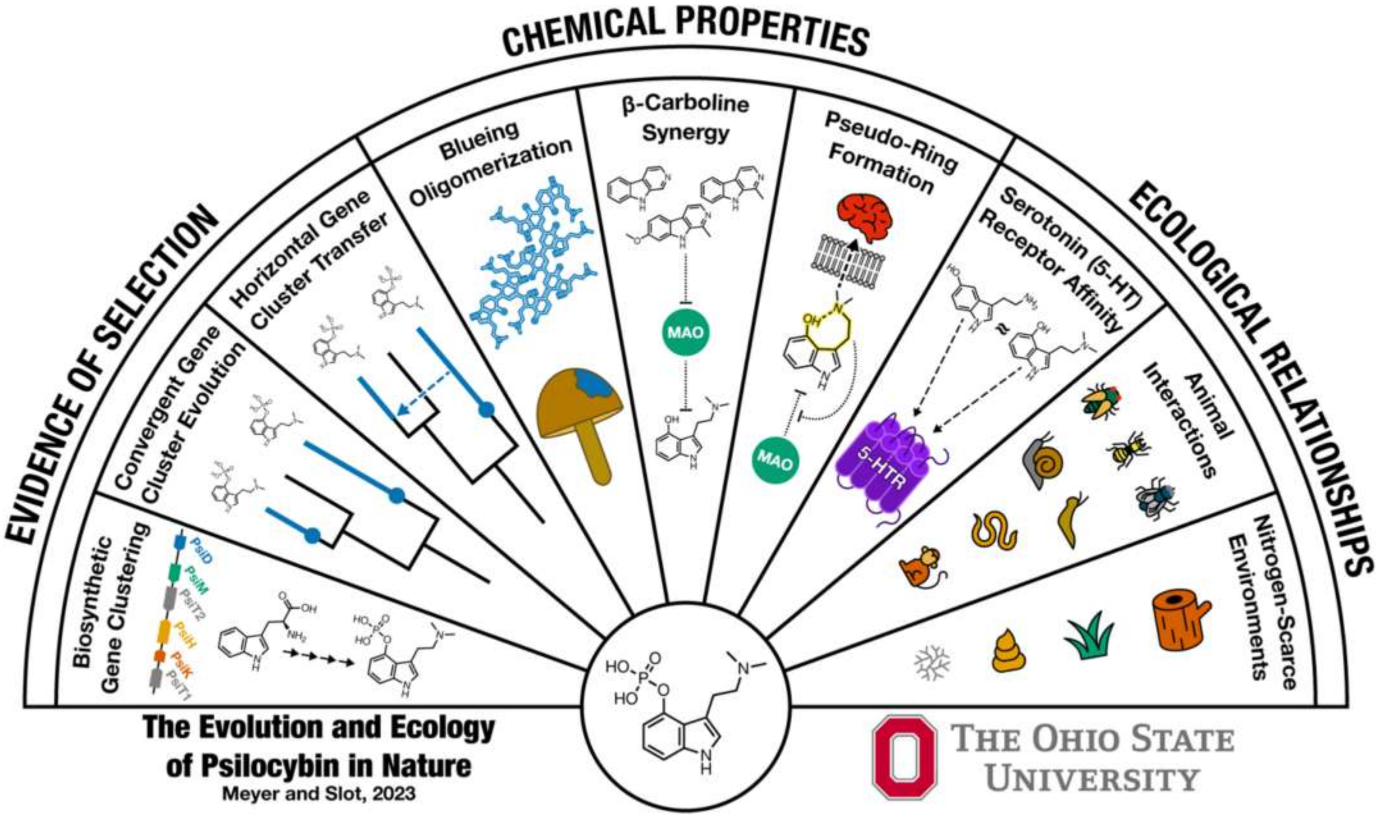
Hannah T. Reynolds, Vinod Vijayakumar, Emile Gluck-Thaler, Hailee Brynn Korotkin, Patrick Brandon Matheny, Jason C. Slot, Horizontal gene cluster transfer increased hallucinogenic mushroom diversity, *Evolution Letters*, Volume 2, Issue 2, 1 April 2018, Pages 88–101, https://doi.org/10.1002/evl3.42

Convergent evolution of psilocybin biosynthesis by psychedelic mushrooms

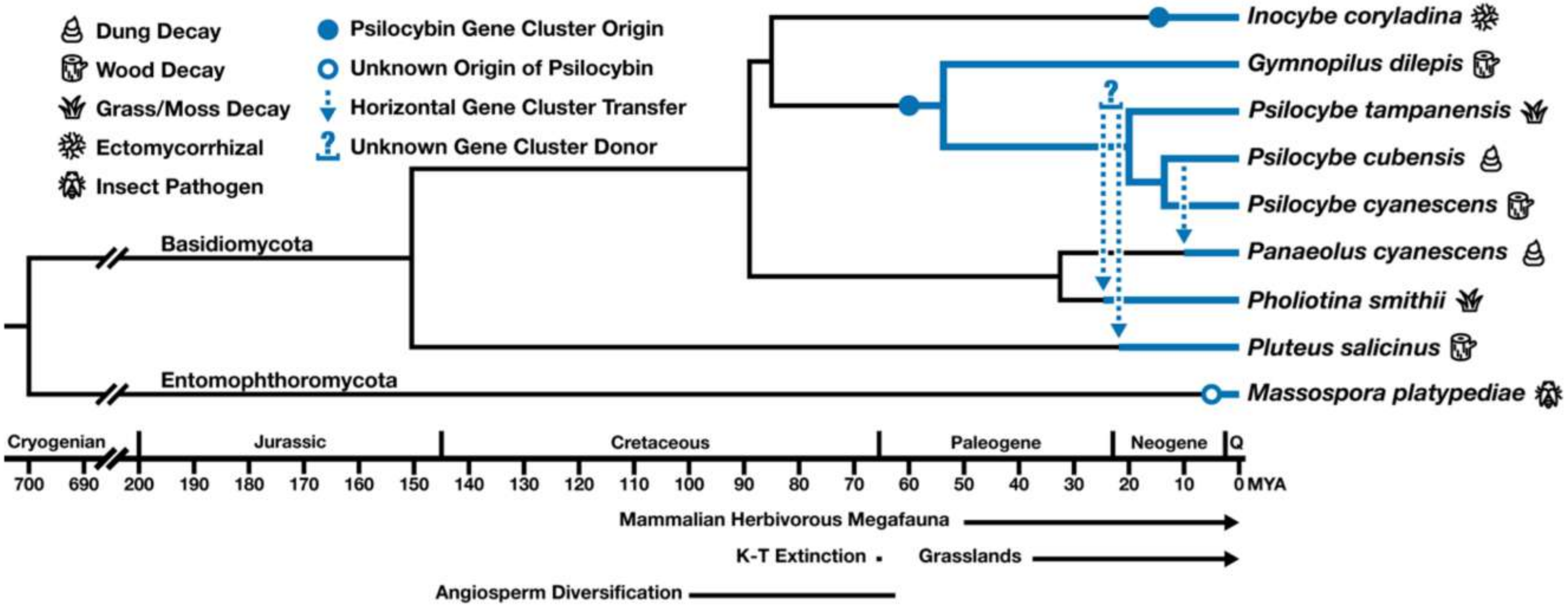
Ali R. Awan, Jaclyn M. Winter, Daniel Turner, William M. Shaw, Laura M. Suz, Alexander J. Bradshaw, Tom Ellis,
Bryn T.M. Dentinger 2018
https://www.biorxiv.org/content/10.1101/374199v2.full

Abstract

Psilocybin is a psychoactive compound with clinical applications produced by dozens of mushroom species[1]. There has been a longstanding interest in psilocybin research with regard to treatment for addiction[2], depression[3], and end-of-life suffering[4]. However, until recently very little was known about psilocybin biosynthesis and its ecological role. Here we confirm and refine recent findings[5] about the genes underpinning psilocybin biosynthesis, discover that there is more than one psilocybin biosynthesis cluster in mushrooms, and we provide the first data directly addressing psilocybin's ecological role. By analysing independent genome assemblies for the hallucinogenic mushrooms *Psilocybe cyanescens* and *Pluteus salicinus* we recapture the recently discovered psilocybin biosynthesis cluster[5,6] and show that a transcription factor previously implicated in its regulation is actually not part of the cluster. Further, we show that the mushroom *Inocybe corydalina* produces psilocybin but does not contain the established biosynthetic cluster, and we present an alternative cluster. Finally, a meta-transcriptome analysis of wild-collected mushrooms provides evidence for intra-mushroom insect gene expression of flies whose larvae grow inside *Psilocybe cyanescens*. These larvae were successfully reared into adults. Our results show that psilocybin does not confer complete protection against insect mycophagy, and the hypothesis that it is produced as an adaptive defense compound may need to be reconsidered.



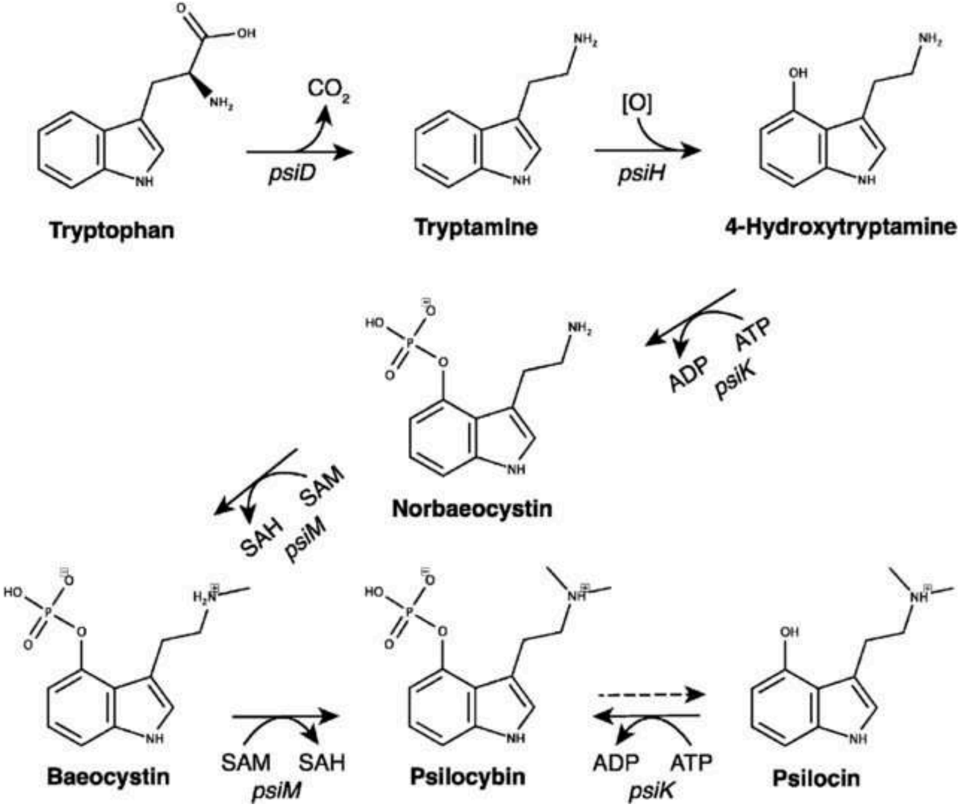
Meyer & Slot 2023: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4384673



Meyer & Slot 2023: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4384673

The most common factor among the various ecological niches of psilocybin-producing fungi appears to be their low-nitrogen substrates. For example, the late stages of wood and dung decay are nitrogen-poor environments (Chen et al., 2013; Cowling and Merrill, 1966; Hao et al., 2004; Hess et al., 2021; Petersen et al., 1998), and ectomycorrhizal species are effective nitrogen scavengers for their host plants (Hernández et al., 2002; Mbarki et al., 2008; Stamets, 1996). Yet, despite environmental limitations, a large portion of nitrogen is allocated to psiloids. For example, psilocybin can make up to 1.6% of a mushroom's total nitrogen content (Borner and Brenneisen, 1987; Braaksma and Schaap, 1996; Gartz, 1994; Kamata et al., 2005). The high nitrogen allocation to psilocybin production suggests that its benefits outweigh any cost to nitrogen-limited growth and reproduction processes.

Meyer & Slot 2023: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4384673

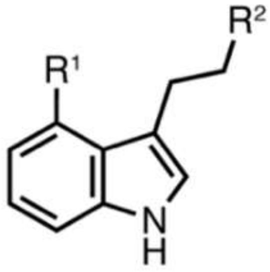


Van Court, R. C. *et al.* Diversity, biology, and history of psilocybin-containing fungi: Suggestions for research and technological development. *Fungal Biol.* **126**, 308–319 (2022)
https://doi.org/10.1016/j.funbio.2022.01.003

Psilocybin construction starts with the essential amino acid tryptophan,

which then undergoes a series of modifications through its interactions with specific proteins.

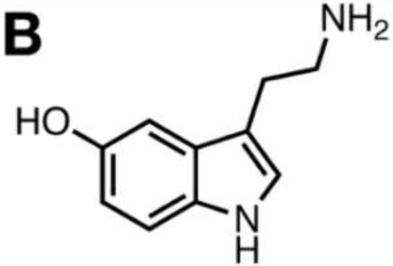
A



Psiloids

	R^1	R^2
4-hydroxytryptamine (4-HT):	OH	NH_2
Norbaeocystin (4-OP-T):	$O\text{-}PO_3H_2$	NH_2
Norpsilocin (4-OH-NMT):	OH	$N(CH_3)H$
Baeocystin (4-OP-NMT):	$O\text{-}PO_3H_2$	$N(CH_3)H$
Psilocin (4-OH-DMT):	OH	$N(CH_3)_2$
Psilocybin (4-OP-DMT):	$O\text{-}PO_3H_2$	$N(CH_3)_2$
4-hydroxytrimethyltryptamine (4-OH-TMT):	OH	$N^+(CH_3)_3$
Aeruginascin (4-OP-TMT):	$O\text{-}PO_3H_2$	$N^+(CH_3)_3$

B



Serotonin (5-HT)

Fig. 1. Tryptophan-derived compounds in psychedelic/magic mushrooms (Gurevich, 1993; Lenz et al., 2021b). (A) Psiloids: the eight known natural 4-substituted tryptamine metabolites of the psilocybin biosynthesis pathway (Fricke et al., 2017; Stijve, 1984) found primarily in mushroom fruiting bodies (Blei et al., 2020). (B) Serotonin: a key signaling molecule found in all domains of life (Erland et al., 2019) and a key neurotransmitter in animals (Andrés et al., 2007).

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Another tryptophan-derived molecule is serotonin, which fulfills diverse cell signaling functions across all lifeforms.

The structural similarity of Psilocin to Serotonin allows Psilocin to interact with animal Serotonin-receptor proteins.

Evolutionary genomics is a powerful tool that can provide insights into the ecological role of psilocybin production. By studying rare molecular evolutionary events surrounding psilocybin's biosynthetic pathway (i.e., gene clustering, convergent evolution, HGT), we are given clues as to how these species have adapted to their environments. Two convergent origins of the psilocybin gene cluster in Agaricales have been established in wood-decay (the inferred ancestral state of *Gymnopilus* and *Psilocybe*) and in the ectomycorrhizal *Inocybe*, with another possible convergence in Entomophthoromycota (Awan et al., 2018; Boyce et al., 2019; Reynolds et al., 2018). Most other known psilocybin producers are saprobes and likely acquired the wood-decay-associated cluster through HGT (Fig. 2A) (Reynolds et al., 2018). This suggests that psilocybin may have different functions in different ecological niches but is most useful in decay niches. The ancestral ecologies of the cluster donor species were likely similar saprobic niches to their recipients, leading to physical contact between them and increasing the chances of HGT (Gluck-Thaler and Slot, 2015; Reynolds et al., 2018). Horizontal acquisition of psilocybin production may also facilitate expansion into new ecological niches (Slot, 2017). For instance, the HGT between the *Ps. cubensis* and *Pa. cyanescens* lineages likely occurred in their shared dung decay niche (Reynolds et al., 2018), suggesting both species faced similar pressures that psilocybin may have at least partially alleviated. Psilocybin production may defend against cohabiting animals, especially insects, that compete for resources or consume the fungus. An ecological association with insects is further supported by the likely convergent origin of psilocybin in *M. levispora/platypedia*, a fungus that is directly antagonistic to an insect.

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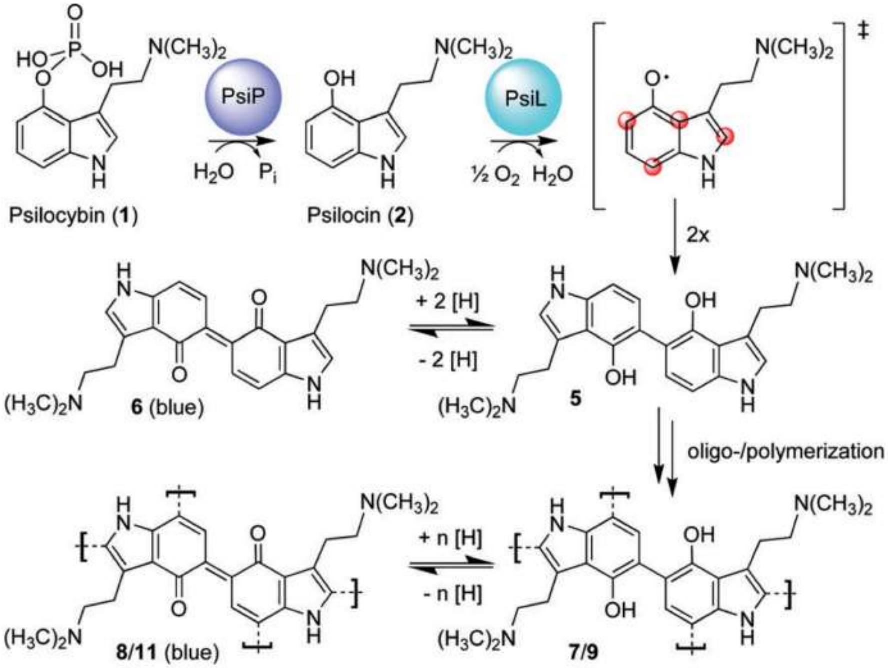

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7004109/pdf/ANIE-59-1450.pdf

Ecological function in the blue bruising reaction?

Caused by "rapid conversion of phosphorylated psiloids into their hydroxylated counterparts, followed by oxidative coupling that forms blue oligomers."

"Chromophoric oligomers may serve a defensive ecological function due to their polyphenolic and aryl-coupling properties. When ingested, these compounds generate reactive oxygen species, causing intestinal lesions in insects (Barbehenn and Peter Constabel, 2011; Salminen and Karonen, 2011)."

Meyer & Slot 2023:
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4384673

Do we why know why mushrooms produce psilocybin?

No. But it must be important different ways in different fungal lineages, whatever they're doing…