Fungi terminology on sexuality

Sexual reproduction is notoriously complex in fungi with species able to produce sexual progeny by utilizing a variety of different mechanisms. This is even more so for species employing **multiple sexual strategies**, which is a surprisingly common occurrence. While heterothallism is relatively well understood in terms of its physiological and molecular underpinnings, homothallism remains greatly understudied. This can be attributed to it involving numerous genetically distinct mechanisms that all result in self-fertility; including primary homothallism, pseudohomothallism, mating type switching, and unisexual reproduction.

In mycology, the term s teleomorph, **anamorph**, and holomorph apply to portions of the life cycles of fungi in the phyla Ascomycota and Basidiomycota:**Anamorph**: an asexual reproductive stage (morph), often mold-like; When a single fungus produces multiple morphologically distinct **anamorphs**, these are called synanamorphs. **Teleomorph**: the sexual reproductive stage (morph), typically a fruiting body. Holomorph: the whole fungus, including anamorphs and teleomorph.

The general sexual procedure is going through- plasmogamy, karyogamy to meiosis.

Plasmogamy is a stage in the sexual reproduction of fungi, in which the cytoplasm of two parent cells (usually from the mycelia) fuses together without the fusion of nuclei, effectively bringing two haploid nuclei close together in the same cell.

Karyogamy is the final step in the process of fusing together two haploid eukaryotic cells, and refers specifically to the fusion of the two nuclei. Before **karyogamy**, each haploid cell has one complete copy of the organism's genome.

Somatogamy : The fusion of two cells (but not their nuclei), especially as the first stage of syngamy.

Pseudohomothallism: Pseudohomothallism adheres to the physiological definition of homothallism and, as such, single spores of species exhibiting this type of self-fertility are fully able to undergo independent sexual reproduction (Whitehouse 1949). However, from a cellular and molecular standpoint, the underlying mechanism is more complex than that of primary homothallism and has consequently been referred to as an example of secondary homothallism or functional heterothallism

Parasexual cycle, a process peculiar to fungi and single-celled organisms, is a nonsexual mechanism of **parasexuality** for transferring genetic material without meiosis or the development of sexual structures.

Homothalli refers to the possession, within a single organism, of the resources to reproduce sexually; i.e., having male and female reproductive structures on the same thallus. The opposite sexual functions are performed by different cells of a single mycelium.

Heterothallic species have sexes that reside in different individuals. The term is applied particularly to distinguish **heterothallic** fungi, which require two compatible partners to produce sexual spores, from homothallic ones, which are capable of sexual reproduction from a single organism

According to Blakeslee (1904) Heterothallic condition is **“essentially similar to that in dioecious plants and animals and although in this case the two complimentary individuals which are needed for sexual reproduction are in general not so conspicuously differentiated morphologically as in higher forms, such a morphological difference is often distinctly visible.”**

- **Morphological heterothallism:**

Morphological heterothallism may be defined as the condition when morphologically different male and female sex organs are produced in two closely associated mycelia.

The two sex organs or gametes are so morphologically different that it is easier to term one of them as male and the other as female-examples of such type of morphological heterothallic fungi are: *Achlya ambisexualis, A. bisexualis, Blastocladiella variabilis, Dictyuchus monosporus, Phytophthora palmivora and Peronospora parasitica*.

However, in *Blastocladiella variabilis* the male and female gametangia are morphologically distinct, the male being smaller than the female.

Whitehouse (1949) also used the term haplodioecious for morphologically heterothallic species of fungi.

- **Physiological heterothallism may be of two types:**

(i) Two Allelomorphs or Two-Allele Heterothallism:

When nuclei of both the mating types are different in genetic characters, this type of Heterothallism is known as Two-Allele heterothallism. In these types compatibility is governed by a pair of Alleles represented by A and a located at single same locus of the chromosome.

Due to the dominance of A over a, A is represented by (+) and a by (-). At the time of meiosis, separation of the chromatids take place. Half of the haploid spores thus have (+) and the other half (-) allele.

The spores bearing (+) allele will produce (+) mycelia and the spores with (-) allele will give rise to (-) mycelia. The mycelia of (+) and (+) and (-) and (-) are self-sterile or self-incompatible. Thus, two complimentary mating types (+) and (-) are essential for sexual reproduction.

Two-Allele heterothallism has been reported in several fungi of like Ascobolus magnificus, Puccinia graminis

(ii) Multiple Allelomorph or Multiple Allele Heterothallism:
In this type of heterothallism, more than two (multiple) alleles determine the sexual compatibility. These may be located at one (bipolar) or two (tetrapolar) loci.

Because of the larger number of alleles involved in this type of heterothallism, chances of mating of compatible strains increase.

As stated above, the multiple allele heterothallism may be of two types:
(a) Bipolar Multiple-allele heterothallism
(b) Tetrapolar multiple-allele heterothallism.

(a) Bipolar Multiple-Allele Heterothallism:
This type of heterothallism is controlled by multiple alleles at a single locus, instead of a pair of Alleles. For example, if the locus is named as L, the multiples alleles will be designated as L_1, L_2, L_3, L_4—Ln and these are present on the single locus L.
The meiotic division will give rise .to thalli which may be of several mating types, generally equal to the number of alleles. The thallus containing the allele L_1 can mate with a thallus of any mating type except L_1.
Similarly L_2 can mate with any thallus except that containing L_2 allele and so on. In this type of heterothallism, incompatibility factors are more commonly involved. Bipolar multiple allele heterothallism is characteristic of Basidiomycetes except rusts and smuts

	L_1	L_2	L_3	L_4
L_1	N	C	C	C
L_2	C	N	C	C
L_3	C	C	N	C
L_4	C	C	C	N

(b) Tetrapolar Multiple Allele heterothallism:

This type of heterothallism is characteristic of Basidiomycetes except rusts. In this type of heterothallism, which is very similar to bipolar multiple allele heterothallism, compatibility is determined by two loci.

Multiple allele—the compatible factor is present on two loci L_1 and L_2 of two Chromatids of a chromosome. At the time of meiotic division, both the loci are separated with chromatids.

It is estimated that at least 100 alleles are present on each locus. In Schizophyllum commune, 122, alleles of factor A and 61 of B have been identified in the laboratory.

According to rough estimates, the number of alleles may be even more, about 350-450 of L_1, and 65 of L_2. Any two mating types, which differ in allele present on L_1 and $L_2$are compatible.

If the allele composition of mating type is A_1 B_1, it would be compatible with any other type of allele composition except A_1 B_1. But the mating type with allele composition is not fully compatible with allele composition A_2 B_2 or A_2 B_2.

Figure 17.4 fully explains type of heterothallism which has been reported in Ustilago maydis and Comprinus firmaterius.

	A_1B_1	A_1B_2	A_2B_1	A_2B_2
A_1B_1	N	NFC	NFC	C
A_1B_2	NFC	N	C	NFC
A_2B_2	NFC	C	N	NFC
A_2B_2	C	NFC	NFC	N

This type of heterothallism encourages out-breeding. Whereas in bipolar multiple Allele heterothallism, the out-breeding is 25%, in tetrapolar, it is 100%. This may be due to enormous increase in the number of possible mating types of thalli.

According to Garrett (1963), **"heterothallism promotes the out-breeding and therefore subserves the same end as the sexual process, which it renders most efficient. Hetrothallism is not the same as sex, it is refinement super imposed upon it."**