Biology of Fungi

Fungal Genetics, Molecular Genetics, and Genomics

Concepts

- Fungi have major tools for classical genetic studies
  - Ease of growth
  - Short life cycles
  - Most are haploid
  - Many have a sexual stage
  - Produce asexual spores that can be used or stored in bulk

Concepts (cont.)

- Fungi also serve as good models for biochemical studies
  - Simple nutrient requirements
  - Can be directly correlated with genetic studies, e.g., “one gene, one enzyme” hypothesis by Beadle and Tatum

Neurospora Classical Genetics

- Neurospora has 4-5 heterothallic species
  - Two mating types: A and a
  - “male spore” fertilizes a female trichogyne to eventually form ascii bearing ascospores
  - Haploid nuclei fuse to form a diploid nucleus, which then undergoes meiosis followed by a second mitotic division

Neurospora Classical Genetics (cont.)

- Resulting 8 nuclei are arranged in a linear fashion within an ascus
- Patterns of sister chromatid segregation of can be deduced from the different types of arrangements
  - Cross-over events
  - Gene mapping
Genome Structure

- A genome is all the genetic information possessed by an organism
  - Chromosomal genes
  - Mitochondrial genes
  - Plasmids/mobile genetic elements
  - Virus genes
  - Each contributes to the overall phenotype of the fungus

Genome Structure (cont.)

- Chromosomes in fungi
  - Most are haploid
  - Difficult to quantify
  - Very condensed
  - Nuclear membrane persists
  - Number of chromosomes vary between 3 and 40 with most fungi having between 6 and 16

Genome Structure (cont.)

- Genomes size is small compared to other eukaryotes
  - 3-8 times larger than E. coli, but 5-30 smaller than fruit flies or humans
  - Reason: limited multicopy DNA, restricted mainly to rRNA and tRNA

Genome Structure (cont.)

- Mitochondrial genes
  - Fungal mitochondrial genomes are small (19-121 kb in size) compared to plants (1 Mb), but larger than humans (6.6 kb)
  - Differences due to non-coding segments
  - Both nuclear and mitochondrial genes are essential for function of this organelle
  - Have an important role in senescence (aging)

Genome Structure (cont.)

- Plasmids and transposable elements
  - Plasmids are self-replicating
  - Usually circular
  - Also, linear capped forms
  - Most common types
    - "2 micron" plasmid found in the nucleus of *Saccharomyces cerevisiae*
    - Many other plasmids found within mitochondria
    - No known function of any
Genome Structure (cont.)

- Plasmids and transposable elements
  - Transposons
    - Short regions of DNA that remain in the chromosome, but encode for enzymes that function in the replication of these transposable elements
    - Produce RNA copies of themselves
    - Encode reverse transcriptase as well
    - RNA is copied into DNA that then inserts itself into various points of a chromosome

- Rare in filamentous fungi
- Several types in S. cerevisiae, including the Ty element (about 30 copies per cell), that can alter gene expression and chromosomal arrangements
- No known function, except for self-replication

Genome Structure (cont.)

- Viruses
  - First discovered as a pathogen of mushrooms
  - Electron microscopy revealed isometric virus-like particles (VLPs)
  - Now found in numerous fungal species
  - With few exceptions, however, VLPs appear not to cause any symptoms

- Common characteristics of fungal VLPs
  - Genome of dsRNA
  - Capsid composed of one polypeptide
  - Genome encodes for a single protein, dsRNA-dependent RNA polymerase
  - Variable genome size
  - Occur as crystalline arrays often near the ER
  - Transmission is by hyphal fusion or via passage into asexual spores

- VLPs are resident genetic elements, i.e., without a natural means of spreading, they don’t cross species barriers
- Can affect virulence of certain species
Genetic Variation

- **Nonsexual variation: the significance of haploidy**
  - Haploid fungi are under constant selection pressure, thereby increasing fitness or causing a loss thereof
  - Benefit: short term acquisition of characteristics
  - Disadvantage: cannot withstand long-term accumulation of mutations not of immediate value

- **Mycelial fungi are typically multinucleate (many nuclei in a common cytoplasm) and reap both the benefits of being haploid and a “functional diploid”**
- Not so for solely diploid organisms (e.g., Oomycota) and it also different for organisms like *S. cerevisiae* which can have either a persistent haploid or diploid state

Genetic Variation

- **Nonsexual variation: heterokaryosis**
  - Heterokaryons have two or more genetically different nuclei in a common cytoplasm (as opposed to homokaryons)
  - Heterokaryons produced in two ways:
    - Mutation of a wild-type nucleus
    - Fusion of two genetically different strains

- **Ratio of genetically different nuclei can vary depending upon selection pressures, e.g., Jinks test involving *Penicillium cyclopium* (see Table 9.3 in Deacon)**
- Heterokaryons do break down or segregate into homokaryons by one of two mechanisms
  - Uninucleate spore production
  - Branch contains a single nuclear type

Genetic Variation

- **Nonsexual variation: parasexuality**
  - Discovered by Pontecorvo in studying heterokaryosis
  - He observed that a heterokaryon having nuclear condition Ab and aB, produced not only parental types (Ab and aB), but also recombinant types, AB and ab.
Further study of this phenomenon led Pontecorvo to propose a parasexual cycle consisting of three stages:

- Diploidization
- Mitotic chiasma formation
- Haploidization

Parasexuality in relatively rare and is not a regular cycle as is sexual reproduction.

Sexual variation is a major mechanism for producing recombinants. Different mechanisms of crossing have evolved due to environmental conditions:

- Heterothallic
- Homothallic
- Others

Sexual spores tend to be dormant.