

21st Century Guidebook to Fungi

The eleven principles that govern fungal development

Principle 1	The fundamental cell biology of fungi on which development depends is that hyphae extend only at their apex, and cross walls form only at right angles to the long axis of the hypha.
Principle 2	Fungal morphogenesis depends on the placement of hyphal branches.
Principle 3	The molecular biology of the management of cell-to-cell interactions in fungi is completely different from that found in animals and plants
Principle 4	Fungal morphogenetic programmes are organised into developmental subroutines, which are integrated collections of genetic information that contribute to individual isolated features of the whole programme. Execution of all the developmental subroutines at the right time and in the right place results in a normal structure.
Principle 5	Because hyphae grow only at their apex, global change to tropic reactions of all the hyphal tips in a structure is sufficient to generate basic fruit body shapes.
Principle 6	Over localised spatial scales co-ordination is achieved by an inducer hypha regulating the behaviour of a surrounding knot of hyphae and/or branches (these are called Reijnders' hyphal knots).
Principle 7	The response of tissues to tropic signals and the response of Reijnders' hyphal knots to their inducer hyphae, coupled with the absence of lateral contacts between fungal hyphae analogous to the plasmodesmata, gap junctions and cell processes that interconnect neighbouring cells in plant and animal tissues suggest that development in fungi is regulated by morphogens communicated mainly through the extracellular environment.
Principle 8	Fungi can show extremes of cell differentiation in adjacent hyphal compartments even when pores in the cross wall appear to be open (as judged by transmission electron microscopy).
Principle 9	Meiocytes appear to be the only hyphal cells that become committed to their developmental fate. Other highly differentiated cells retain totipotency - the ability to generate vegetative hyphal tips that grow out of the differentiated cell to re-establish a vegetative mycelium.
Principle 10	In arriving at a morphogenetic structure and/or a state of differentiation, fungi are tolerant of considerable imprecision (= expression of fuzzy logic), which results in even the most abnormal fruit bodies (caused by errors in execution of the developmental subroutines) being still able to distribute viable spores, and poorly (or wrongly-) differentiated cells still serving a useful function.
Principle 11	Mechanical interactions influence the form and shape of the whole fruit body as it inflates and matures, and often generate the shape with which we are most familiar.

From Moore, D. (2005). Principles of mushroom developmental biology. *International Journal of Medicinal Mushrooms*, **7**: 79-101.