The Curious Case of Radiotrophic Fungi

Tyreke White
March 13, 2017

Submitted as coursework for PH241, Stanford University, Winter 2017

Introduction

Superheroes exist among us, but not in forms we might traditionally expect. They aren't the cape-cladded, flying, crime-stopping superhumans we have come to know and love. They exist in more covert ways, for example, as microbial organisms (Fig. 1) that emerge as a result of extreme environmental stresses that force them to adapt. They are astonishing organisms imbued with powers not from the "Power Cosmic" (a comic book reference that any Marvel fanatic will understand) but from radical forms of evolution.

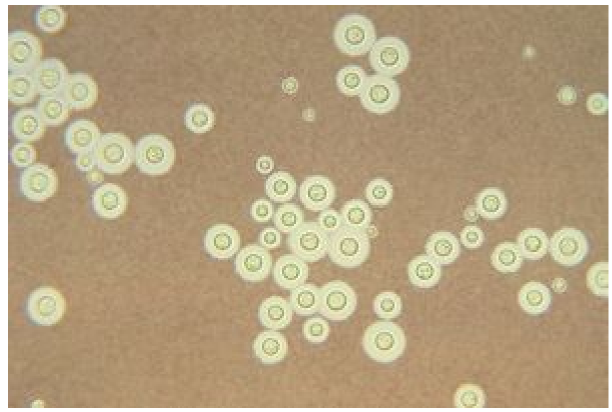

Fig. 1: *Cryptococcus neoformans*, a specific type of radiotrophic fungus. (Source: Wikimedia Commons)

Superheroes in Plain Sight

Over ten years ago, it was discovered that certain single-celled fungi were thriving in the remnants of a Nuclear Reactor in Chernobyl, Ukraine. [1] Nicknamed "Hulk bugs" (just like the pulsing, green monster of comic book lore), gamma rays seemed to make these fungi stronger, grow hyphae faster, and they grew in the direction of radioactive particle sources, [2,3] Castelvecchi and his colleagues later noted seeing reports that corroborated initial observations, that the cooling water in some working reactors turns black from colonies of melanin-rich fungi that appear to grow over time in the water. [1] This observation led to Castelevecchi's hypothesis: maybe the fungi were growing thanks to the radiation and NOT in spite of it. [1]

Scientists have since prescribed a name to this phenomenon: radiotropism. Radiotropism is defined as the directed growth of microfungi towards sources of ionizing radiation. But constraining exactly which mechanisms allow these organisms to flourish and thrive in such harsh radioactive environments remains poorly understood. [4]

De-Mystifying the Mysterious

To better make sense of the effects of radiation on fungal species and model radiotropism, scientists have conducted numerous experiments on other, more commonly occurring fungi. Robertson *et al.* studied black yeast (*Wangiella dermatitidis*) subjected to low-dose ionizing radiation. [5] They wanted to deduce the impacts of chronic radiation on the melanin-containing yeast (recall that melanin is the pigment that results in human skin color), as well as melanin-lacking yeast. They discovered that radiation led to increased survivability in the melanin-containing fungi, as they were able to absorb more nutrients and export more toxic metabolites from their cellular systems. The scientists even found that fungi were able to safeguard their DNA and utilize ionizing radiation as energy for DNA repair in some extreme cases. [5] Dadachova *et al.* also noted that while melanin-lacking fungi grew better in non-irradiated environments, this observation quickly reversed in the presence of radiation, with melanin saturated fungi actually increasing rapidly in dry weight in the presence of continual radiation. [3]

This growth can be at least partially explained by melanin's ability to catalyze an oxidative-reduction reaction typical of cell metabolism. [1] According to Dadachova *et al.*, the electron transfer properties of melanin in the NADH oxidation/reduction reaction sequence necessary to supply cellular energy increased 4-fold after prolonged exposure to radiation. [3] Furthermore, even melanin-containing fungi cells subjected to limited nutrient conditions responded by growth when exposed to radiation as compared to their non-melanized cell counterparts. [3]

Conclusion

While radiative effects on fungal cells are only moderately understood, one thing is certain: specific types of melanized fungi are able to respond favorably to increased amounts of radiation, an observation that goes counter to the otherwise, unanimously harsh effects of radiation on living organisms. More research will be needed to confidently explain the consequences of chronic radiation on fungi, but preliminary studies suggest powerful results that could reshape how we think about electron transfer in traditional metabolic pathways and could even help redefine the term "superhero" to more accurately reflect the supernatural organisms that live among us.

References

[1] D. Castelvecchi, "Dark Power: Pigment Seems to Put Radiation to Good Use," Science News **171**, 325 (2007).

[2] J. Dighton, T. Tugay, and N. Zhdanova, "Fungi and Ionizing Radiation from Radionuclides," FEMS Microbiol. Lett. **281**, 109 (2008).

[3] E. Dadachova *et al.* "Ionizing Radiation Changes the Electronic Properties of Melanin and Enhances the Growth of Melanized Fungi," PLoS ONE **2**, e457 (2007).

[4] T. Tugay *et al.* "The Influence of Ionizing Radiation on Spore Germination and Emergent Hyphal Growth Response Reactions of Microfungi." Mycologia **98**, 521 (2006).

[5] K. L. Robertson *et al.* "Adaptation of the Black Yeast Wangiella Dermatitidis to Ionizing Radiation: Molecular and Cellular Mechanisms," PLoS ONE **7**, e48674 (2012).