ARTICLE

Microbial Resistance to Triclosan: A Case Study in Natural Selection

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Charles Darwin's theory of evolution by natural selection is a cornerstone concept in biology (White, 2007). Natural selection is the mechanism of evolution caused by the environmental selection of organisms most fit to reproduce, sometimes explained as "survival of the fittest" (Mader, 2004). An example of evolution by natural selection is the development of bacteria that are resistant to antimicrobial agents as a result of exposure to these agents (Yazdankhah et al., 2006). Antimicrobials kill off susceptible members of a population, but cells that have some resistance from the start or that acquire it later through mutation or gene exchange may survive. These survivors are "best fit" in that particular environment where they proliferate (Levy, 2007).

While acquisition of knowledge of evolution by natural selection is a seminal goal of science education (NABT, 2008), it is difficult for students to observe this phenomenon directly in their own lives. Perhaps the reason for this is that humans have a generation time of about 25 years. It takes 100 years – a period of time beyond the life expectancy of most people – for four generations of progeny to be traced from the original parents (National Oceanic and Atmospheric Administration, 2008). This sharply contrasts with bacteria that have shorter generation times, in some cases as little as 20 minutes (Tortora, Funke & Case, 2010). Theoretically, that means that over 100 years, about 2,500,000 generations of bacterial descendents could be produced from an original cell. This huge reproductive potential makes bacteria especially well-suited for use in the study of natural selection and, as genetic differences accumulate to produce major transformations, to clearly illustrate evolution.

This article describes research on the resistance of wild clonal populations of *Escherichia coli* and *Staphylococcus aureus* to triclosan and the subsequent reversion of these resistant bacteria back to wild-type when triclosan is removed from their environment. These experiments can serve as a practical, timely, and engaging model for the study of natural selection in the biology classroom and can be performed either as a long-term open inquiry (Welden & Hossler, 2003) or as a teacher-guided inquiry.

Background Information

Triclosan (2, 2, 4´-trichloro-2´-hydroxydiphenyl ether) is a broad-spectrum antimicrobial agent that is effective against bacteria (Perencevich et al., 2001), fungi (McMurry et al., 1998), and viruses (Schweizer, 2001). See Figure 1 for a diagram of triclosan.

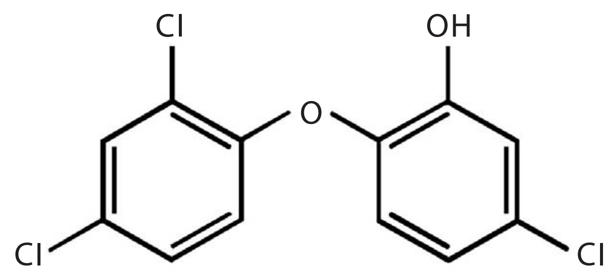

Figure 1. Molecular structure of triclosan.

Invented at Ciba, triclosan is the generic name of the chemical that Ciba sells as Irgasan® (Ciba.com, 2008). Triclosan is also used in plastics and clothing by other manufacturers under the name Microban®, and used in acrylic fibers as Biofresh® (Glaser, 2004). It was introduced as a surgical scrub in 1972, typically at 0.3% bactericidal concentrations, and used primarily to limit the spread of infections in health care settings. Since the mid-1990s, triclosan has been marketed to the general consumer, typically at 0.1% bacteriostatic concentrations, and is now a ubiquitous presence in our lives. Triclosan is used in many personal care products such as toothpaste, shower gels, deodorant soaps, hand lotions and creams, mouthwashes, underarm deodorants, and hand soap. Eighty-four percent of antibacterial bar soaps and 100% of antibacterial liquid soaps contain triclosan. It is also infused into many household items such as cutting boards, counter tops, mops, paint, floor tiles, wallpaper, and even toys (Levy, 2000; Schweizer, 2001).

This practice is not restricted to the U.S., but is a worldwide phenomenon. One billion dollars are spent annually on antimicrobial household products (Glaser, 2004) and the rate is rising at 3-7% per year (Jagger, 2008). Concerns about the Influenza A virus subtype H1N1 during 2009 heightened the importance of hand washing to infection control (CDC, 2009) and will likely contribute to even greater use of antimicrobial products.

An example of evolution by natural selection is in development of bacteria that are resistant to antimicrobial agents as a result of exposure to these agents.

While it is promoted as an antimicrobial agent (i.e., a substance toxic to bacteria, fungi and protists, and viruses), there is no evidence that the use