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Predicting Parasitic Virulence through a Synthesis  
of Spatial and Temporal Factors

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Abstract

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Why do some parasites kill the host they depend on while others coexist with their host? Two prime factors determine parasitic virulence: the manner in which the parasite is transmitted and the evolutionary history of the parasite and its host. Parasites that are transmitted horizontally tend to be more virulent than those transmitted vertically. Parasites that colonize a new host species tend to be more virulent than parasites that have coevolved with their hosts. It used to be assumed that parasite-host interactions inevitably evolve toward lower virulence, but this assumption has been contradicted by studies showing conservation of or increase in virulence over time. The modulation of virulence in parasite-host systems can be predicted by using a model that synthesizes spatial (transmission) and temporal (evolutionary) factors.

Introduction

Why do certain parasites exhibit high levels of virulence within their host populations while others exhibit low virulence? The two prime factors most frequently cited<sup>1,2</sup> are evolutionary history and mode of transmission. Incongruently evolved parasite-host associations are characterized by high virulence, while congruent evolution may result in reduced virulence<sup>2</sup>. Parasites

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transmitted vertically (from parent to offspring) tend to be less virulent than parasites transmitted horizontally (between unrelated individuals of the same or different species). Studies that show an increase in virulence during parasite-host interaction, such as Ebert's experiment<sup>3</sup> with *Daphnia magna*, necessitate a synthesis of traditionally discrete factors to predict a coevolutionary outcome. Changes in virulence during parasite-host interaction are better described as modulation than as increase or decrease, because the word *modulation* implies the potential for an inclusive, predictive paradigm for parasite-host interaction.

Scientific terms may be italicized or underlined

#### Methods

Evolutionary history and mode of transmission will first be considered separately in this paper and then integrated by means of an equation discussed by Antia, Levin, and May<sup>4</sup> and a model proposed by Childs, Mills, and Glass<sup>5</sup>. Transmission is defined by host density and specific qualities of host-parasite interaction. It is a spatial factor that gives direction to the modulation of virulence. Evolution is a temporal factor that determines the extent of the modulation. The selective equilibrium model gives it great potential for accurate predictability of a broad range of parasite-host interactions.

#### Conclusion

Traditional assumptions about the factors determining parasitic strategy have been largely apocryphal, ignoring contradictory evidence<sup>1</sup>. Equilibrium models synthesize the temporal (i.e., evolutionary) factors and the spatial (i.e., transmission) factors characteristic of parasite-host systems. Time

is required to modulate virulence, and spatial factors, such as host density and transmission strategy, determine the direction of the modulation.

The development of an inclusive, accurate model has significance beyond theoretical biology, given the threat to human populations posed by pathogens such as HIV<sup>10</sup>. Mass extinctions, such as the Cretaceous event, may have resulted from parasite-host interaction<sup>21</sup>, and sexual reproduction (i.e., recombination of genes during meiosis) may have evolved to increase resistance to parasites<sup>22</sup>. Parasitism constitutes an immense, if not universal, influence on the evolution of life, with far-reaching paleological and phylogenetic implications. A model that synthesizes the key factors determining parasitic virulence and can predict the entire range of evolutionary outcomes is crucial to our understanding of the history and future of species interaction.

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