Trade-offs and the evolution of age-specific resistance to infectious disease

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Background

Many organisms across taxa experience changes in their disease resistance as they age. Adults may be more resistant than juveniles, or vice versa. Acquired immunity, physiological constraints and age-related virulence all contribute towards, but cannot fully explain, differences between juvenile and adult resistance.

Here we explore how trade-offs with other life-history traits shape the evolution of age-specific resistance.

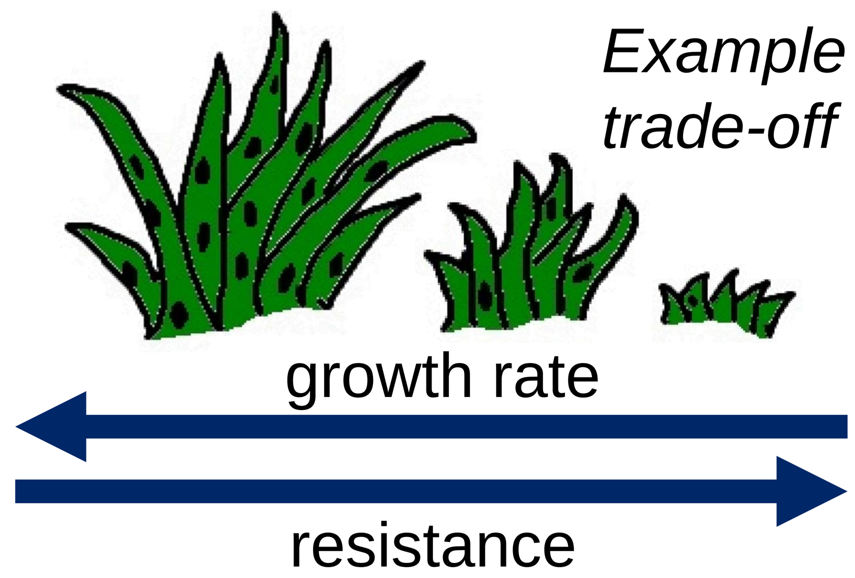
Image 1: The crustacean Daphnia Magna is more resistant to bacterial infections as a juvenile than as an adult (Garbutt *et al.* 2014)

Image 2: The leaf-cutting ant has higher disease resistance as an adult than as a juvenile (Armitage & Boomsma 2010)

Trade-offs

Higher levels of resistance often incur a fitness cost to other life-history traits. For example, investing in resistance may require resources to be allocated away from reproduction or growth and development, which may in turn impact on mortality.

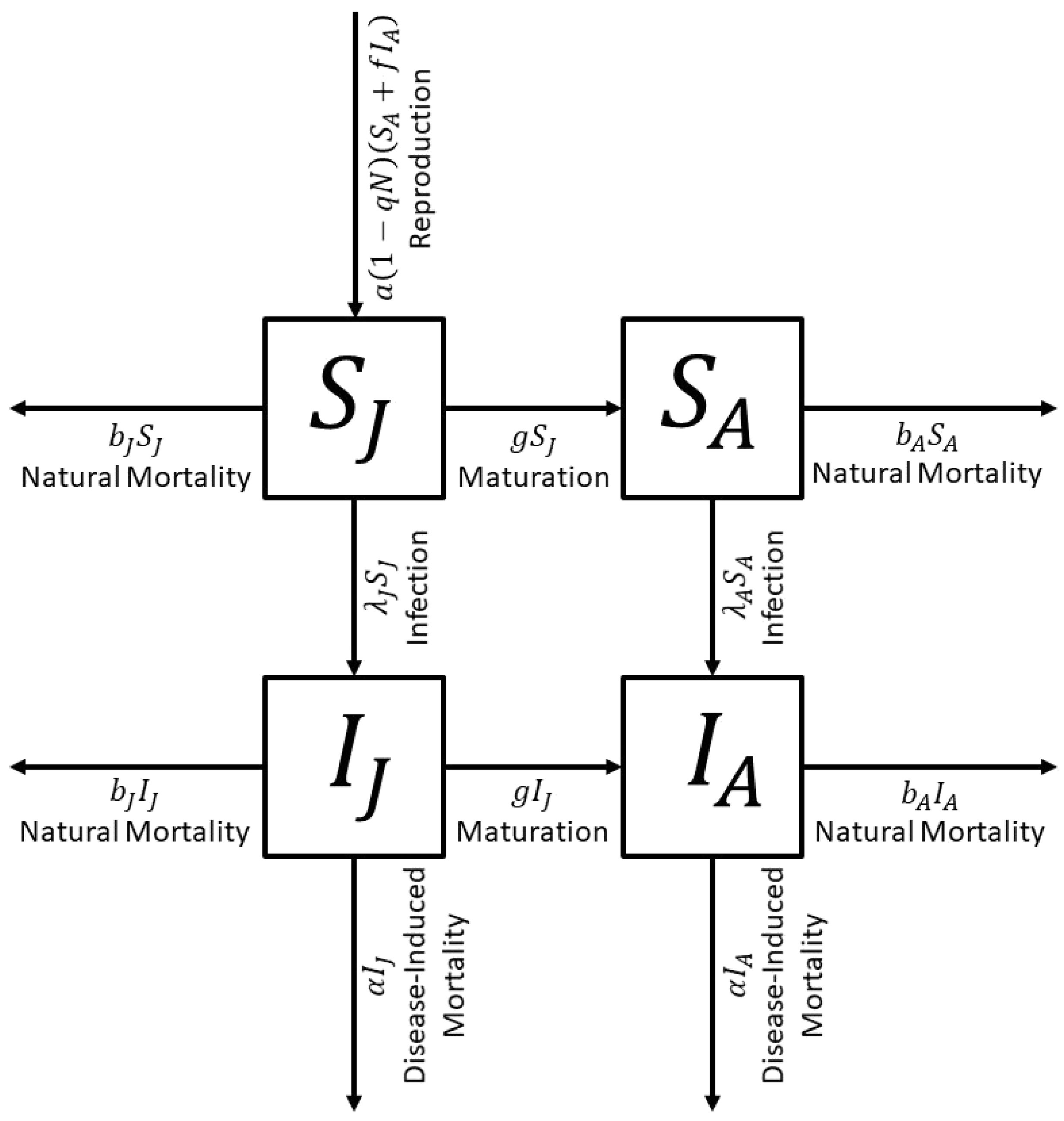
Theoretical models usually incorporate only one type of trade-off. Here, we determine whether certain trade-offs are inherently more costly than others (all else being equal) and so whether different trade-offs could generate different age-specific patterns of disease resistance in populations of juveniles and adults.



The Model

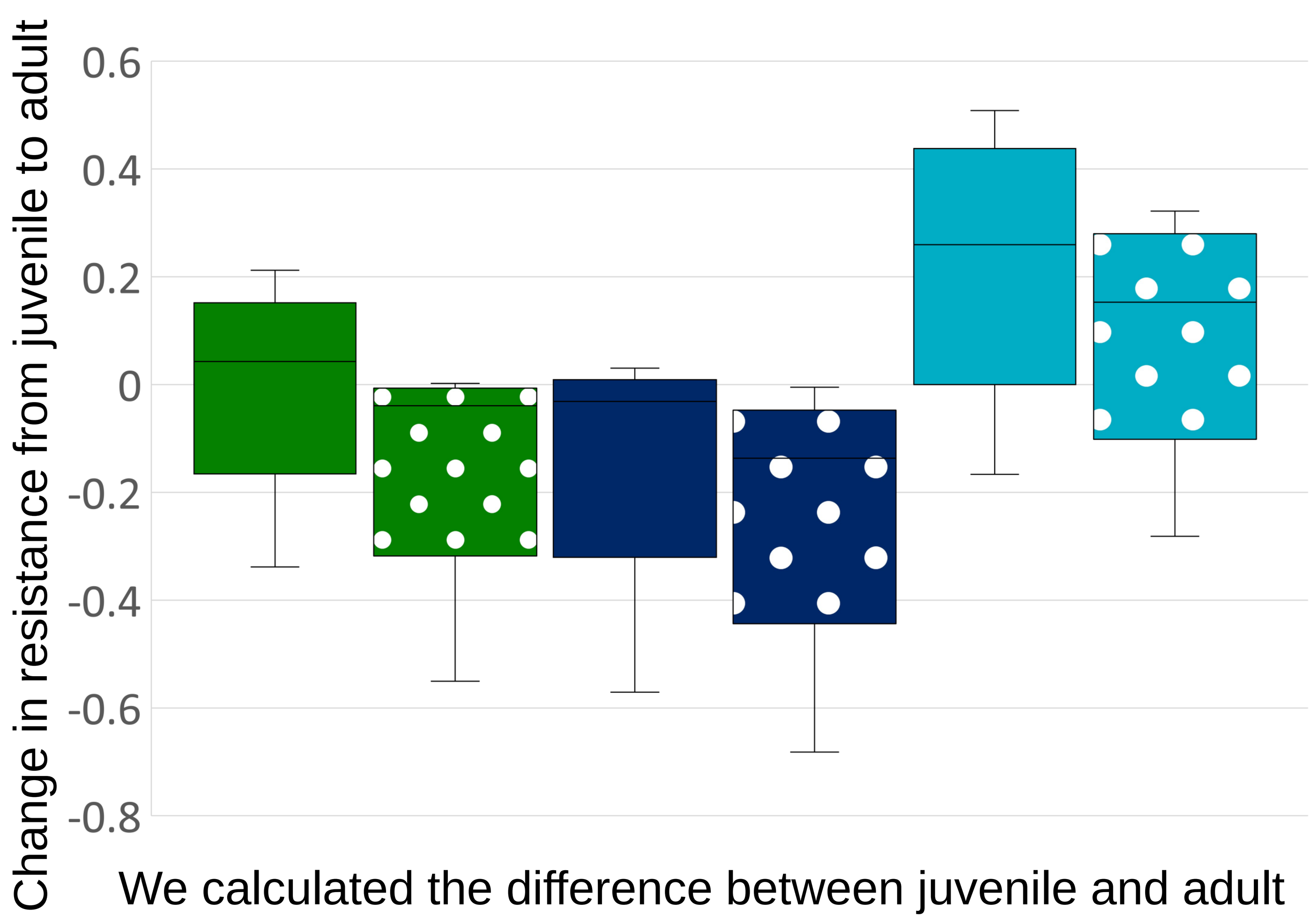
We modelled the coevolution of juvenile ($k = J$) and adult ($k = A$) resistance, r_k, in a well-mixed population of susceptible (S_k) and infected (I_k) hosts, where the force of infection is $\lambda_i \propto (1 - r_i)(I_J + I_A)$.

Using evolutionary invasion analysis, we determined how trade-offs between juvenile resistance and maturation (g), reproduction (a) or mortality (b_J), and between adult resistance and reproduction (a) or mortality (b_A) affected the evolution of resistance across the host lifespan.



Results

All else being equal, we found that juvenile resistance evolved to exceed adult resistance in the majority of cases when juvenile resistance traded off with maturation or mortality. However, the opposite was true when juvenile resistance traded off with reproduction. This result was robust to variation in a wide range of model parameters, suggesting that this trade-off is inherently more costly than others.



We calculated the difference between juvenile and adult resistance for each of our six combinations of trade-offs, over a wide range of parameter sets. The distributions of these differences are shown in the box plots.

- Juvenile resistance trade-off with maturation rate
- Juvenile resistance trade-off with mortality rate
- Juvenile resistance trade-off with reproduction rate
- Adult resistance trade-off with mortality rate
- Adult resistance trade-off with reproduction rate

Conclusion

Trade-offs between juvenile resistance and adult reproduction are inherently more costly than other trade-offs (e.g. with maturation or mortality). Differences in the types of trade-offs present may therefore help to explain why there is variation in whether juveniles or adults are more susceptible to infection.

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References

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2. Armitage SAO & Boomsma JJ. (2010) *J. Ins. Phys.* 56 pp780-787