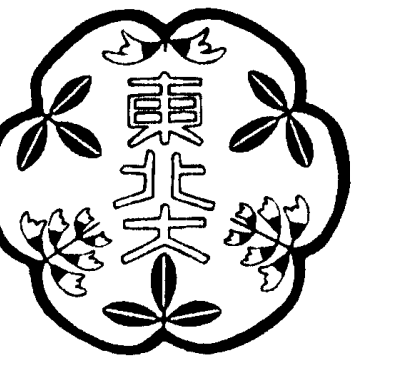




Information Threshold and Compartmentalization: limited diffusibility and small population size counteract group selection



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Introduction

Compartmentalization[1] (group selection) has been proposed as a solution for information (error) threshold[2]. However compartmentalization imposes limited diffusibility[3] and small population size[4], and both are known to decrease the amount of information which can be kept in a system. In this study, we examine the effect of compartmentalization on the amount of information which can be maintained in a single replicator species.

Conclusions

- (1) If no extra functions in master sequences are assumed, group selection can not compensate limited diffusibility.
- (2) The time scale difference between vesicle dynamics and replicator dynamics diminishes group selection.
- (3) Spatial pattern formation on the vesicle level further decreases error threshold.

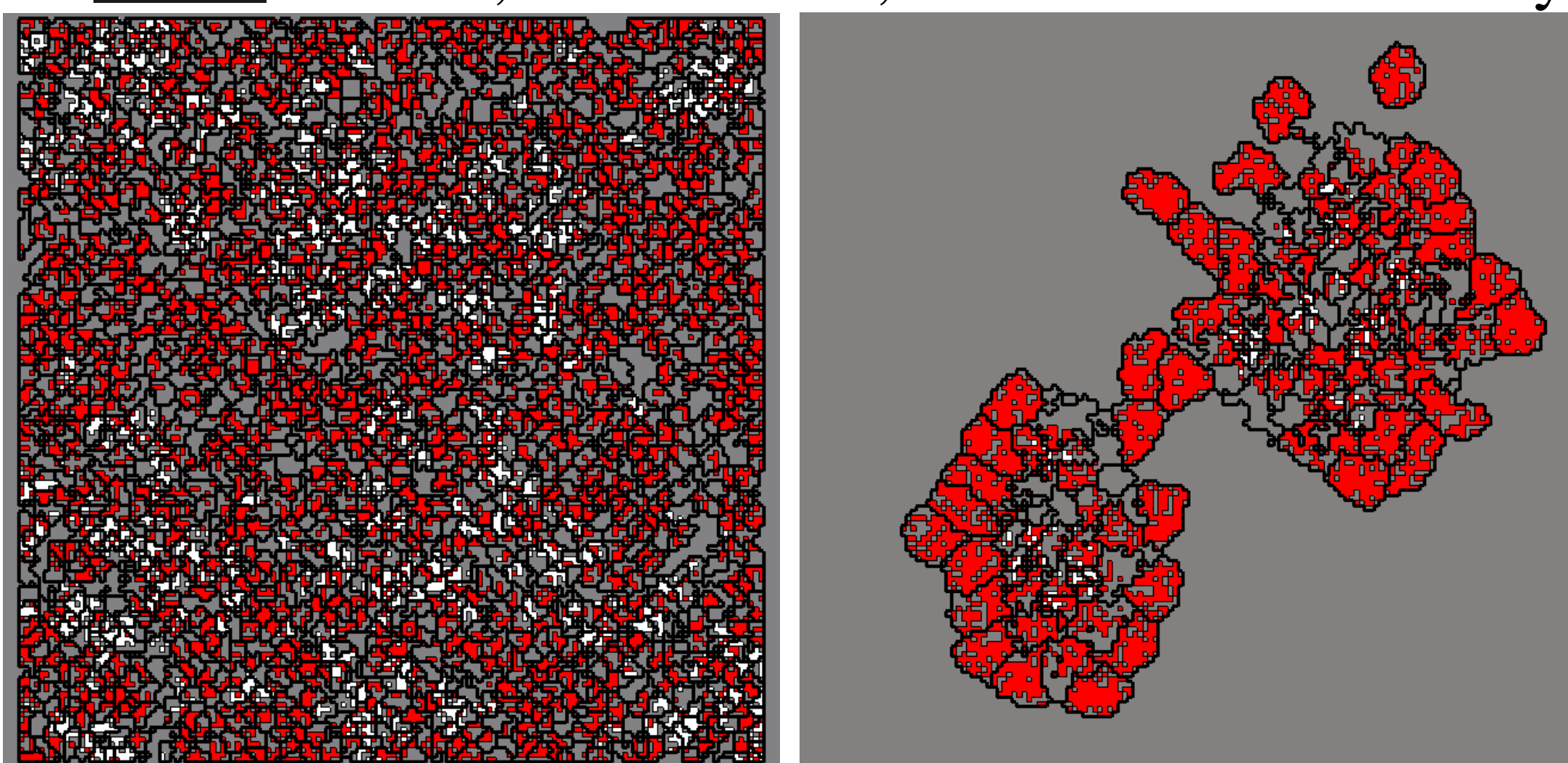
Model

- (1) Replicator model: CA, master sequence and mutants
- (2) Vesicle (compartment) model: Glazier Graner cell sorting model or Cellular Potts Model[5]

$$\mathcal{H} = \sum J + \lambda(v - V_{\text{target}})^2$$

Screen shot of models

white: master; **red**: mutants; **black**: vesicle boundary.



Neutral model

Step division model

- Birth: vesicles divide when the # of replicators reaches a threshold value (DIVPOP).
- Death: vesicles are taken out by chance (Death rate).
- We compare 3 models, changing the functions of replicators on vesicle level:
 - (1) Neutral: no functional difference in replicators.
 - (2) Step mortality: without master sequences, vesicles die.
 - (3) Step division: vesicles divide when # of master sequences exceeds a threshold.

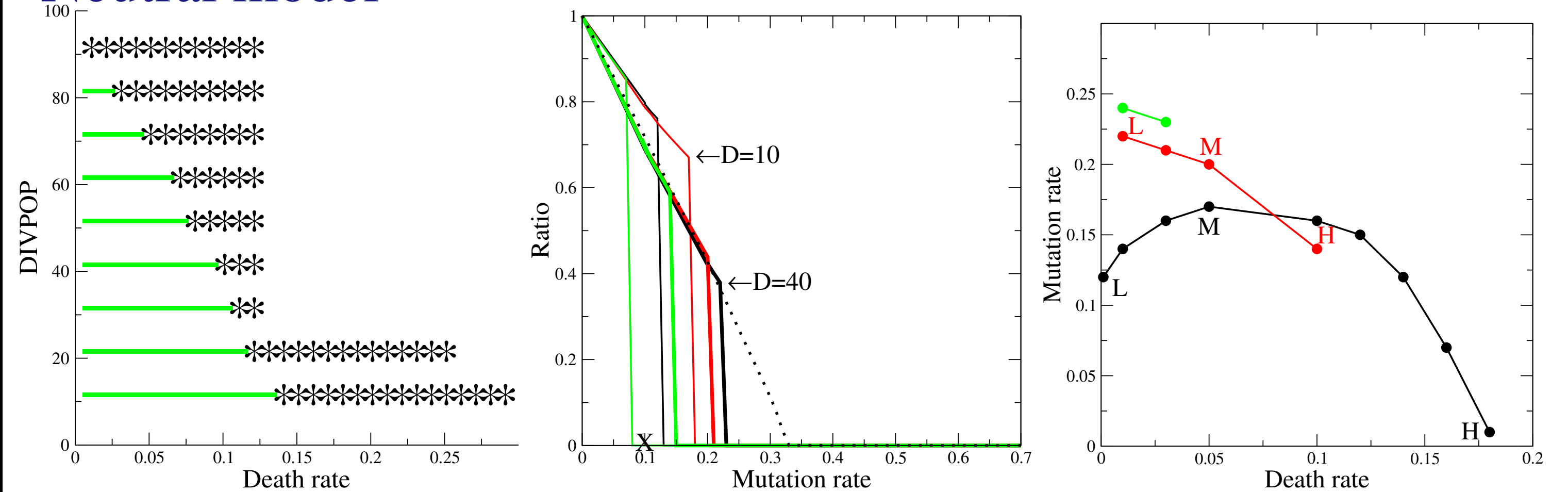
References

- [1] M Eigen & P Schuster The Hypercycle - A Principle of Natural Self-Organization (Springer-Verlag 1979)
 - [2] E Szathmary & L Demeter, J Theor Biol **128** 463 (1987)
 - [3] M Nowak & P Schuster, J Theor Biol **137** 375 (1989)
 - [4] S Altmeyer & JS McCaskill, Phys Rev Lett **86** 5819 (2001)
 - [5] J Glazer & F Graner, Phys Rev Lett **69** 2013 (1992)
- The article on this study is in press: P Hogeweg and N Takeuchi, "Multilevel selection in models of prebiotic evolution: compartments and spatial self-organization", Orig Life Evol Biosph, a special issue on theoretical models of prebiotic evolution, ed. E Szathmary (2003)

Results

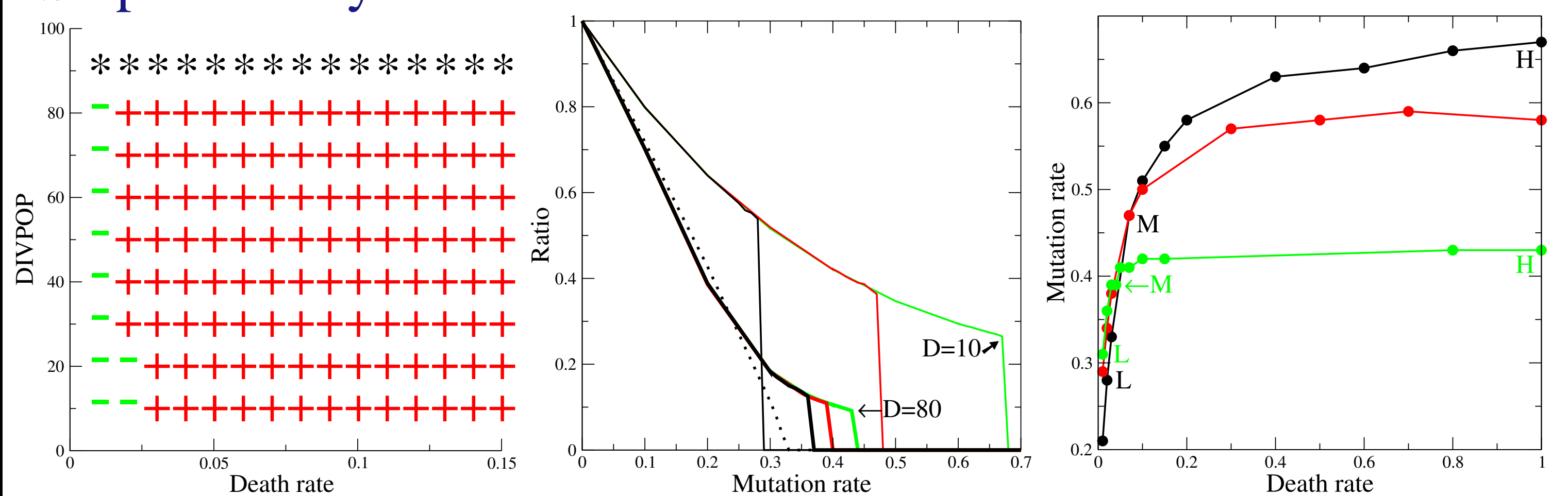
- **Parameter space plot**
 - +: error threshold increases
 - : decrease
 - *: a system collapses
- **Quality of vesicles**
 - black: low death rate
 - red: middle death rate
 - green: high death rate
 - · ·: reference (without vesicles)
- **Error threshold**
 - black: low DIVPOP
 - red: middle DIVPOP
 - green: high DIVPOP

Neutral model



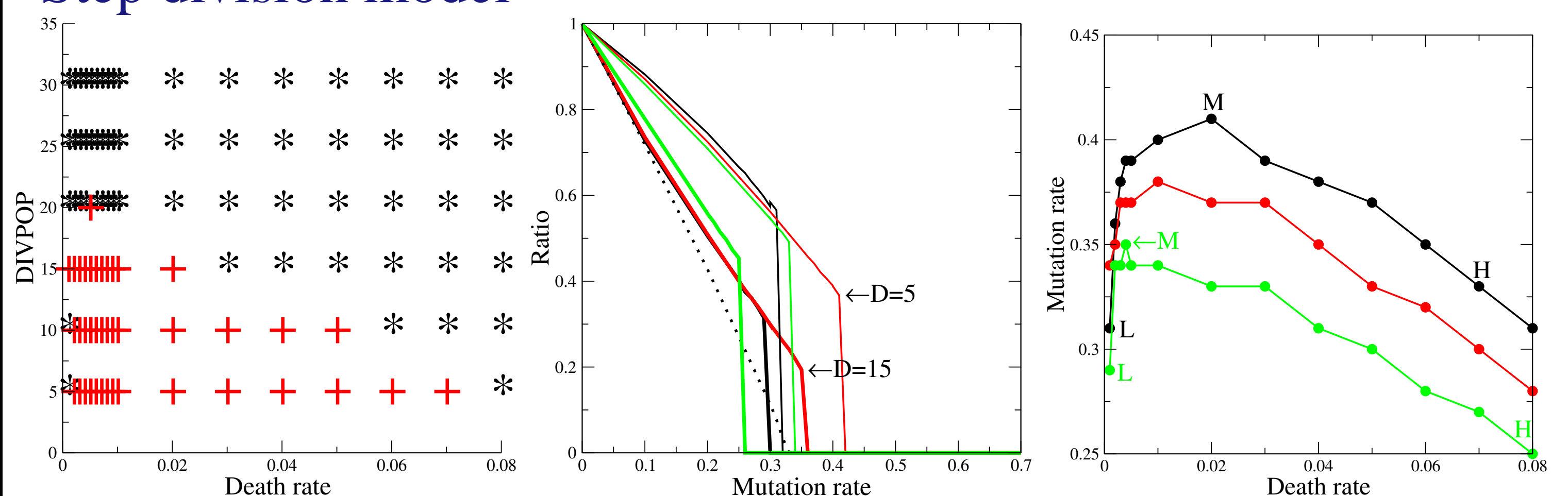
Limited diffusibility dominates group selection: (1) **vesicles decrease error threshold**; (2) quality is still high at error threshold; (3) large DIVPOP vesicles have a higher error threshold. (4) Middle death rate gives max. error threshold.

Step mortality model



Group selection dominates limited diffusibility: (1) vesicles can increase error threshold very much. (2) small vesicles have a higher error threshold. (3) However, note that at a small death rate, large vesicles are better.

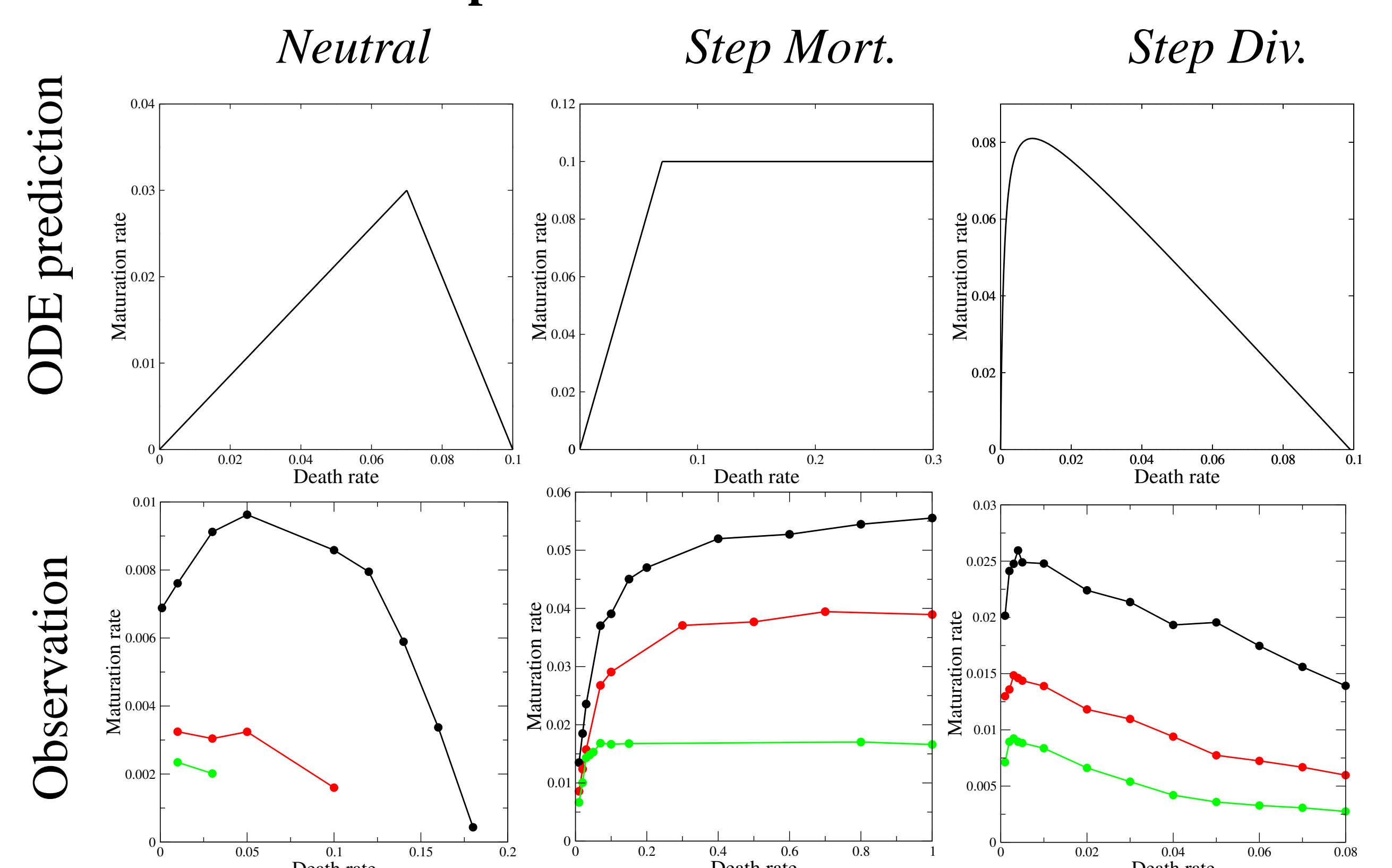
Step division model



A purely vesicle level discrimination in replicators shows a limited increase in error threshold.

Vesicle dynamics

- **Maturation rate comparison: the models & models of the models**



- Vesicle dynamics imitated by ODE

$$\frac{dX}{dt} = G(1 - M)X(1 - X - Y) - \mu X - DX$$

$$\frac{dY}{dt} = gY(1 - Y - X) + \mu X + GMX(1 - X - Y) - DY$$

color: DIVPOP;
 black: low;
 red: middle;
 green: high.