Evolution with migration and mixed methods of reproduction

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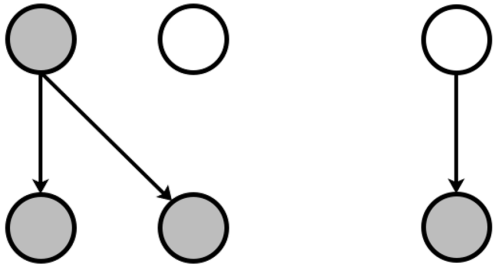
An equation for evolution

- **The Price equation (Price, 1970)** describes total evolutionary change in one time step ($\bar{w}\Delta\bar{z}$) as the sum of natural selection and transmission alone:

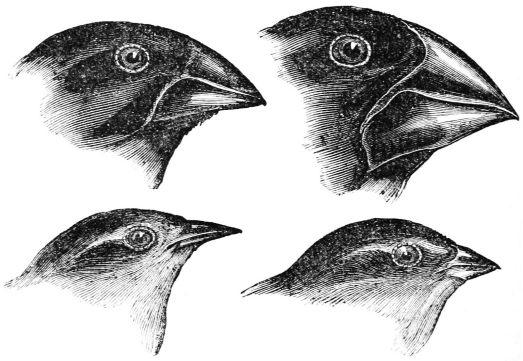
$$\bar{w}\Delta\bar{z} = \mathrm{Cov}(w_i, z_i) + \mathrm{E}(w_i\Delta z_i)$$

Natural Selection Transmission



- The entities (circles above) can be anything: **genes, cells, individuals, social groups, species etc.** Arrows represent parent → offspring connections.

Notation: w_i is individual fitness (≈ number of offspring), z_i is individual trait value (shaded/unshaded), overbars represent population averages.



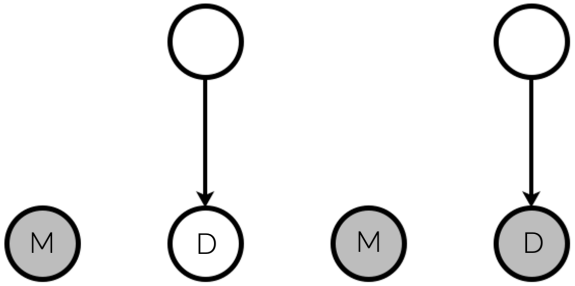
Results

- Migration and mixes of asexual and sexual reproduction are **not accounted for** by the original Price equation (directly).
- We derived a **generalised Price equation** incorporating both of the above phenomena:

$$\bar{w}\Delta\bar{z} = \mathrm{Cov}(w_i, z_i) + \mathrm{E}(w_i\Delta z_i) - \frac{n_d}{n_a}\mathrm{Cov}(c_j, z_j)$$

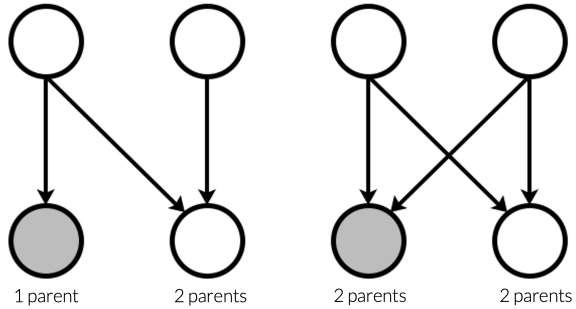
Notation: c_j is a measure of how many parents a descendant has relative to siblings. For migrants, $c_j = 0$. n_d and n_a are the sizes of ancestral and descendant populations respectively. $\mathrm{Cov}(c_j, z_j)$ is connectedness bias — is there a relationship between the relative number of ancestors you have and your trait value?

Migration (1) Migration (2)



- **Migration (1)** cannot be accounted for by the original Price equation. M's distinct trait value is invisible to natural selection and transmission. $\mathrm{Cov}(c_j, z_j) \neq 0$.
- **Migration (2)** can be accounted for by the original Price equation. Since M looks like D, transmission alone accurately models the situation. $\mathrm{Cov}(c_j, z_j) = 0$.

Mixed Sexual



- **Mixed reproduction** cannot be accounted for by the original Price equation; Transmission alone *undercalculates* overall change. $\mathrm{Cov}(c_j, z_j) < 0$.
- **Uniform sexual reproduction** can be accounted for by the original Price equation; $\mathrm{Cov}(c_j, z_j) = 0$.

Applications

- Explaining the **evolution of altruism** *including migration* via a new version of Hamilton's rule: $rb - (m + c) > 0$
- We also began looking at an overlapping generations model for the **evolution of menopause**.
- Investigating the **origins of sexual reproduction**.

Experience

During my time as a vacation scholar, I not only learnt how to conduct (applied maths) research but also amplified my passion for both mathematics and biology; I am more eager than ever to pursue a career in theoretical biology. On top of that, I finally learnt how to use LaTeX and improved my Python programming skills by making a GUI to visualise the Price equation. I will continue working on the project with Jared to investigate some of the applications mentioned above.

References

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