Coevolution II

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Problems

- Coevolutionary arms races are supposed to *escalate* to increasing levels of sophistication… but sometimes that doesn't happen:
  - Stagnation: populations reach a poised state in which there is a turnover of individuals in the population but no phenotypic progress
  - Cycling: populations repeatedly cycle through the same weak strategies as if they were playing a game of scissors-paper-stone (the Red Queen)
  - Disengagement: every host is beaten by every parasite, all selection pressure is extinguished and coevolution effectively ceases (see Lab 2)
  - Measuring Progress: without a fitness function it can be difficult to assess whether genuine progress is being made by coevolving populations.

Diversity

- To a large extent the problems with coevolution are familiar:
  - Our old foe: the loss of genetic and phenotypic diversity
- How can we stop the populations from converging and becoming vulnerable to stagnation, cycling, disengagement?
- Three different ideas:
  - Population structure
  - Fitness sharing
  - Reduced virulence

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Population Structure

- The natural world is not randomly mixed up like an evolving soup.
- Populations are structured such that not every organism can interact with or compete directly with every other organism
- This is why island ecologies can be so distinctive and interesting
- GAs can do something similar
  - split populations into quasi-isolated sub-populations called ‘demes’
  - spread a population over a space and only allow local interactions

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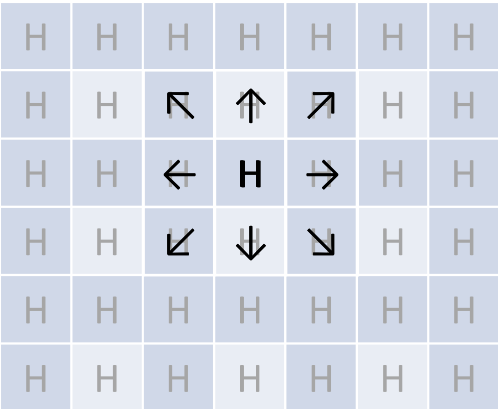
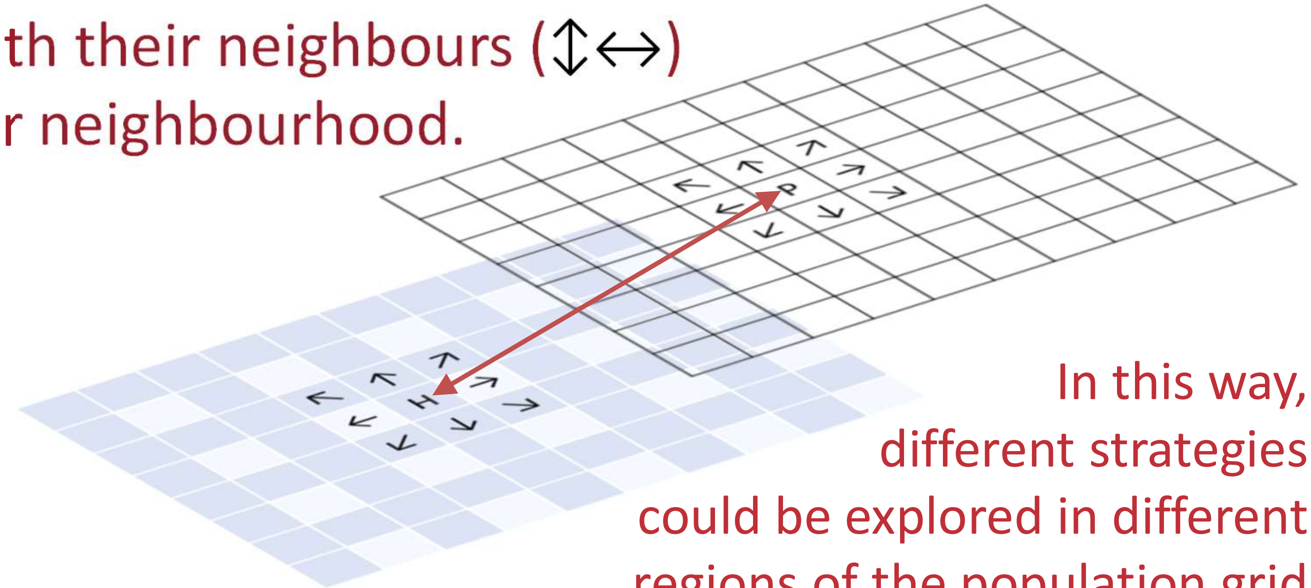
Population Structure

- Hillis employed this idea in his list sorting work:
  - Each host was placed on a grid. Parasites were placed in a different grid.
  - Each host played the parasite at the same location in the other grid (⟷)
  - Individuals competed with their neighbours (↕↔) to leave offspring in their neighbourhood.

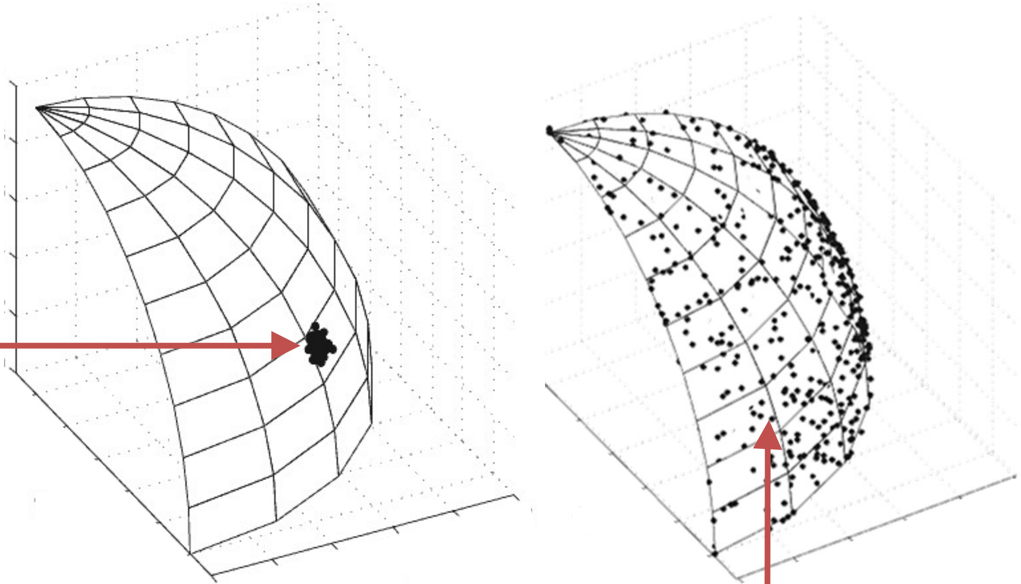




In this way, different strategies could be explored in different regions of the population grid

Fitness Sharing

- A more deliberate way of maintaining diversity is to punish solutions that are similar to other solutions in the population:
  - Define a similarity measure (e.g., genetic hamming distance < threshold)
  - If solution *i* is similar to *n* others:
    - $f'_i = f_i / \sum_{j=1}^{j=n} \mathrm{sim}(i,j)$
  - Now, instead of converging on one region of this manifold of equally fit solutions…
    - …fitness sharing pushes solutions to spread out



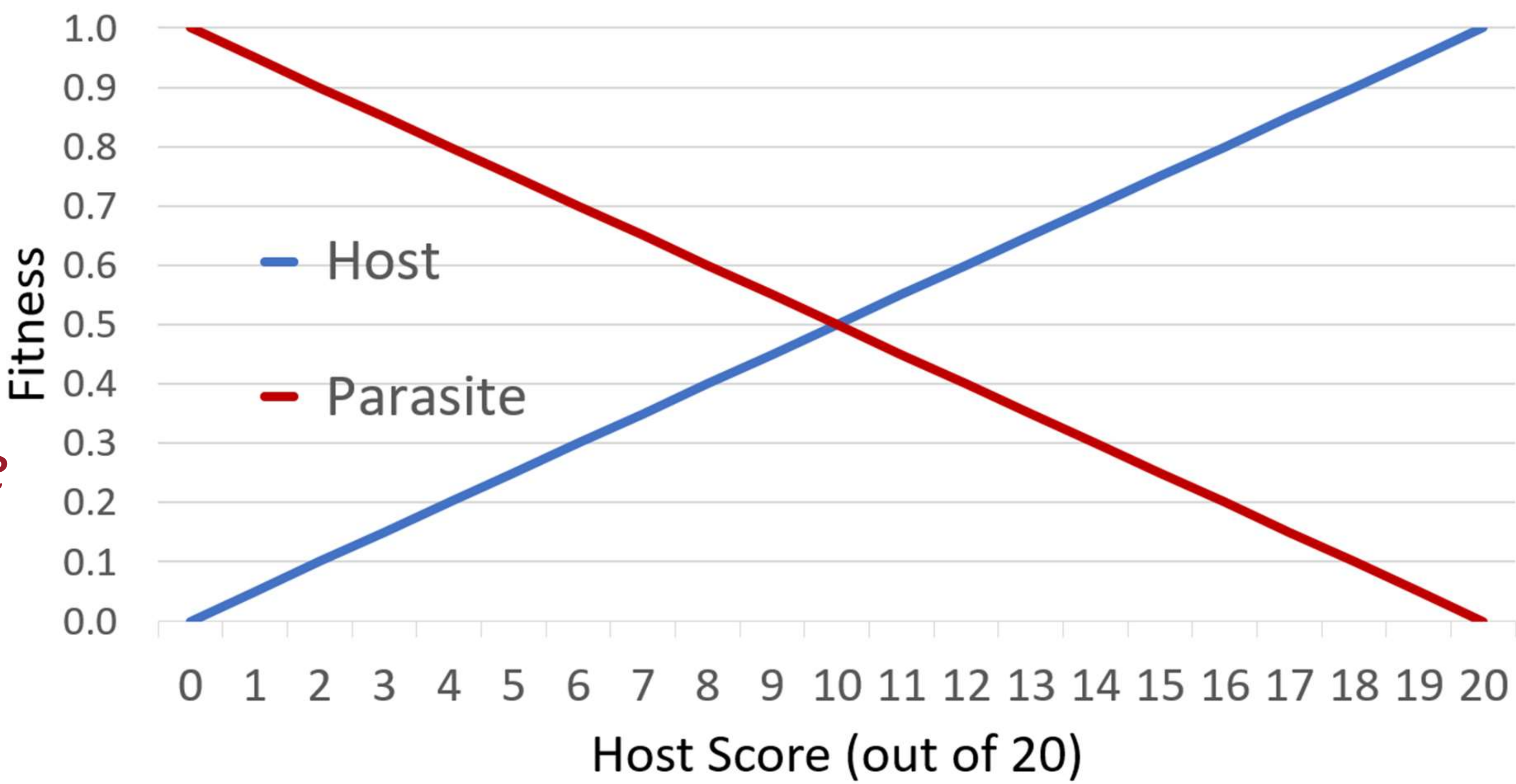
Reduced Virulence

- Natural parasites / viruses often reduce their *virulence* over time
  - …it's not in their interest to kill their host quickly.
  - Consider the common cold or a tapeworm vs. extremely virulent Ebola
- But parasites in a coevolutionary GA are often rewarded for being *maximally damaging* to the hosts that they are assessed against…
- Our initial random robot goalkeepers won't benefit from facing penalty takers that smack the ball into the top corner every time.
- It would be better to start off with shots that are easy to save, and then get gradually harder…

(Normal) Maximal Virulence

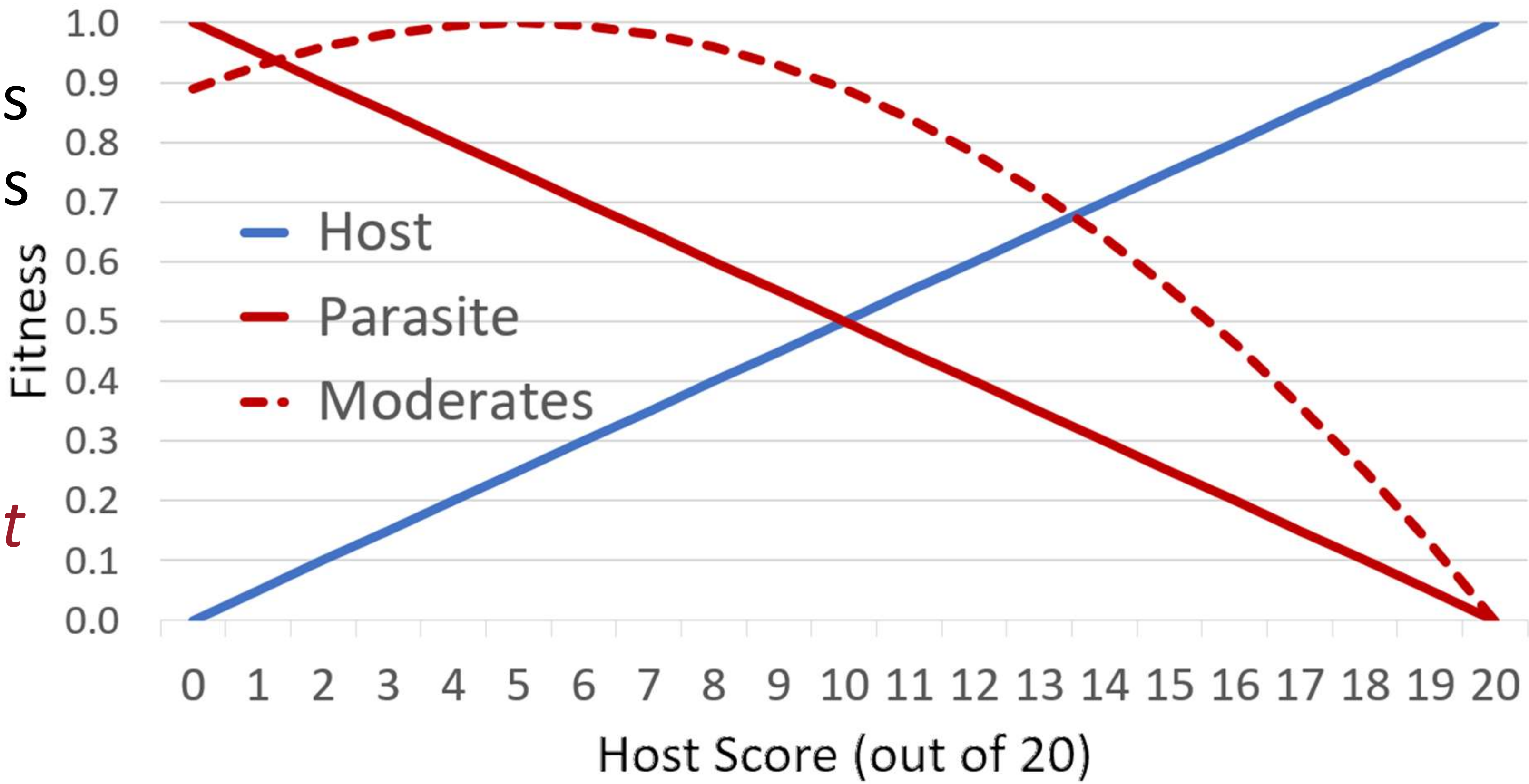
Normally, when a parasite plays against a host:

- If the *Host* scores x …
- … the *Parasite* scores $1-x$



Reduced Virulence

A 'moderate virulence' fitness function rewards parasites most for defeating hosts *most of the time, but not all of the time*…



Coevolution

- More on these ideas in this weeks’ GA Lab
- Ahead of the lab, please take a look at
  - Cartlidge, J. & Bullock, S. (2004). Combating coevolutionary disengagement by reducing parasite virulence. *Evolutionary Computation*, **12**(2), 193-222.
  - This lays out the details of the virulence idea, and introduces a simple game that we will be using to explore it.
  - It’s a long paper, so don’t feel you need to deep read all of it. ☺
    - Just focus on sections 1-4 (15 pages)

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Free Lunches?

- Recall Wolpert & Macready’s (1995) No Free Lunch theorem
  - No search alg. can do better than random across *all* problems.
- More recently, in 2005, the same authors claim that *coevolutionary* free lunches are possible…
  - By using a separate (non-random) population to steer its search, a search algorithm may be able to always rule out some bad solutions, and thus out-perform random search…
- Check this stack exchange post for some intuitions…

Example Questions

- Give an example of coevolution from nature. *[1 mark]*
- Name 3 problems that beset coevolutionary GAs. *[2 marks]*
- Why did Hillis embed his populations on a grid? *[4 marks]*
- What is premature convergence in a GA population. How do coevolutionary GAs hope to avoid it? *[4 marks]*
- Explain why a coevolutionary GA might cycle through the same poor solutions over and over again, rather than finding a better general purpose solution. *[6 marks]*

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Thank you!