Can Learning Guide Evolution?

- "Baldwin Effect":
  - proposed independently in 1890s by Baldwin, Poulton, C. Lloyd Morgan
  - spread of genetic predispositions to acquire certain knowledge/skills
- Gene-culture coevolution
- Special case of *niche construction*: organisms shape the environments in which they evolve
- Also involves *extragenetic inheritance*
- Indirect causal paths from individual adaptation to genome

Evolution in Broad Sense

- Evolution in the broadest terms:
  - blind variation
  - selective retention
- Has been applied to nonbiological evolution
  - evolutionary epistemology
  - creativity
  - memes

Genetic Algorithms

- Developed by John Holland in ‘60s
- Did not become popular until late ‘80s
- A simplified model of genetics and evolution by natural selection
- Most widely applied to optimization problems (maximize “fitness”)

Assumptions

- Existence of fitness function to quantify merit of potential solutions
  - this “fitness” is what the GA will maximize
- A mapping from bit-strings to potential solutions
  - best if each possible string generates a legal potential solution
  - choice of mapping is important
  - can use strings over other finite alphabets

Outline of Simplified GA

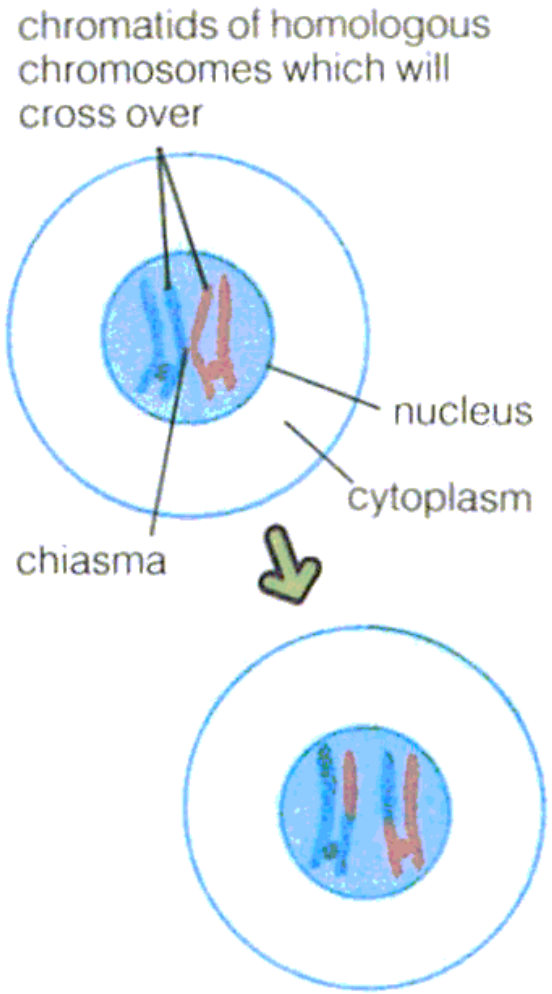
1. Random initial population $P(0)$
2. Repeat for $t = 0, \ldots, t_{max}$ or until converges:
   a) create empty population $P(t + 1)$
   b) repeat until $P(t + 1)$ is full:
      1) select two individuals from $P(t)$ based on fitness
      2) optionally mate & replace with offspring
      3) optionally mutate offspring
      4) add two individuals to $P(t + 1)$

Fitness-Biased Selection

- Want the more "fit" to be more likely to reproduce
  - always selecting the best
    ⇒ premature convergence
  - probabilistic selection ⇒ better exploration
- Roulette-wheel selection: probability relative fitness:

$$\Pr\{i \text{ mates}\} = \frac{f_i}{\sum_{j=1}^{n} f_j}$$

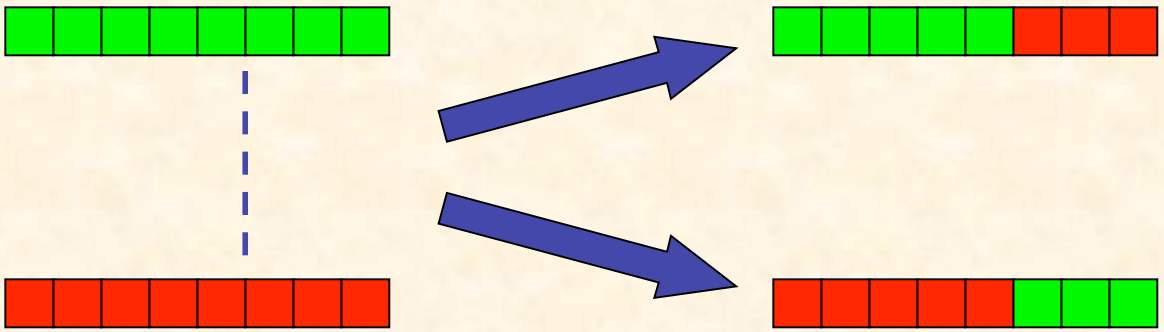
Crossover: Biological Inspiration



- Occurs during meiosis, when haploid gametes are formed
- Randomly mixes genes from two parents
- Creates genetic variation in gametes

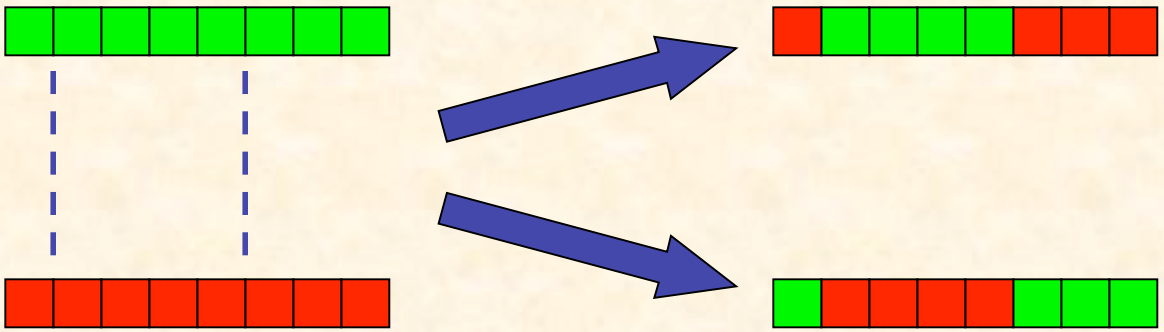
(fig. from *B&N Thes. Biol.*)

GAs: One-point Crossover



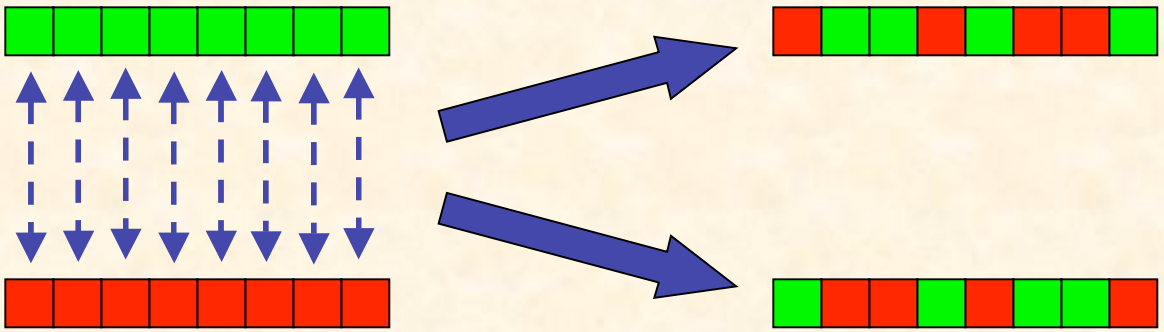
parents offspring

GAs: Two-point Crossover



parents offspring

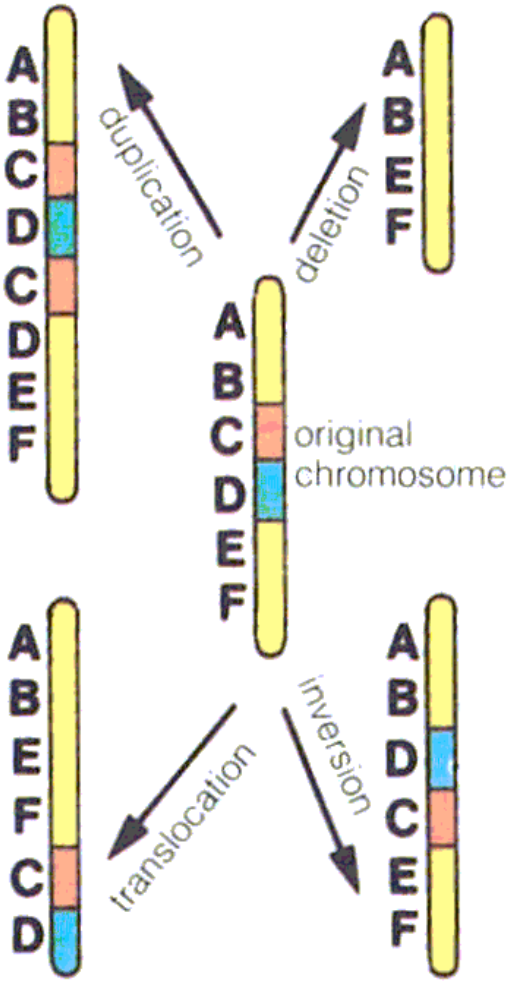
GAs: *N*-point Crossover



parents offspring

Mutation: Biological Inspiration

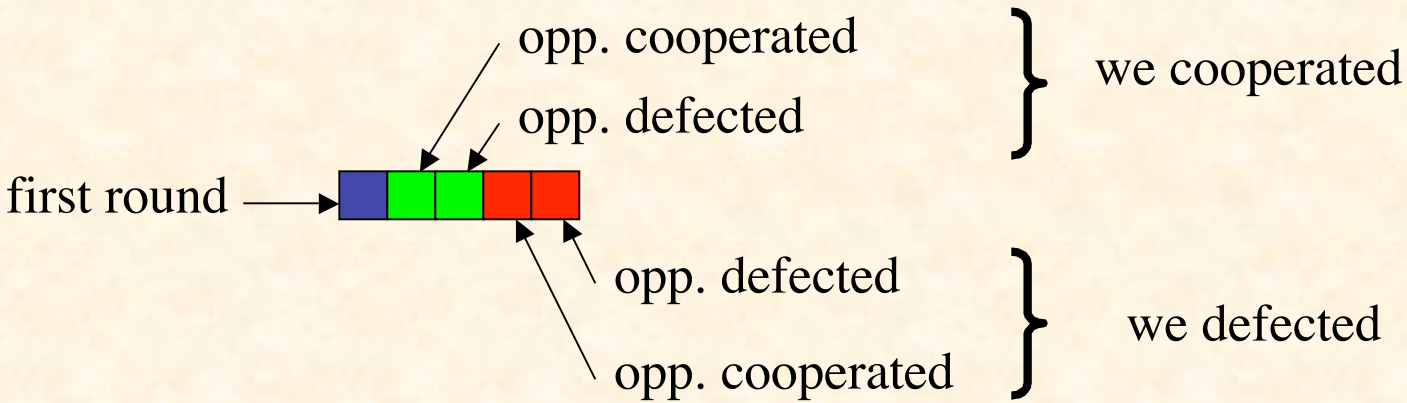
- Chromosome mutation
- Gene mutation: alteration of the DNA in a gene
  - inspiration for mutation in GAs
- In typical GA each bit has a low probability of changing
- Some GAs models rearrange bits



(fig. from *B&N Thes. Biol.*)

Example: GA for IPD

- Genetic strings encode strategy
  - for first round
  - based on self's & opponent's action on *r* previous rounds
  - hence $2^{2r} + 1$ bits
- E.g., for $r = 1$:



Typical Result

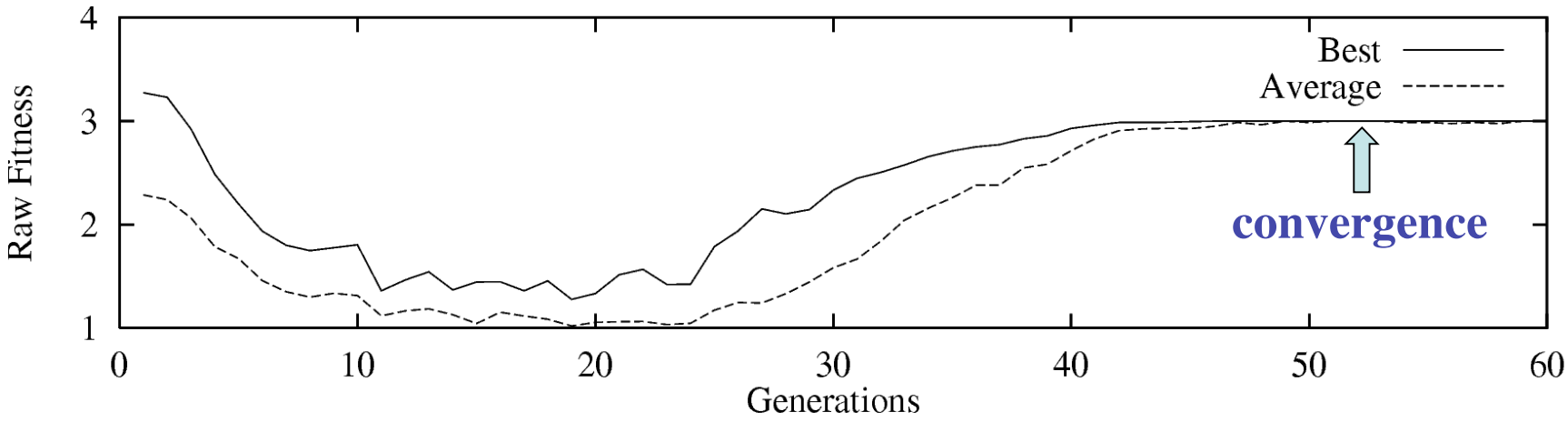
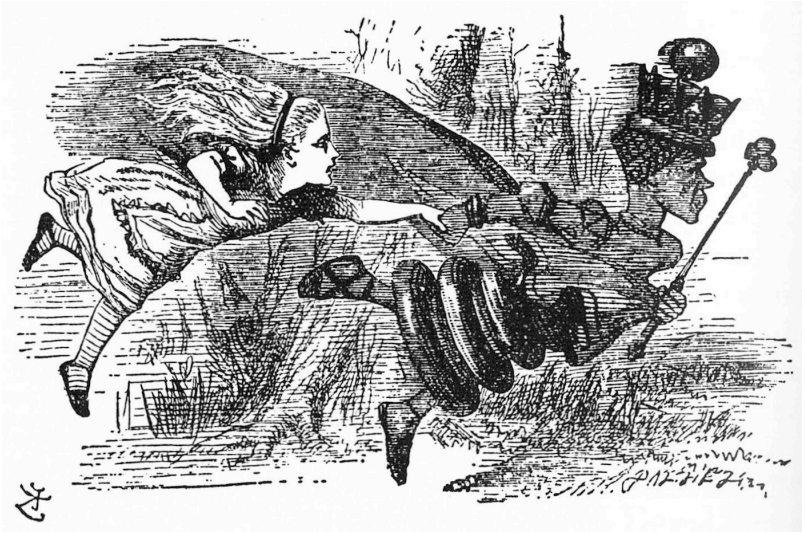


Figure 20.4 Average and best raw fitness scores for the IPD-playing GA

The Red Queen Hypothesis



"Now, *here*, you see, it takes all the running *you* can do, to keep in the same place."

— *Through the Looking-Glass and What Alice Found There*

- *Observation*: a species probability of extinction is independent of time it has existed
- *Hypothesis*: species continually adapt to each other
- Extinction occurs with insufficient variability for further adaptation