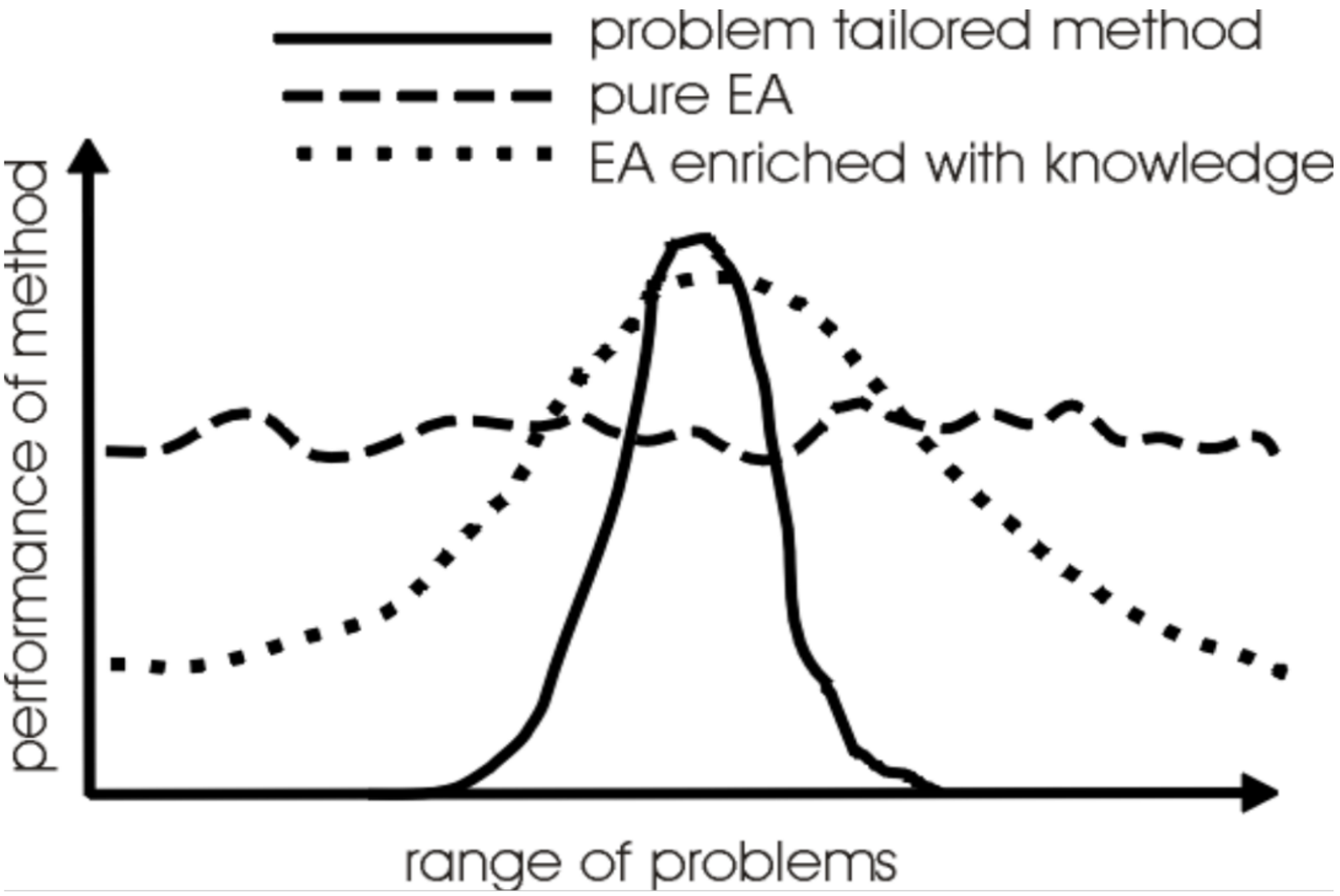
24: Memetic Algorithms

- Hybridization
- Memetic algorithms
- Local search
- Adaptive memetic algorithms
- Textbook Chapter 10

Motivation

- Need to put in EA as part of a larger system
- Need to improve on existing techniques but not re-invent wheel
- Need to improve EA search for good solutions

Why hybridize?



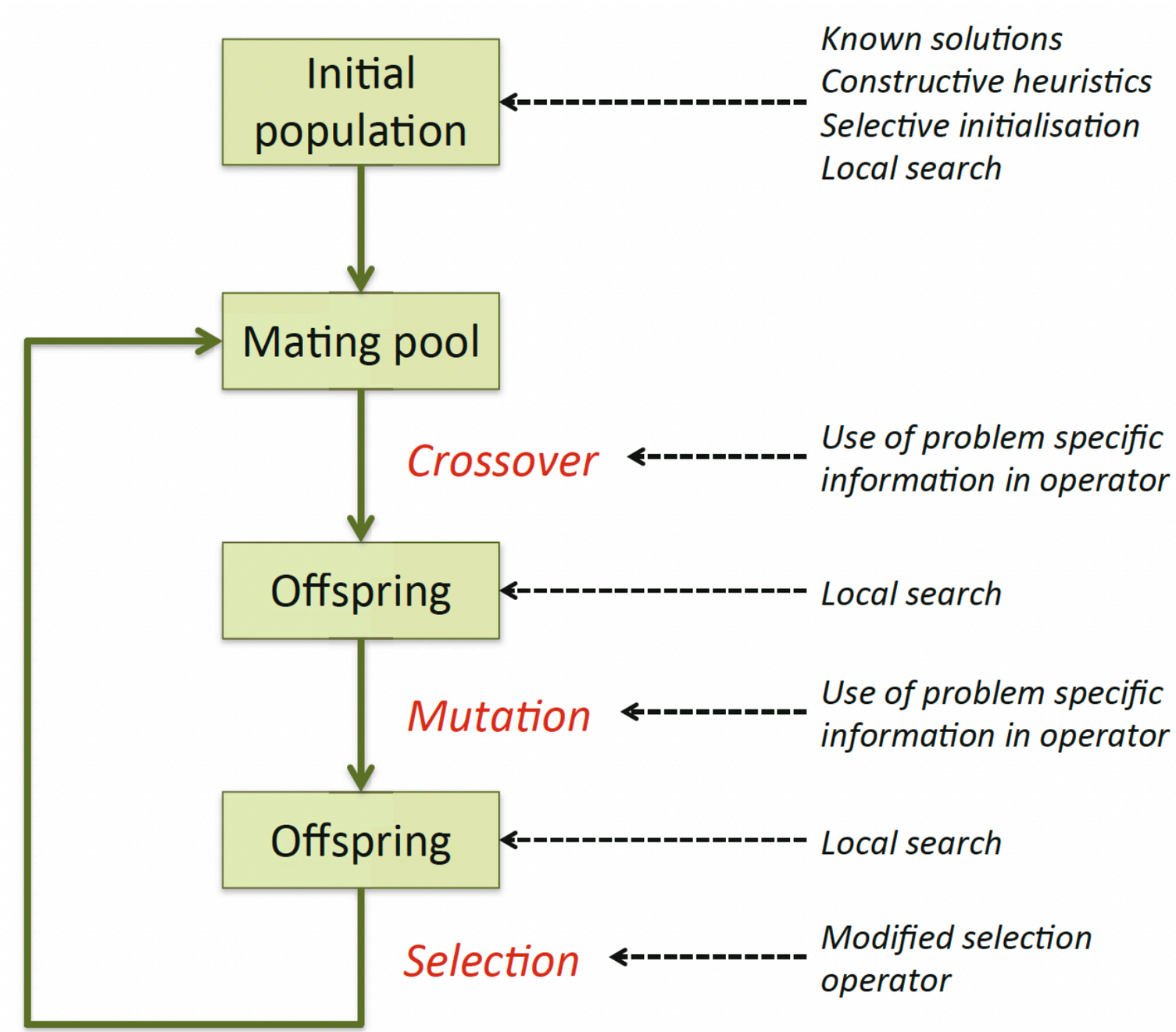
Memes

- Units of cultural transmission
- Genes are the units of biological transmission, selected for replication according to their perceived utility or popularity
- Memes are agents that can transform a candidate solution of direct interest
- Consider the addition of a learning phase to the evolutionary cycle as a form of meme-gene interaction

Memetic Algorithms

- The combination of EAs with Local Search that work within the EA loop
- Term also applies to EAs that use instance-specific knowledge in operators
- Memetic Algorithms have been shown to be faster and more accurate than plain EAs

How to hybridize?



Heuristics for initializing population

- Use tournament selection among randomly created solutions to pick initial population
- Multi-start local search
- Use problem-specific heuristics to generate initial individuals

Intelligent operators

- Incorporate problem or instance specific knowledge within crossover or mutation operators
  - Crossover operator for TSP through inheriting common sub tours from parents, then connects them using a nearest neighbor heuristic
- Evolving instruction sequences by grouping them into classes so mutations are more likely to switch genes to values of a similar effect

Local Search acting on offspring

- Can be viewed as "lifetime learning"
- For instance, use EAs to evolve neural networks and then back-propagation to learn connection weights
- Can speed up the "endgame" of an EA by making the search in the vicinity of good solutions more systematic than mutation alone

Local Search

- Defined using ***neighborhood*** and ***pivot rule***
- Related to landscape metaphor
- The neighborhood of a solution/point x is the set of points can be reached with one application of a move operator

Local Search

```
BEGIN
  /* given a starting solution i and a neighbourhood function n */
  set best = i;
  set iterations = 0;
  REPEAT UNTIL ( depth condition is satisfied ) DO
    set count = 0;
    REPEAT UNTIL ( pivot rule is satisfied ) DO
      generate the next neighbour j ∈ n(i);
      set count = count + 1;
      IF (f(j) is better than f(best)) THEN
        set best = j;
      FI
    OD
    set i = best;
    set iterations = iterations + 1;
  OD
END
```

Pivot rule

- Is the neighborhood search random, systematic, or exhaustive?
- Steepest ascent vs. greedy ascent
  - Steepest ascent: the search stops when the entire neighborhood has been searched
  - Greedy ascent: the search stops when the first improvement is found
- There is no one best answers

Variations of local search

- Does the search happen in representation (genotype) space or solution (phenotype) space
- Is local search applied to the entire population?
  - or just the best individuals?
  - or just the worst individuals?
  - or the medium individuals?

Two models of lifetime learning

- Lamarckian
  - traits acquired by an individual during its lifetime can be transmitted to its offspring
  - no proofs in biology
  - but can be implemented in EAs!
- Baldwinian
  - traits acquired by individual cannot be transmitted to its offspring
  - but individuals with better learning abilities receive better fitness values

Choice of operators

- Theoretical advantages to using a local search with a move operator that is different from mutation and crossover
- Use a range of local search operators with mechanism for choosing which one to use under different circumstances
- Can be learned and adapted online!

Adaptive memetic algorithms

- Most important is the choice of move operator
- Considerations
  - using domain-specific information
  - using multiple local search operators in tandem
  - adding a gene indicating which local search operator to use and can be part of evolution

Evolution of memetic algorithms

- First generation: global search paired with local search
- Second generation: global search with multiple local optimizers
  - memetic information (choice of local optimizer) passed to offspring (Lamarckian evolution)
- Third generation: global search with adaptive multiple local optimizers
  - a mapping between evolutionary trajectory and choice of local optimizer is learned