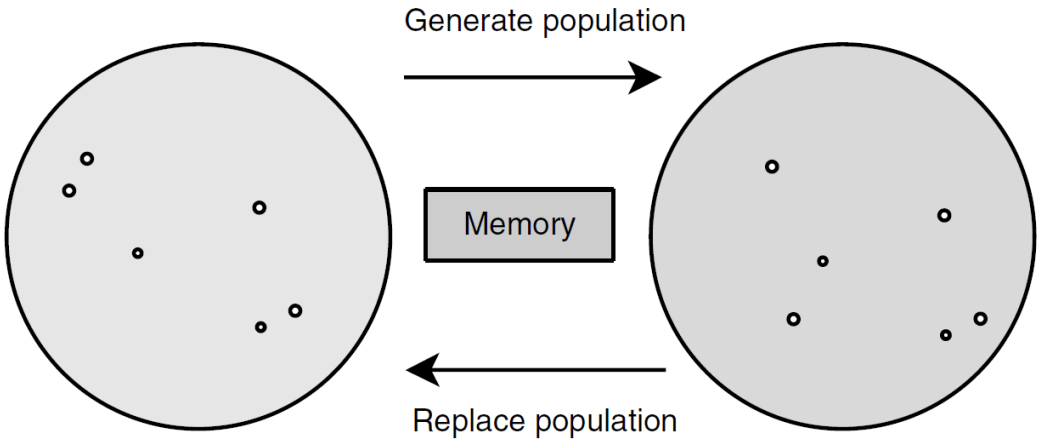
3. Population solution based metaheuristics (P-metaheuristics)

P-metaheuristics

- Properties
  - Nature inspired
  - Population of solutions
  - Iterative process to improve “population”
  - Keep best solution

P-metaheuristics

- Design



High-level template of P-metaheuristics.

$P = P_0$; /* Generation of the initial population */
$t = 0$;
Repeat
  Generate(P'_t); /* Generation a new population */
  P_{t+1} = Select-Population($P_t \cup P'_t$); /* Select new population */
  $t = t + 1$;
Until Stopping criteria satisfied
Output: Best solution(s) found.

3.1 P-metaheuristics
Genetic Algorithms (GA)

P-metaheuristics – Genetic Algorithms (GA)

Evolution theory of Charles Darwin

Within a population, the individuals are different from each other and some of them are better adapted to their environment. This will increase their life and reproduction chances. The next generations will inherit these advantageous characteristics that will let them to become predominant in the population.

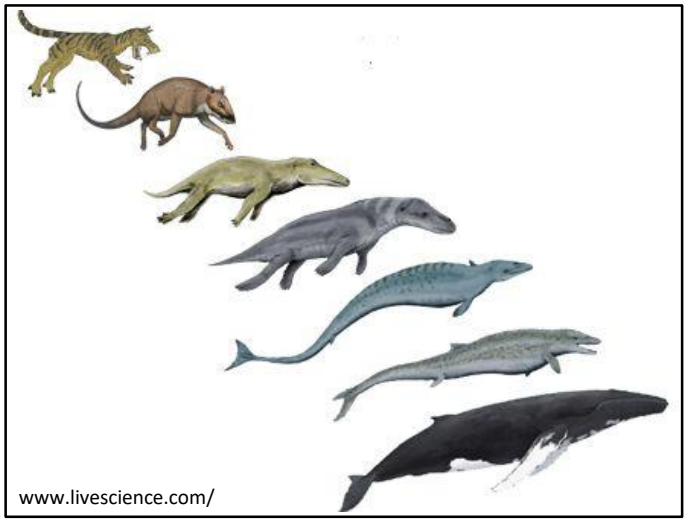
P-metaheuristics – Genetic Algorithms (GA)

Evolution theory of Charles Darwin

Within a population, the individuals are different from each other and some of them are better adapted to their environment. This will increase their life and reproduction chances. The next generations will inherit these advantageous characteristics that will let them to become predominant in the population.

Species evolution

Progressive, very slow and requires thousands years or even millions.



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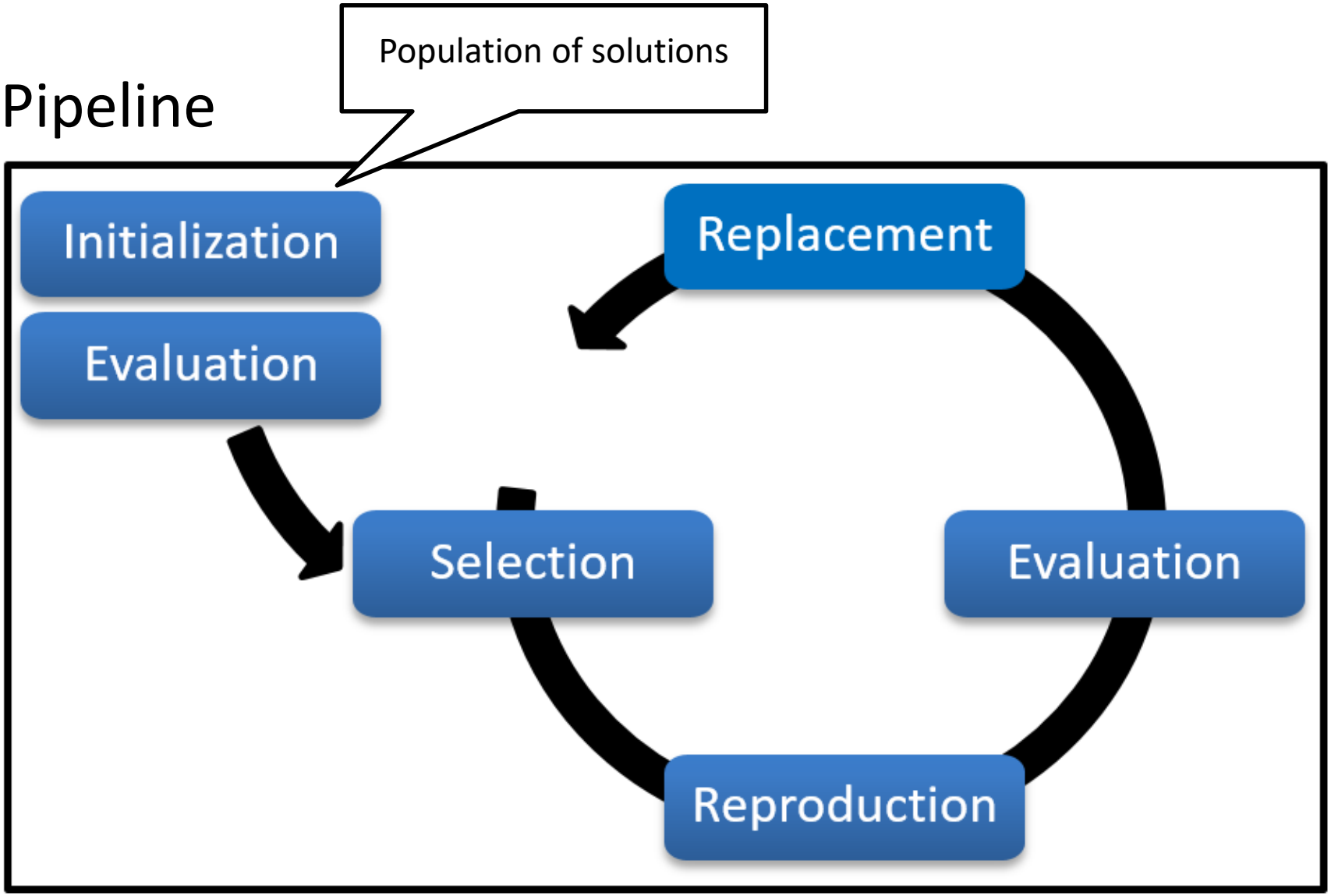
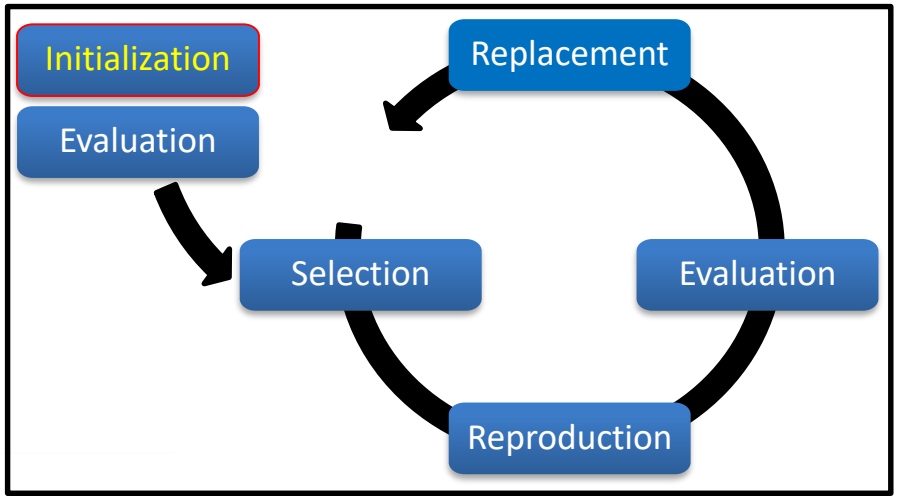
P-metaheuristics – Genetic Algorithms (GA)

- Pipeline



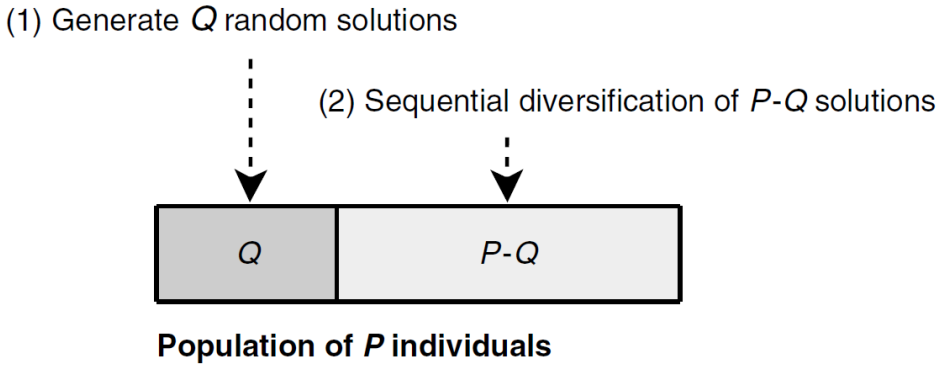
P-metaheuristics – Genetic Algorithms (GA)

- Initial population
  - Diversification
  - Multiple strategies



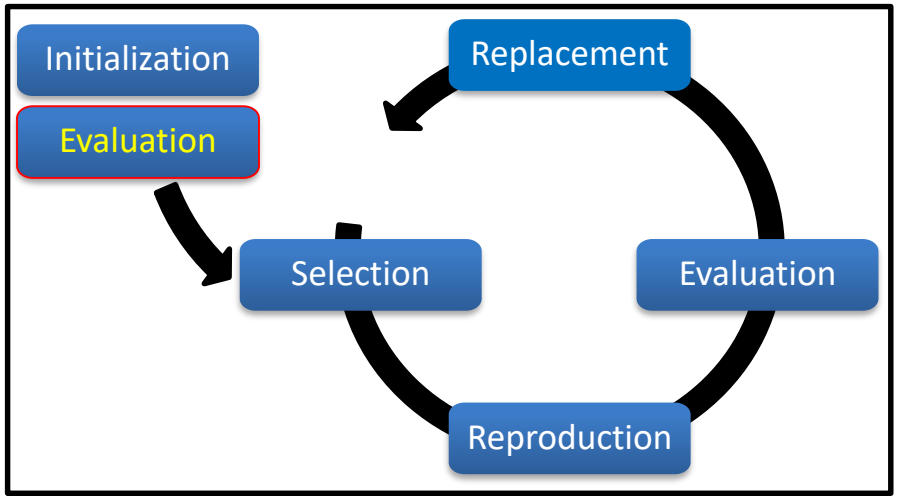
Analysis of the Different Initialization Strategies

Strategy	Diversity	Computational Cost	Quality of Initial Solutions
Pseudo-random	++	+++	+
Quasi-random	+++	+++	+
Sequential diversification	++++	++	+
Parallel diversification	++++	+++	+
Heuristic	+	+	+++



P-metaheuristics – Genetic Algorithms (GA)

- Evaluation (fitness fct) (problem dependent)



1	4	8	9	3	6	5	2	7

Permutation

Traveling salesman problem

$\pi = (\pi_1, \pi_2, \ldots, \pi_n)$

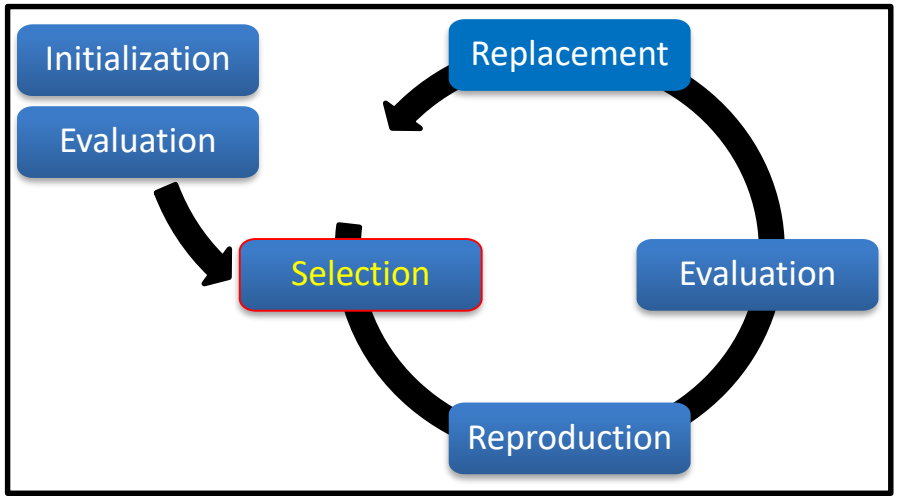
Fitness function

$f : S \rightarrow \mathbb{R}$

$$f(s) = \sum_{i=1}^{n-1} d_{\pi(i),\pi(i+1)}$$

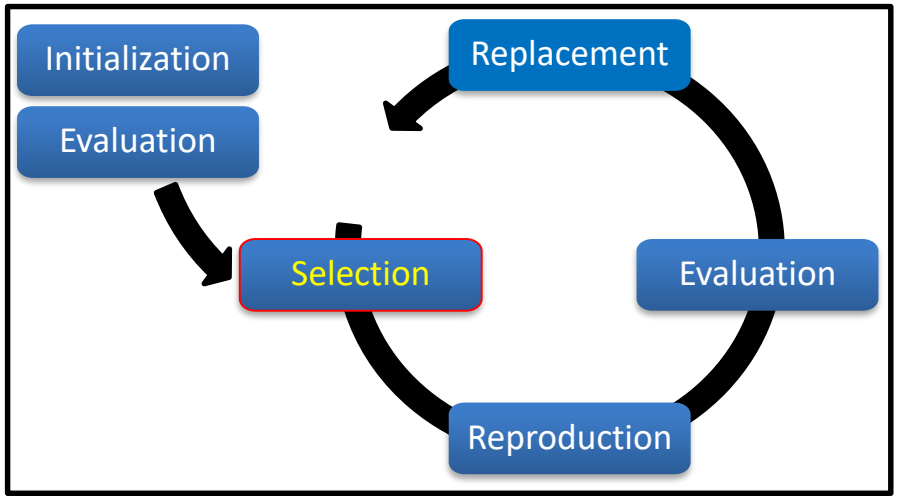
P-metaheuristics – Genetic Algorithms (GA)

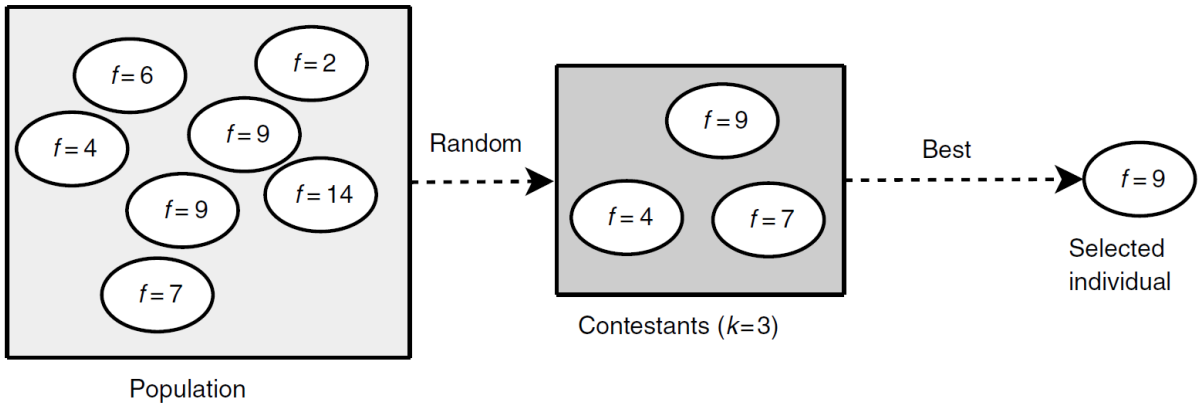
- Selection
  - Better is the individual more is his chance for being a parent
  - Multiple strategies



P-metaheuristics – Genetic Algorithms (GA)

- Selection
  - Better is the individual more is his chance for being a parent
  - Multiple strategies
    - Tournament

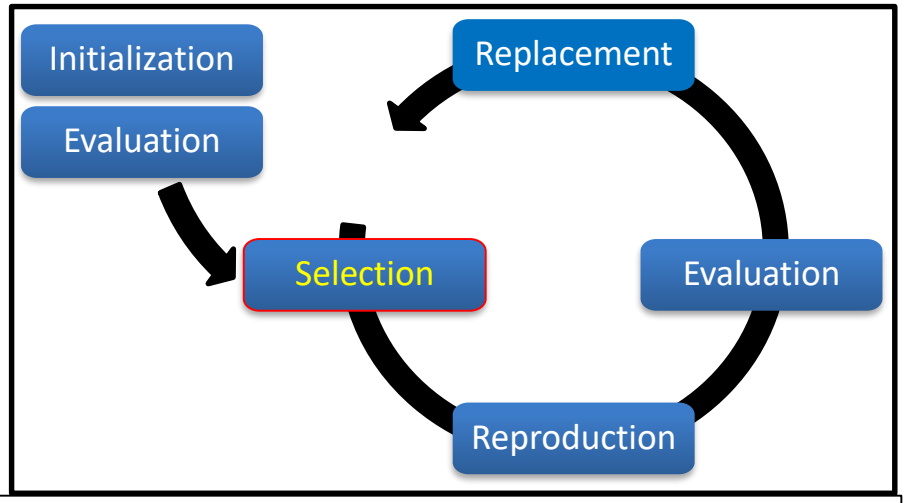


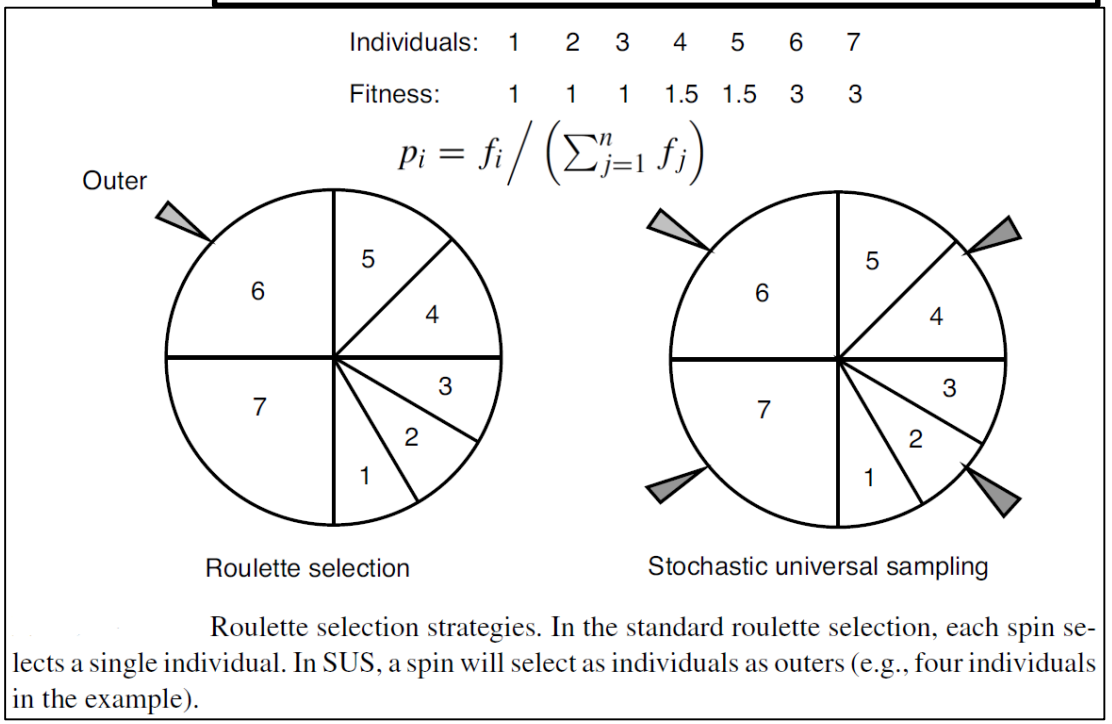


Tournament selection strategy. For instance, a tournament of size 3 is performed. Three solutions are picked randomly from the population. The best solution from the picked individuals is then selected.

P-metaheuristics – Genetic Algorithms (GA)

- Selection
  - Better is the individual more is his chance for being a parent
  - Multiple strategies
    - Roulette Wheel

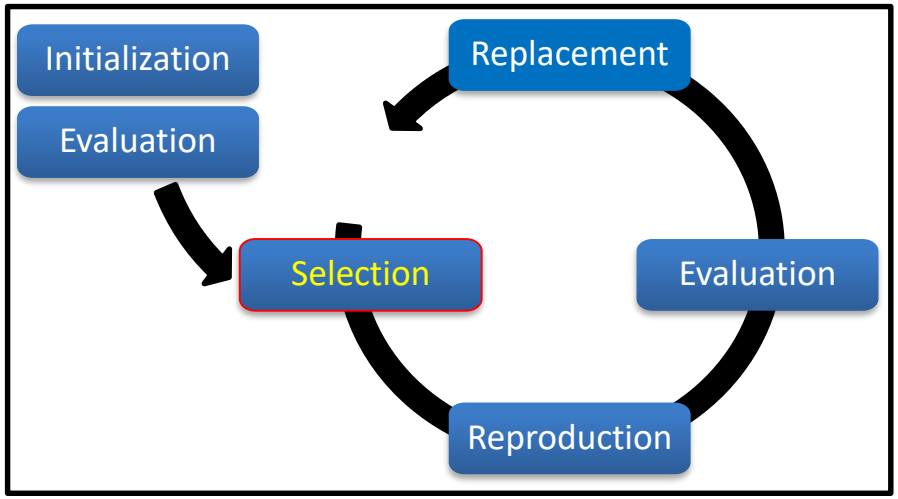


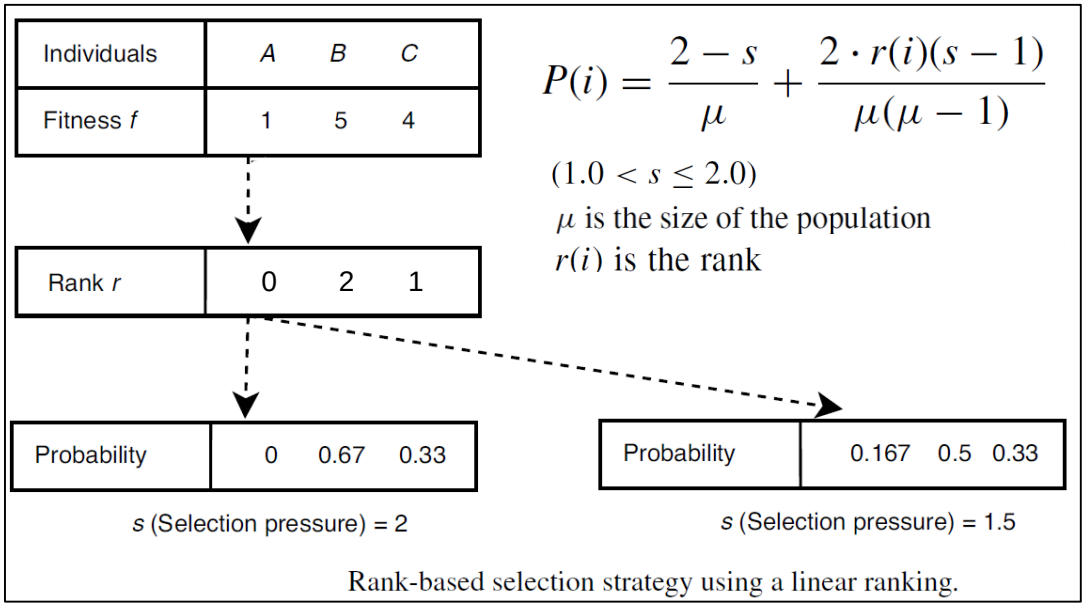


Roulette selection strategies. In the standard roulette selection, each spin selects a single individual. In SUS, a spin will select as individuals as outers (e.g., four individuals in the example).

P-metaheuristics – Genetic Algorithms (GA)

- Selection
  - Better is the individual more is his chance for being a parent
  - Multiple strategies
    - Rank-based

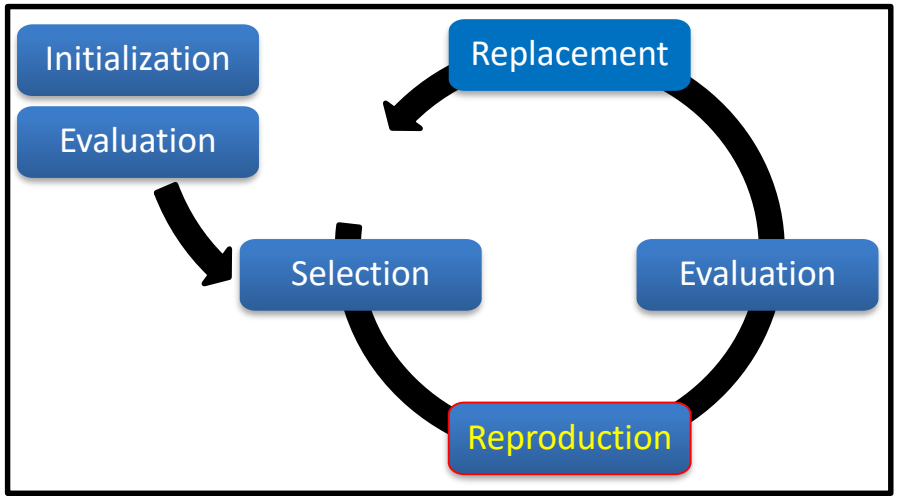




Rank-based selection strategy using a linear ranking.

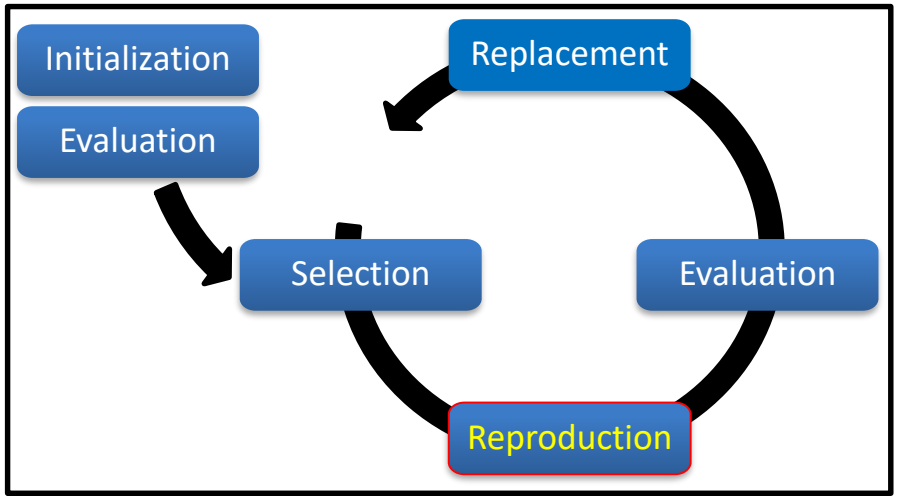
P-metaheuristics – Genetic Algorithms (GA)

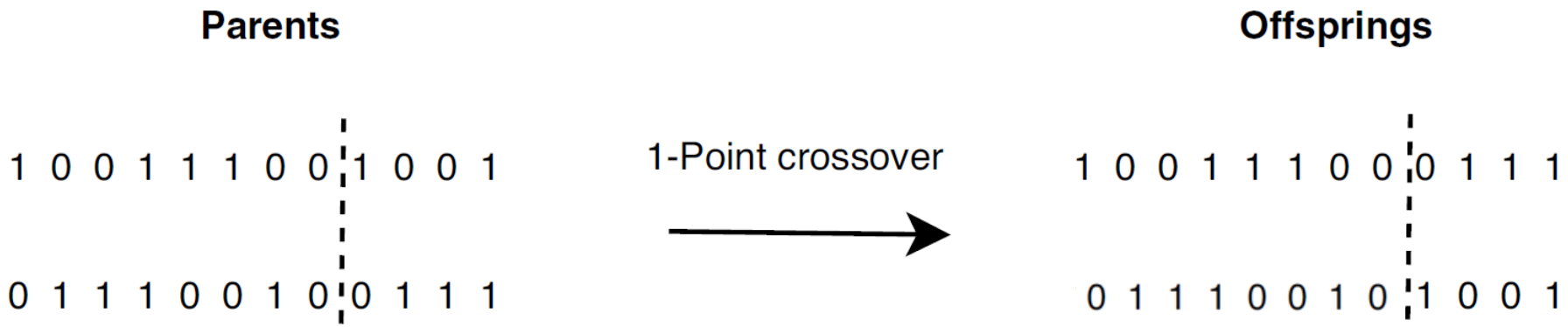
- Reproduction
  - Crossover
    - Inherit characteristics of parents to generate offsprings
  - Mutation
    - Small changes within individuals of the population (congenital)



P-metaheuristics – Genetic Algorithms (GA)

- Reproduction
  - Crossover (high prob.)
    - Heritability
    - Validity





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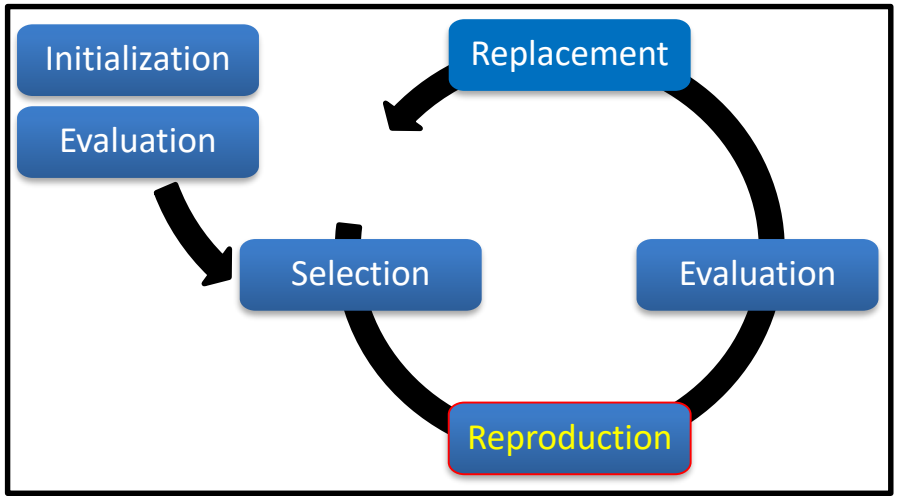
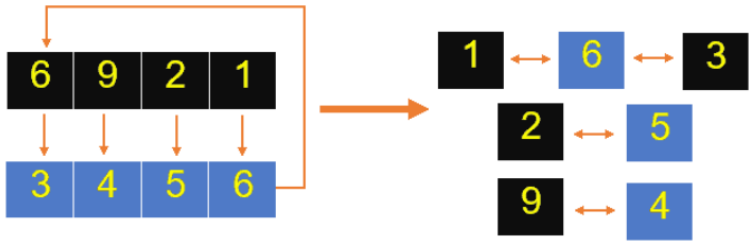


Partially Mapped Crossover (PMX) for TSP problem



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  - Crossover (high prob.)
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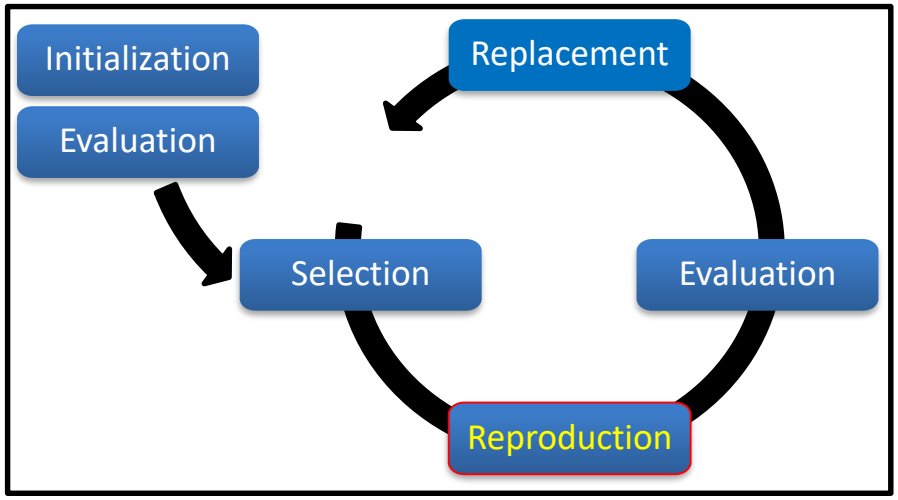

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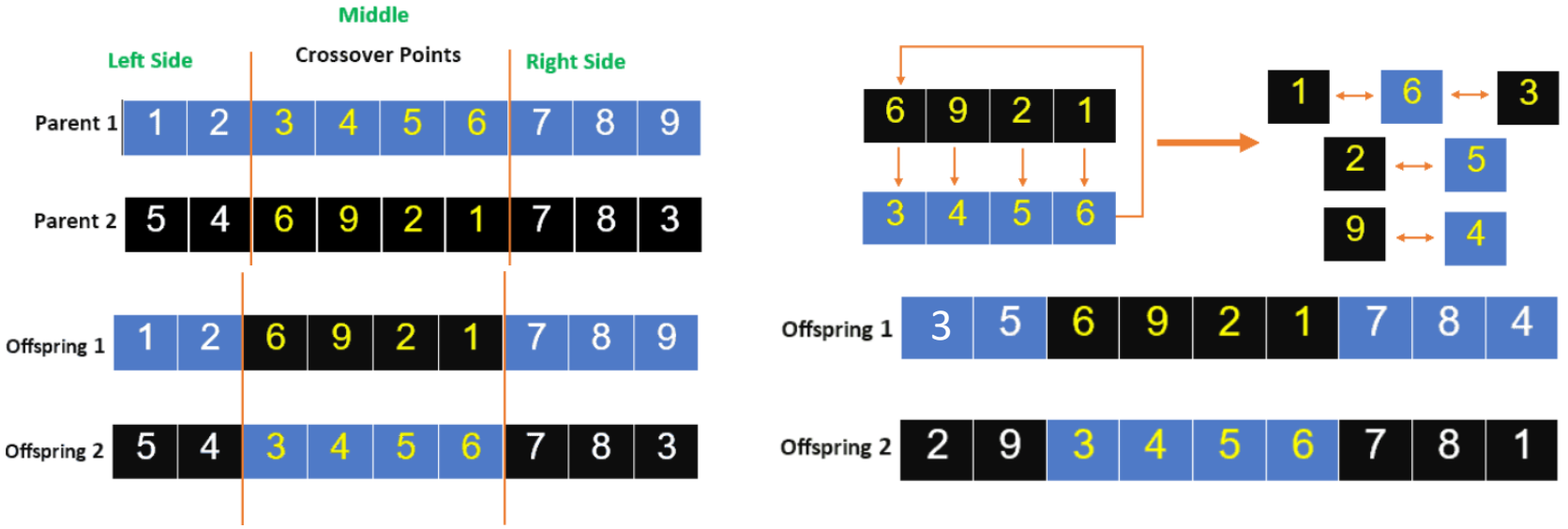
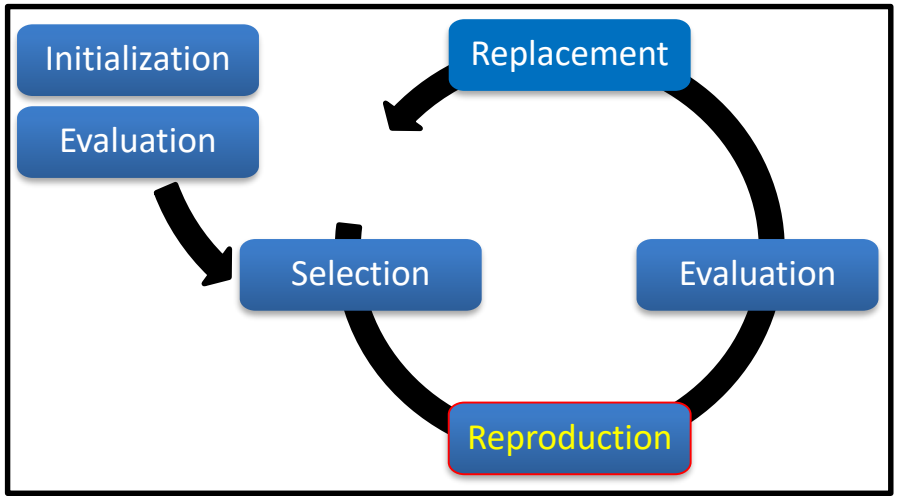
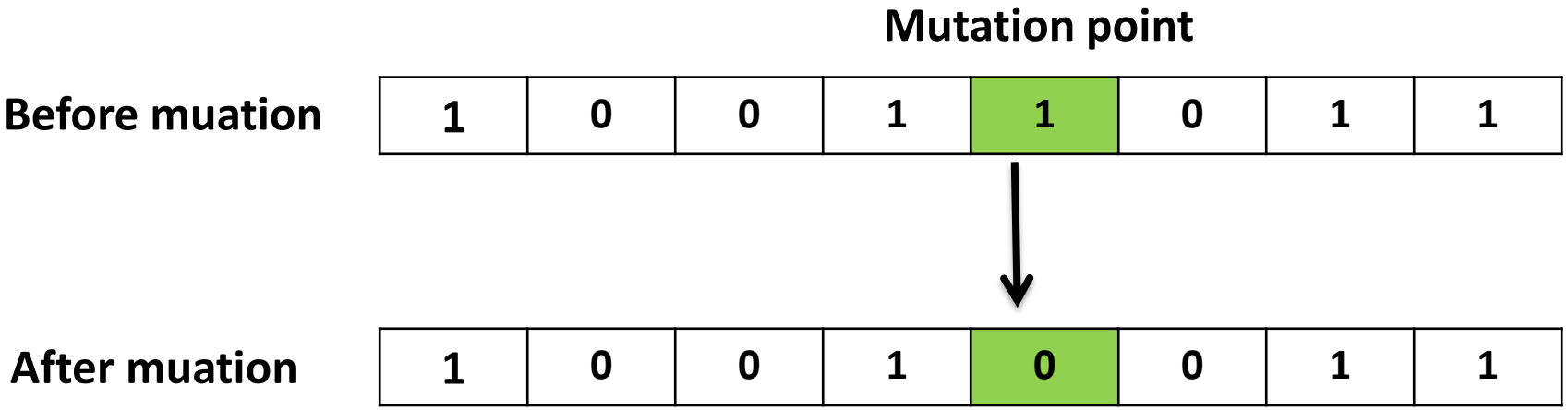


P-metaheuristics – Genetic Algorithms (GA)

- Reproduction
  - Mutation (low prob.)
    - Locality
    - Validity





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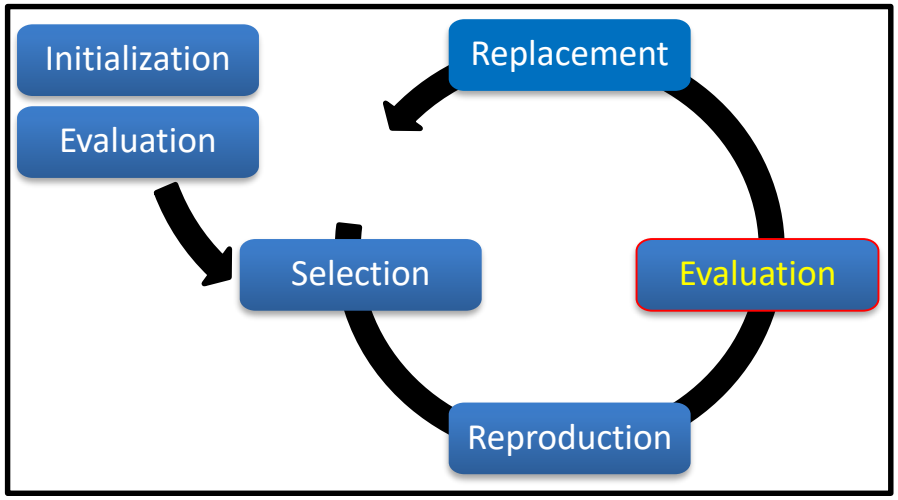

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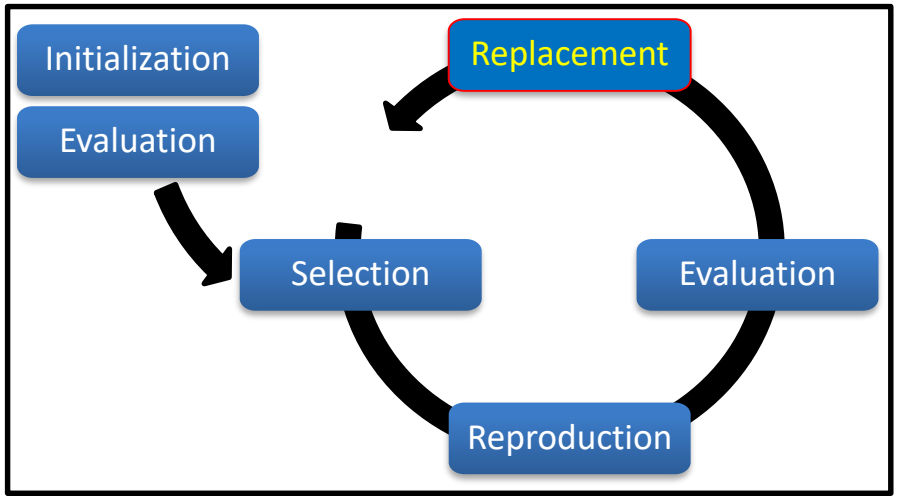
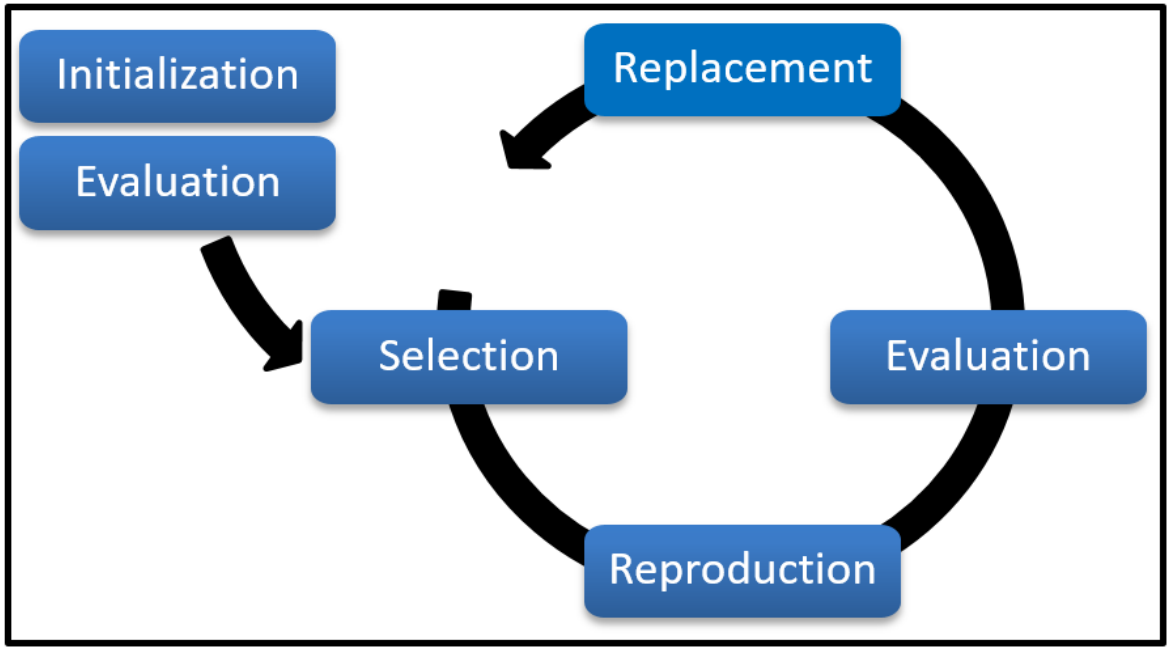


- Replacement
  - Survival selection (parents vs. offsprings)
  - Multiple strategies
    - Generational: offsprings replace totally the previous population (generation)
    - Steady state: for two parents one of them (worst one) is replaced by one offspring (best one)
    - Elitism: keep the best individual(s) through the different generations

P-metaheuristics – Design

- Stopping criteria
  - Static → max iterations
  - Dynamic → num iterations without improvement or some statistics on the population



P-metaheuristics – Genetic Algorithms (GA)

- Lab session 

Develop your own GA version and apply it to two problems

- Max one problem, a simple problem

1	1	1	1	1	1	1	1

- TSP problem