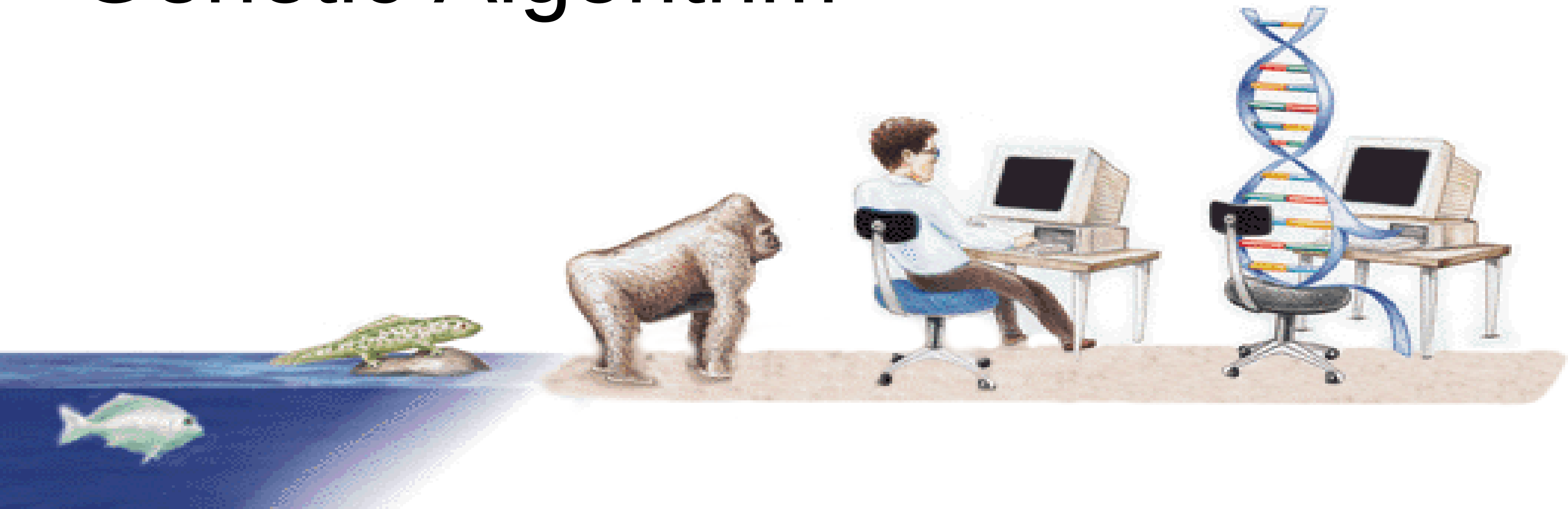
Intelligent systems

Lecture 9:

Dr. Bassam Kurdy

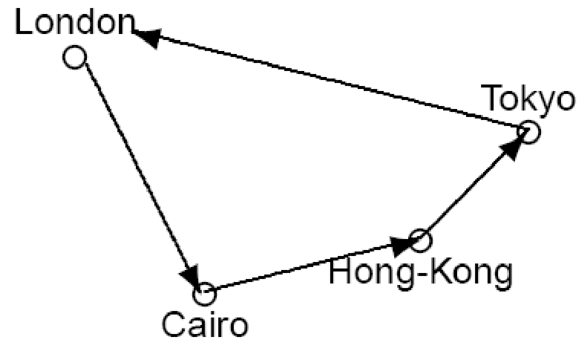
Genetic Algorithm



Combinatorial Problem

- No clear method to find the optimum solution
- Seem to have only one way of finding a solution: by random search
- They have many possible combinations and it is impossible to try all of them.
- “Neural networks are second best way to solve about anything… and GA are the third.”

The travel salesman problem



- A salesman goes on a tour around several cities.
- Each city have to be visited only once.
- What is the shortest tour ?
- N City => (n-1)! possible solution
- 50 City => $6*10^{62}$
  - each calculation 1 ηs => $2*10^{45}$ years to try all possible solution !!!

The Timetabling problem

- Balancing resource (Teachers, students, rooms)
  - Teachers at one place at one time
  - Rooms can only be used by one teacher
  - Each teacher can only teach certain subjects
  - …

Charles Darwin

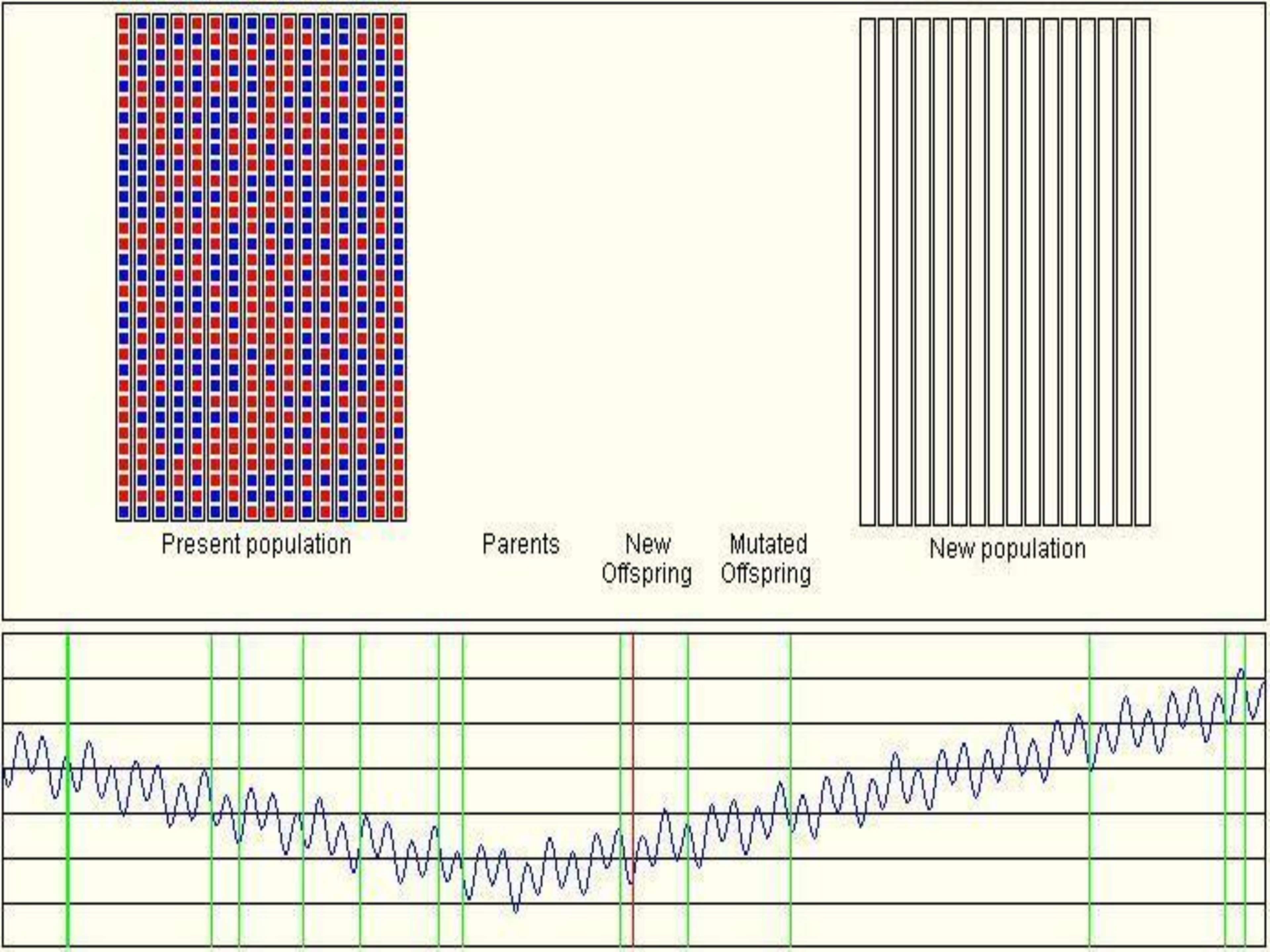
- Living organisms are fighting the forces of nature to survive. Those who are the fittest (strongest, fastest, biggest) are most likely to survive
- Those who survive mate and reproduce **(selection)**
- Children are similar **(inheritance)**, but not exactly like parents because of cross-fertilization and mutation, thus children can be more or less fitness than parents
- Children repeat the path of their parents, after several generations the organisms become much fitter.

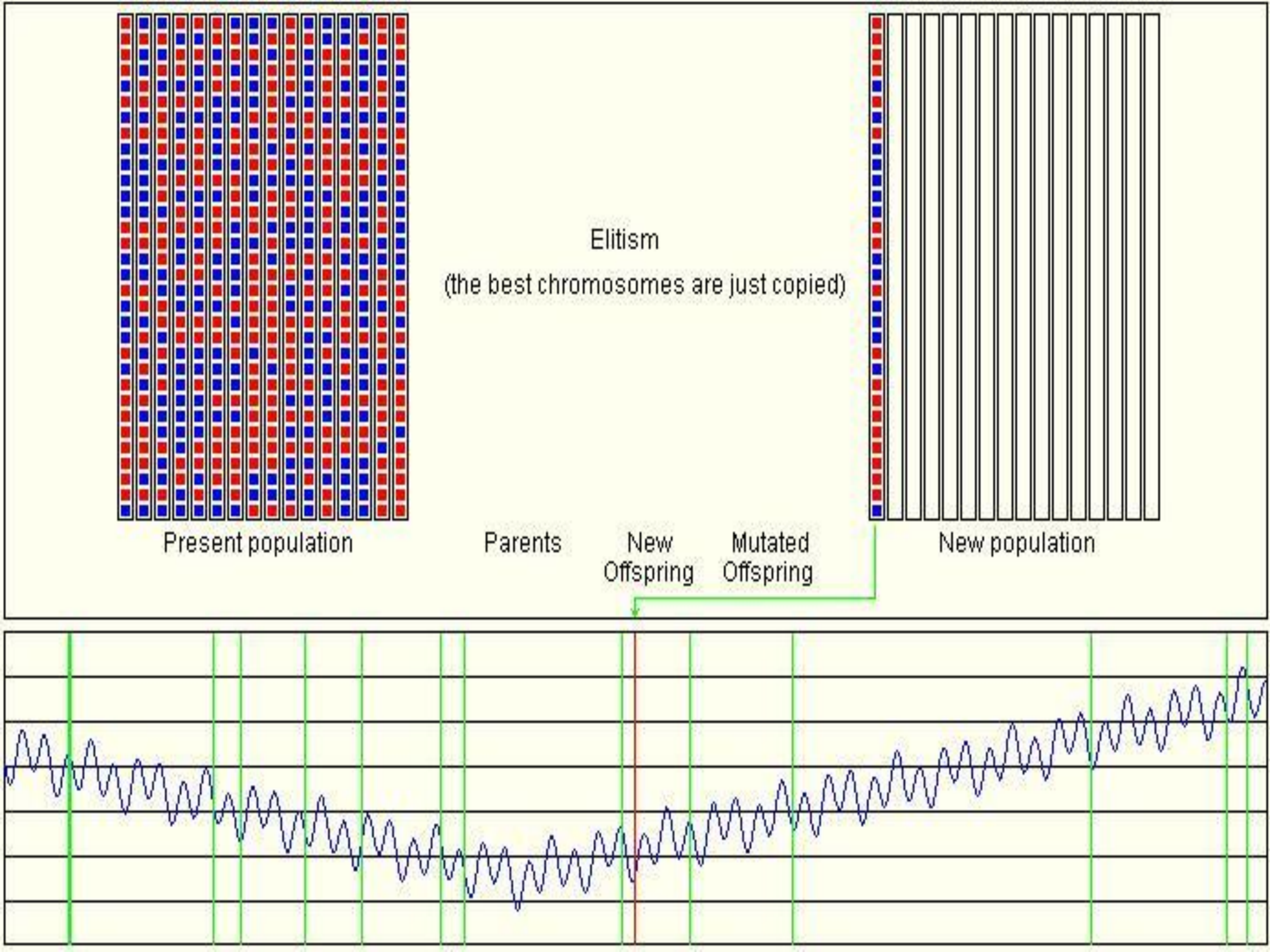
Genetic Algorithm

- Suppose that there is many possible solutions for the problem: $x_1,x_2,x_3,x_4,\ldots$. The main idea is to view each solution x_i of the problem as an individual living organism.
- the number of possible solution can be incredibly large $n \rightarrow \infty$, so we consider $m < n$ and chose a **Population:**
- $P(t) = \{x_1^t, x_2^t, \ldots , x_m^t\}$
- With time the organisms and the whole population will be evolving.

Genetic Algorithm

- The next slides show how Genetic Algorithm work. Like Charles Darwin theory


Present population
Parents
New
Offspring
Mutated
Offspring
New population


Elitism
(the best chromosomes are just copied)
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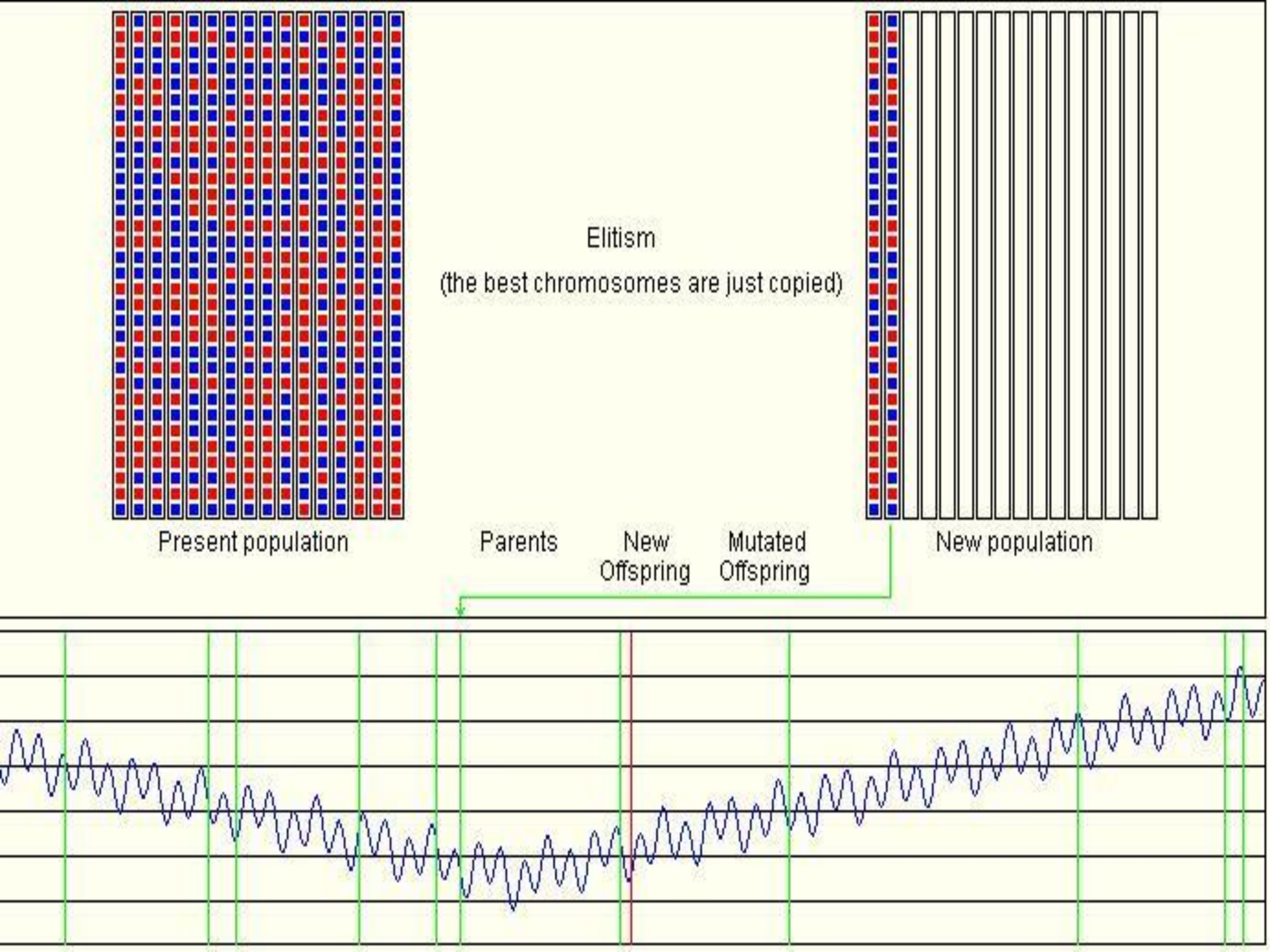
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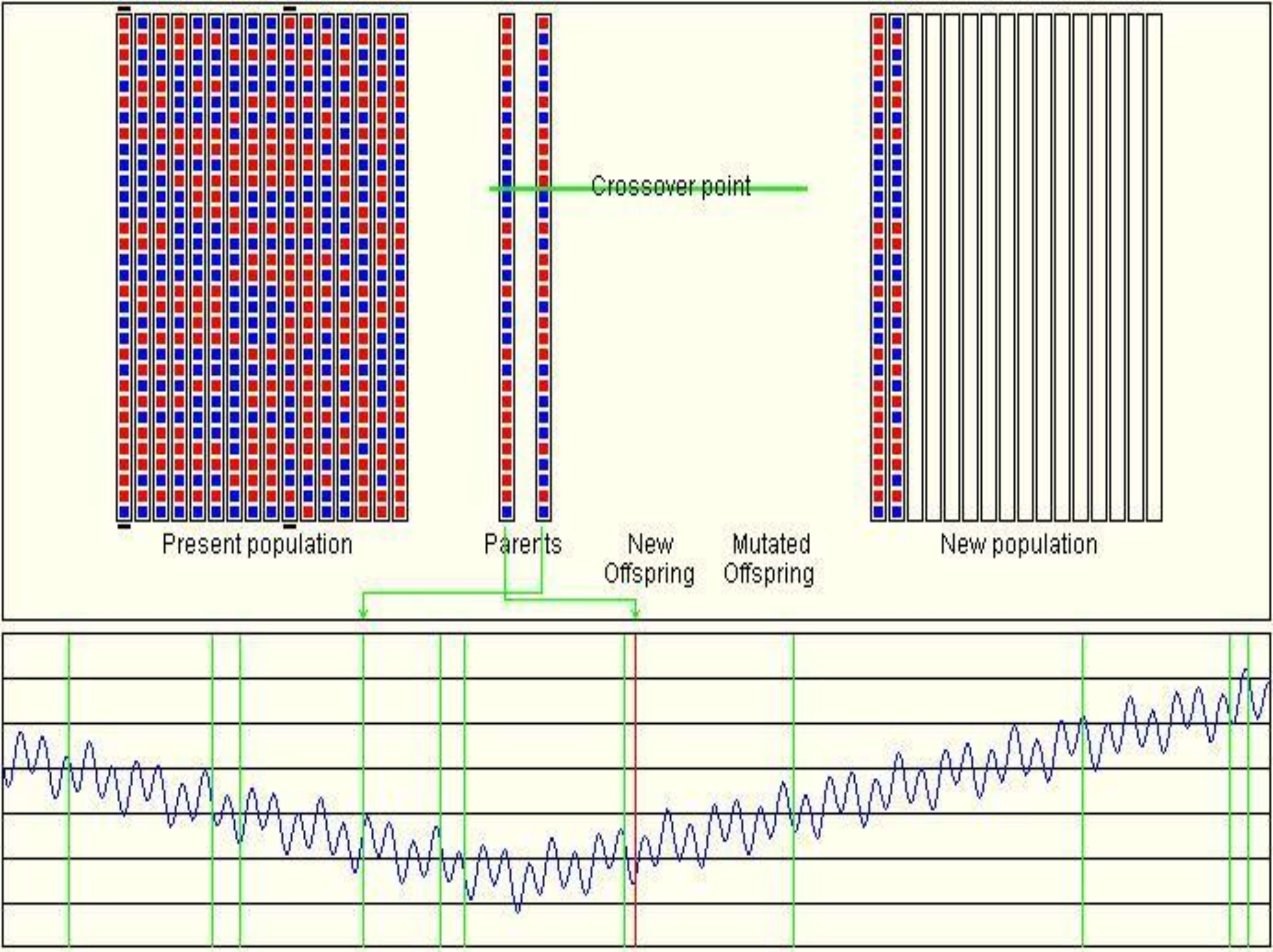
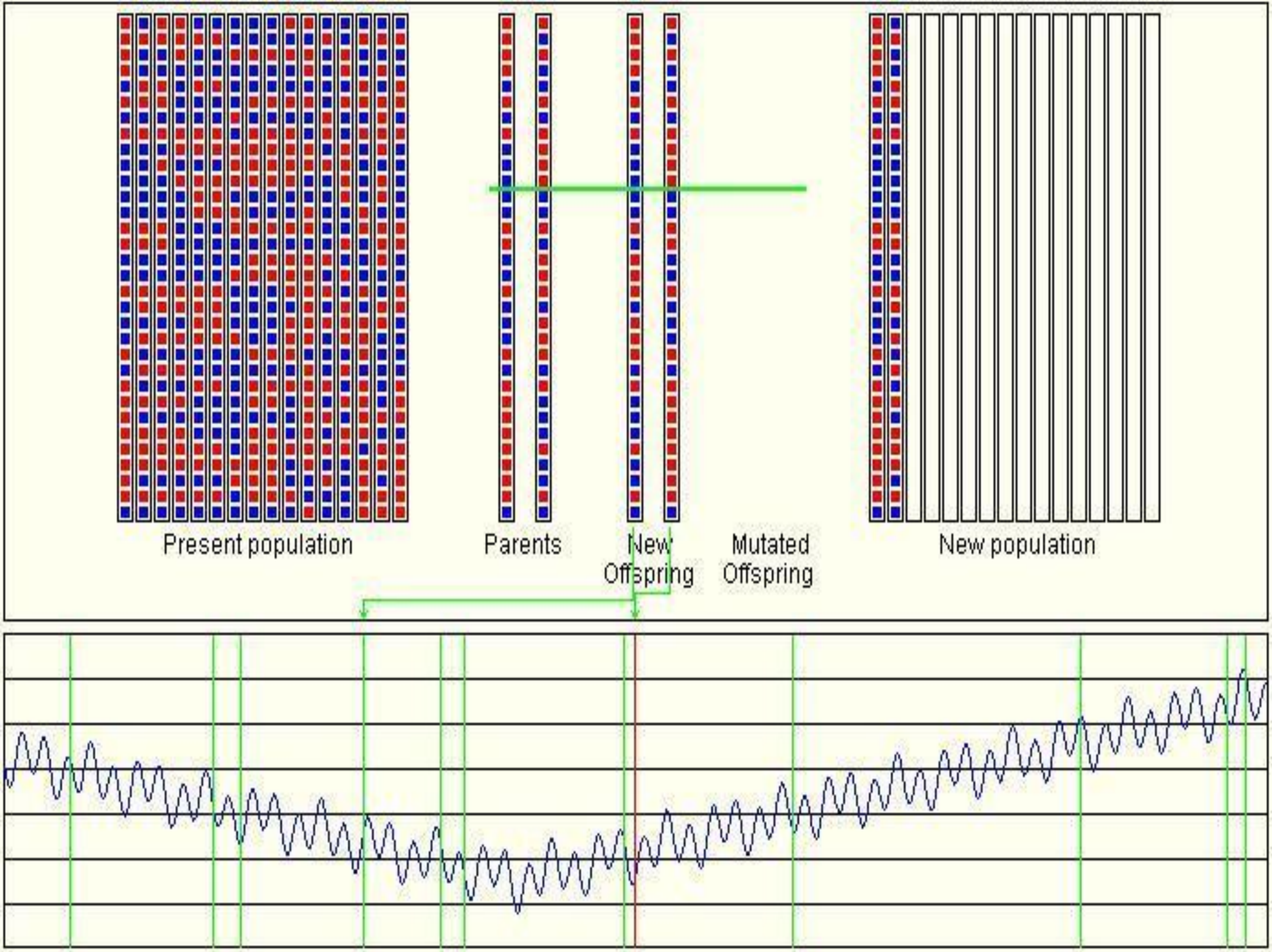


Crossover point
Present population
Parents
New Offspring
Mutated Offspring
New population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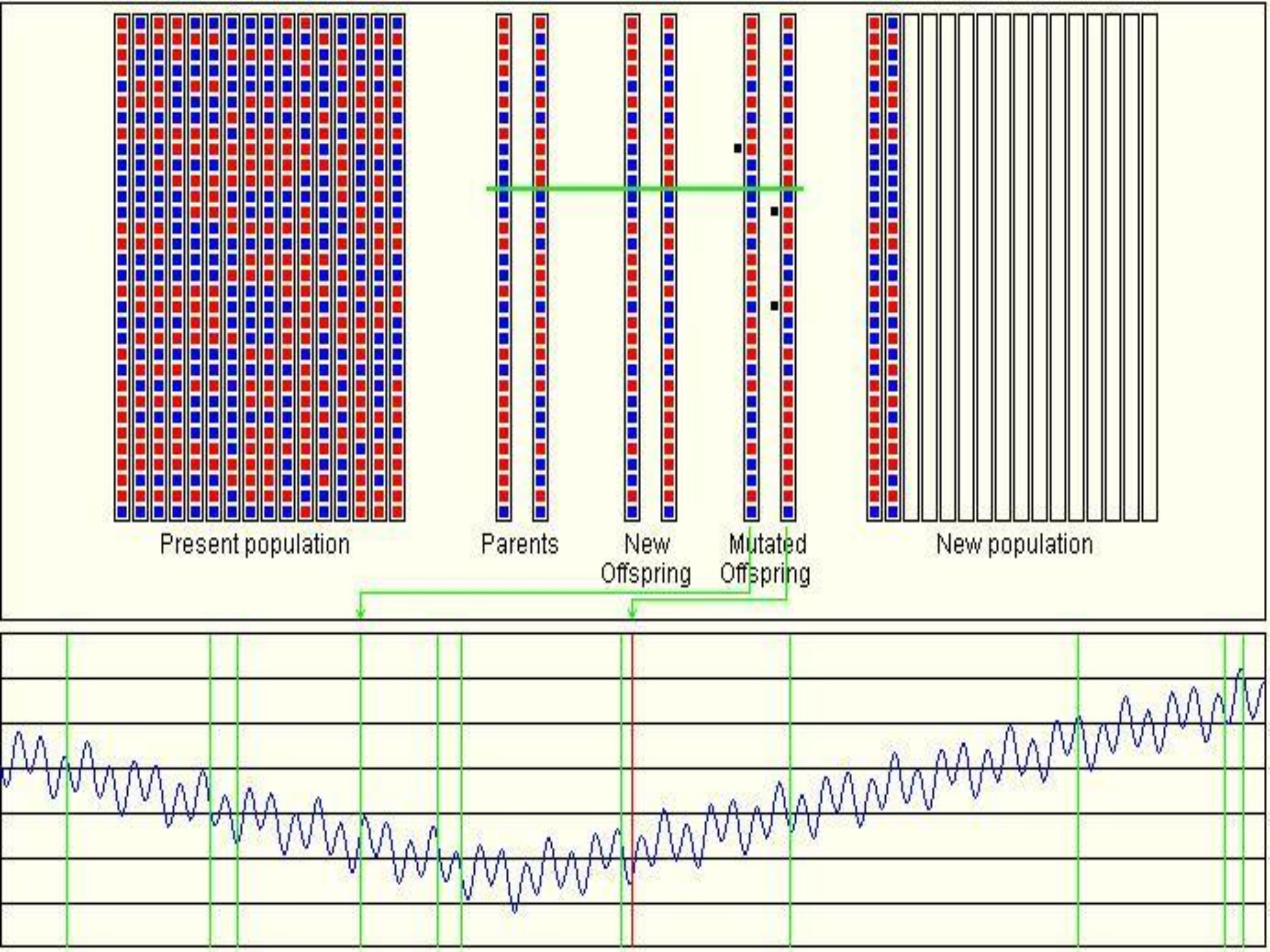

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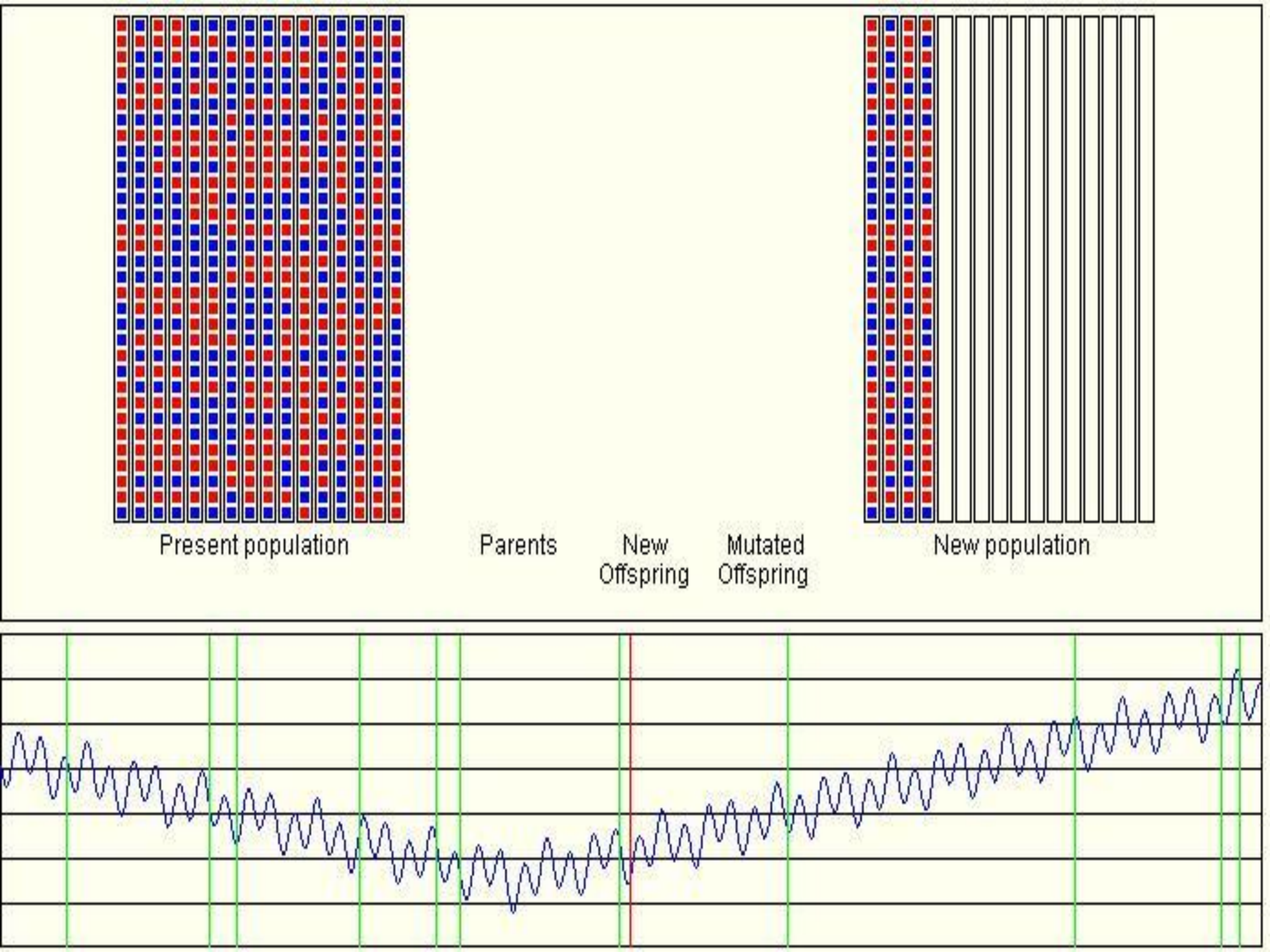
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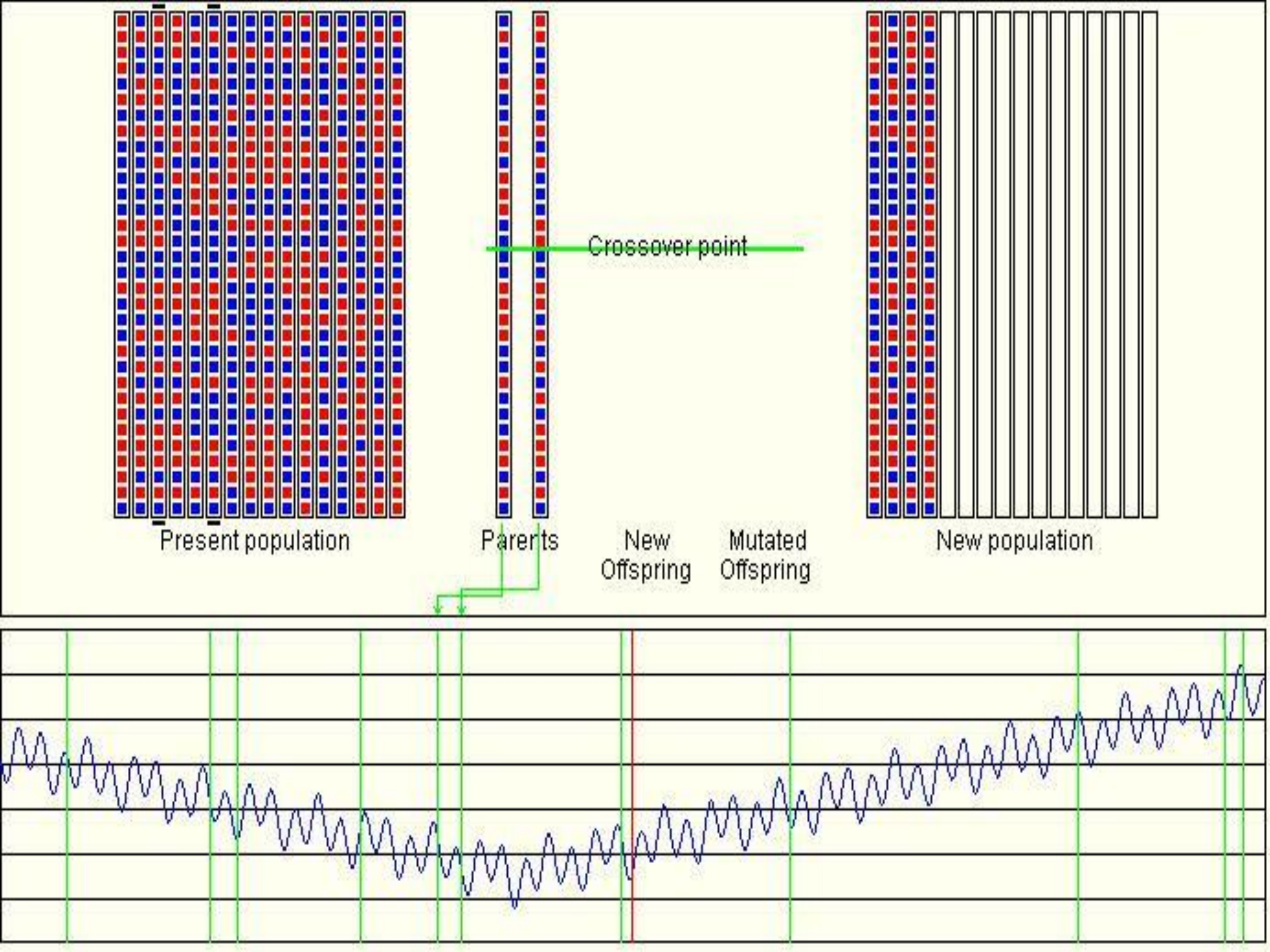
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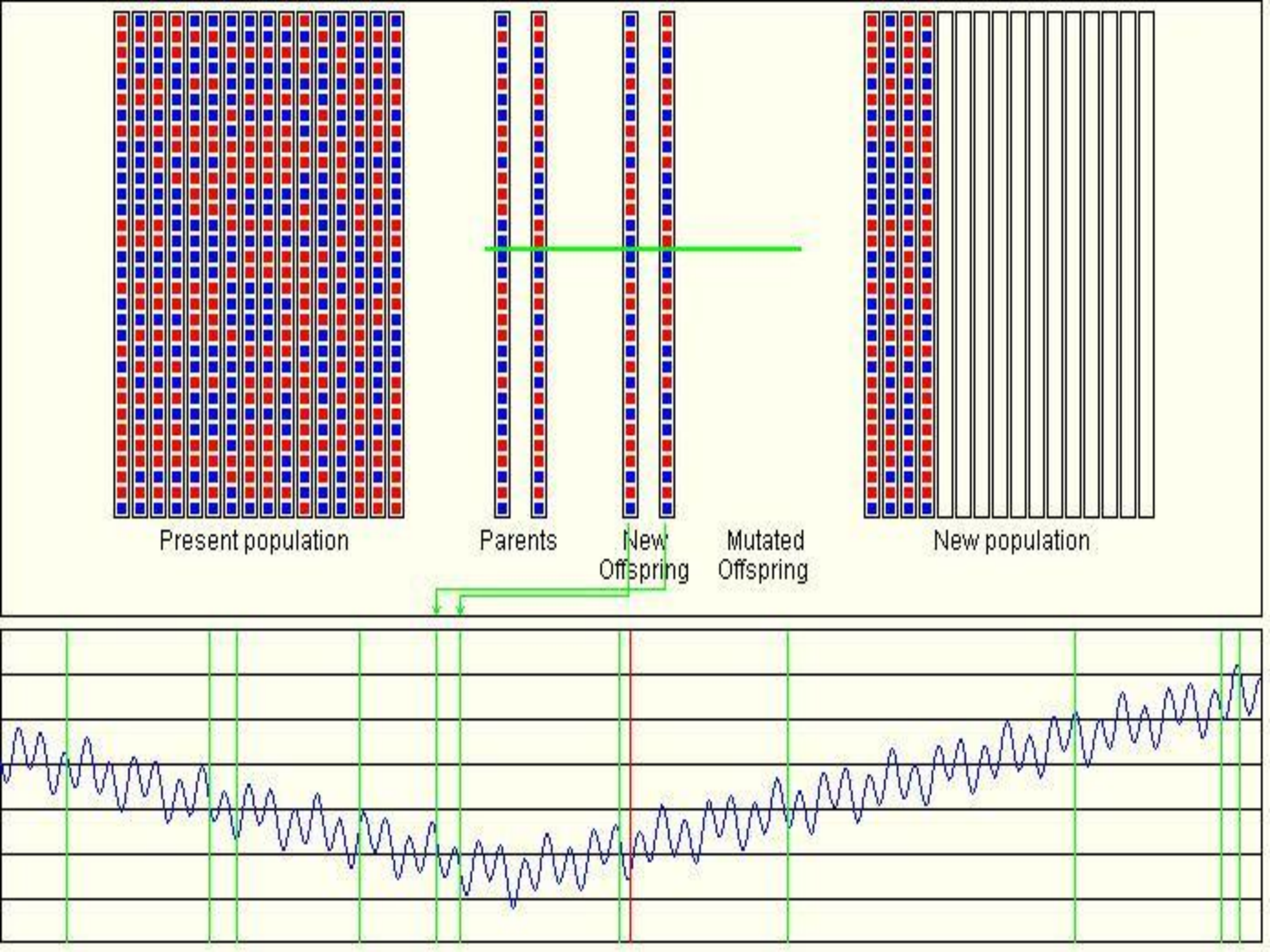

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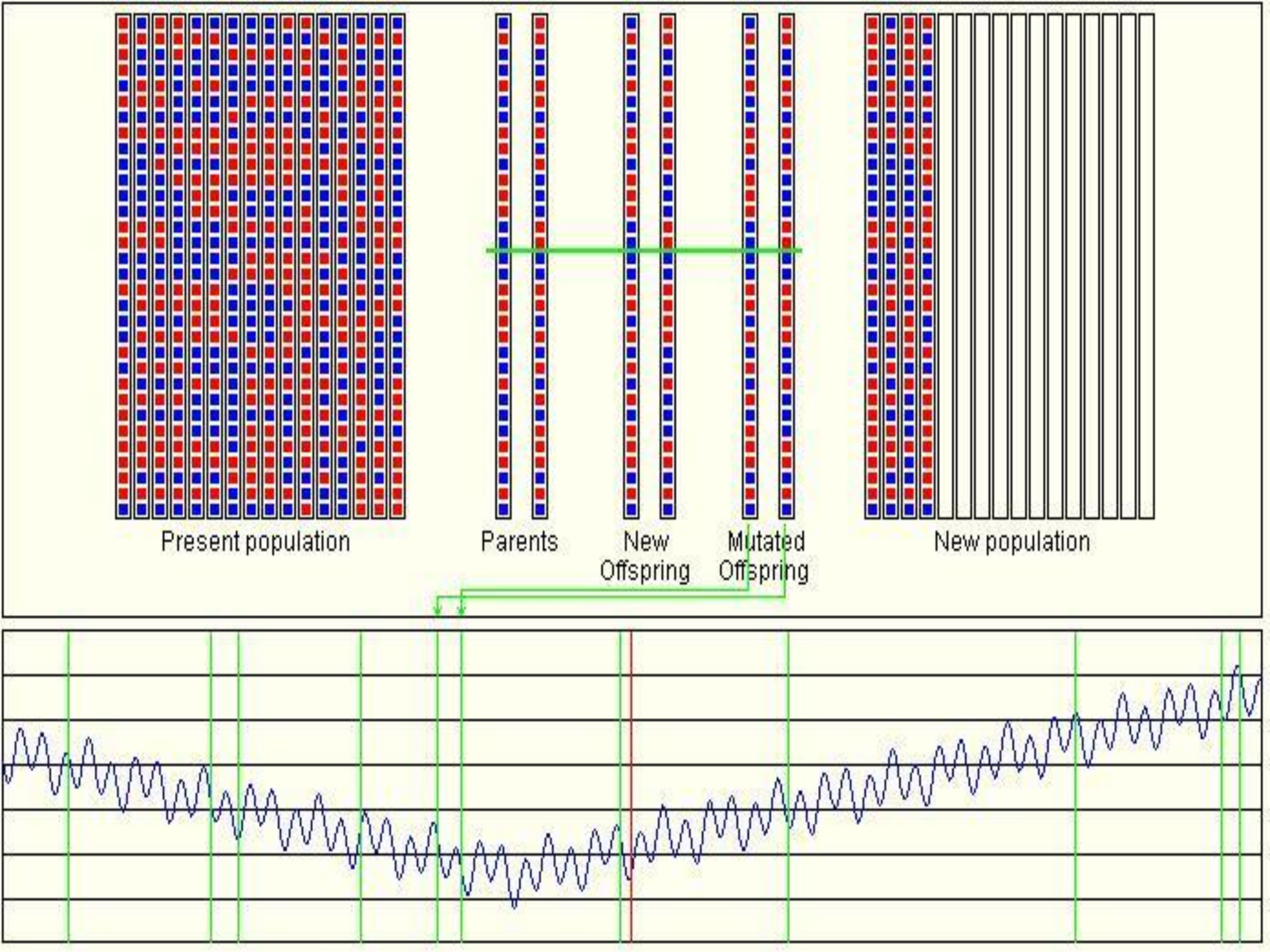
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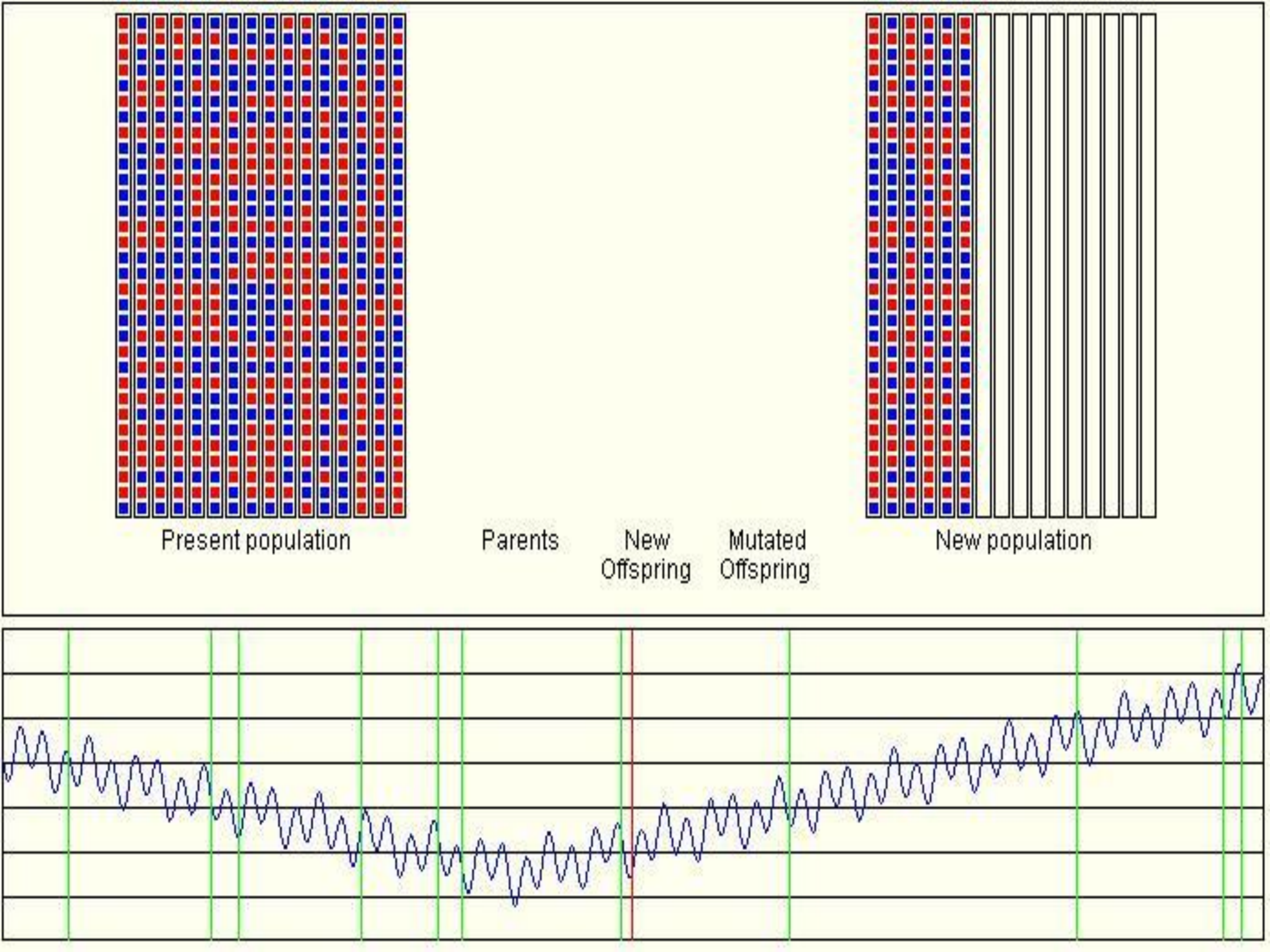
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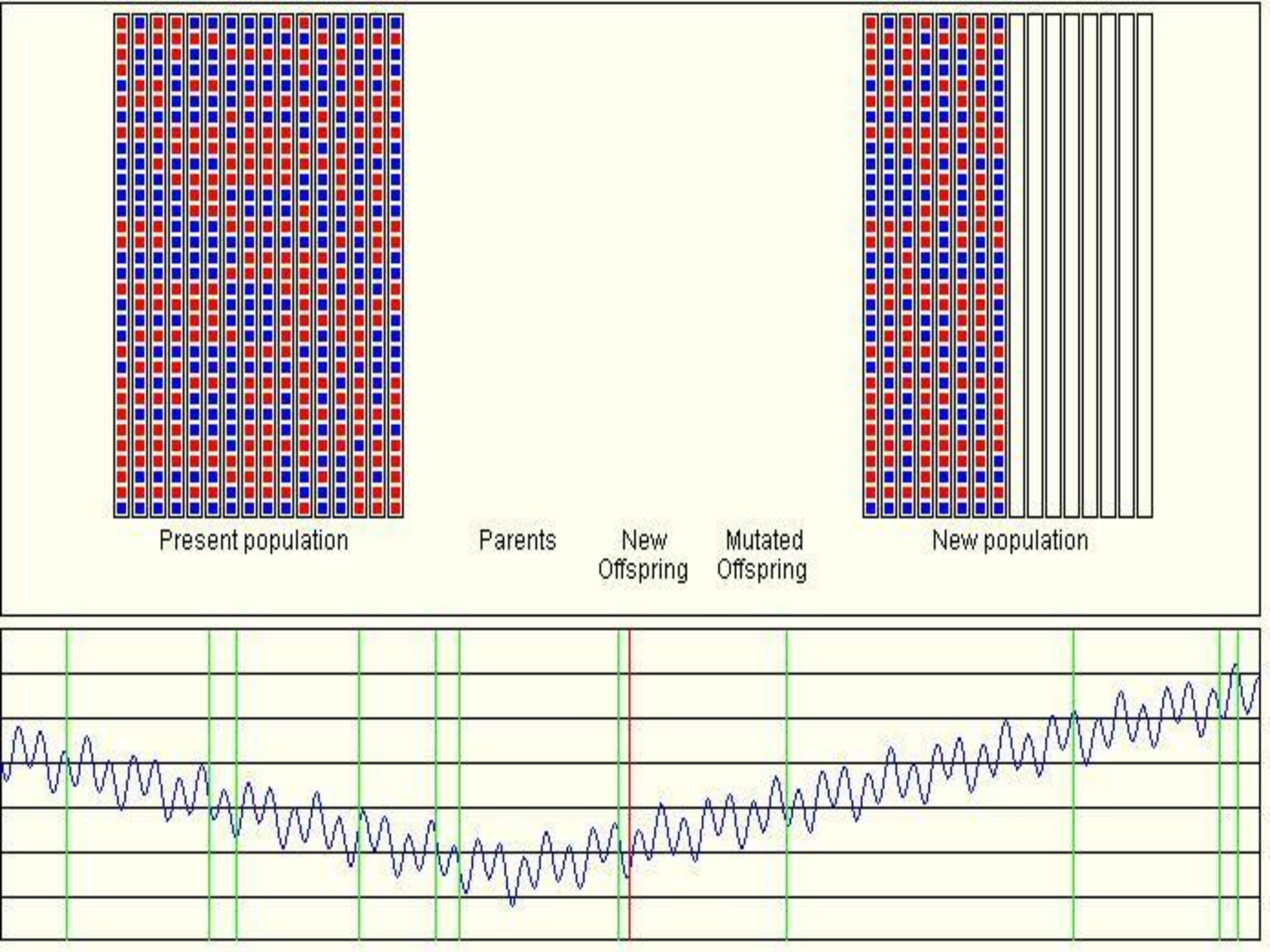
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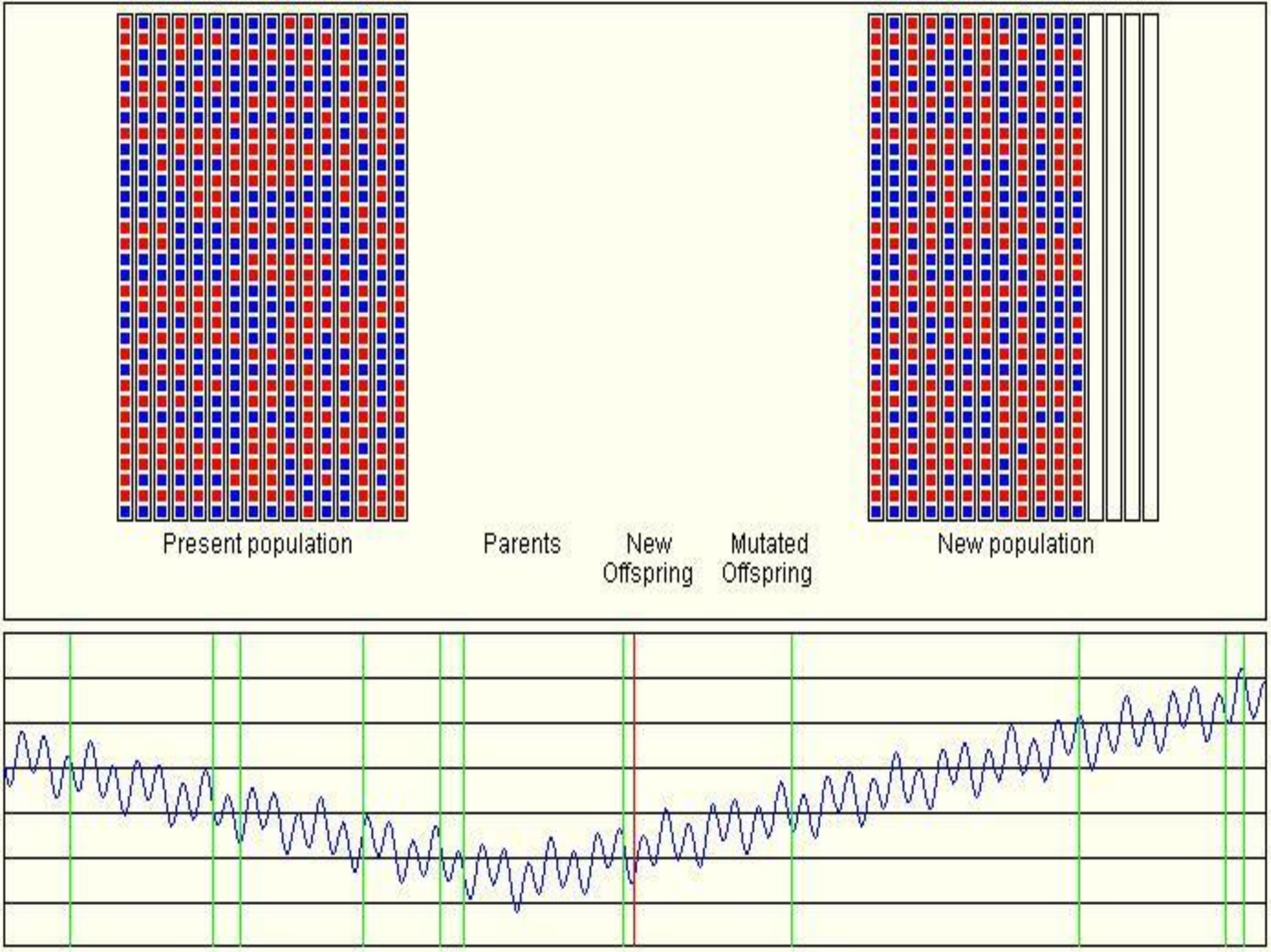
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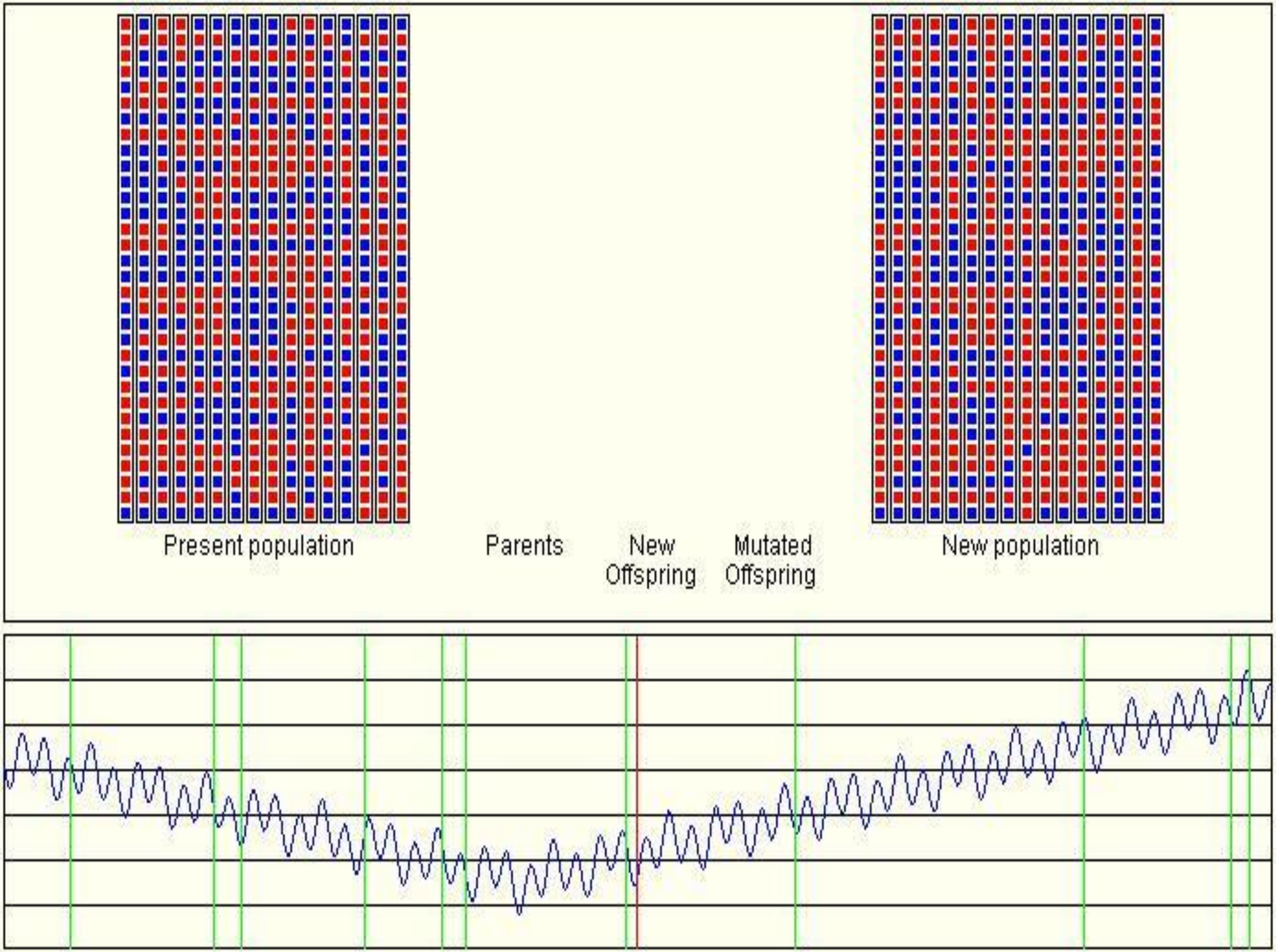
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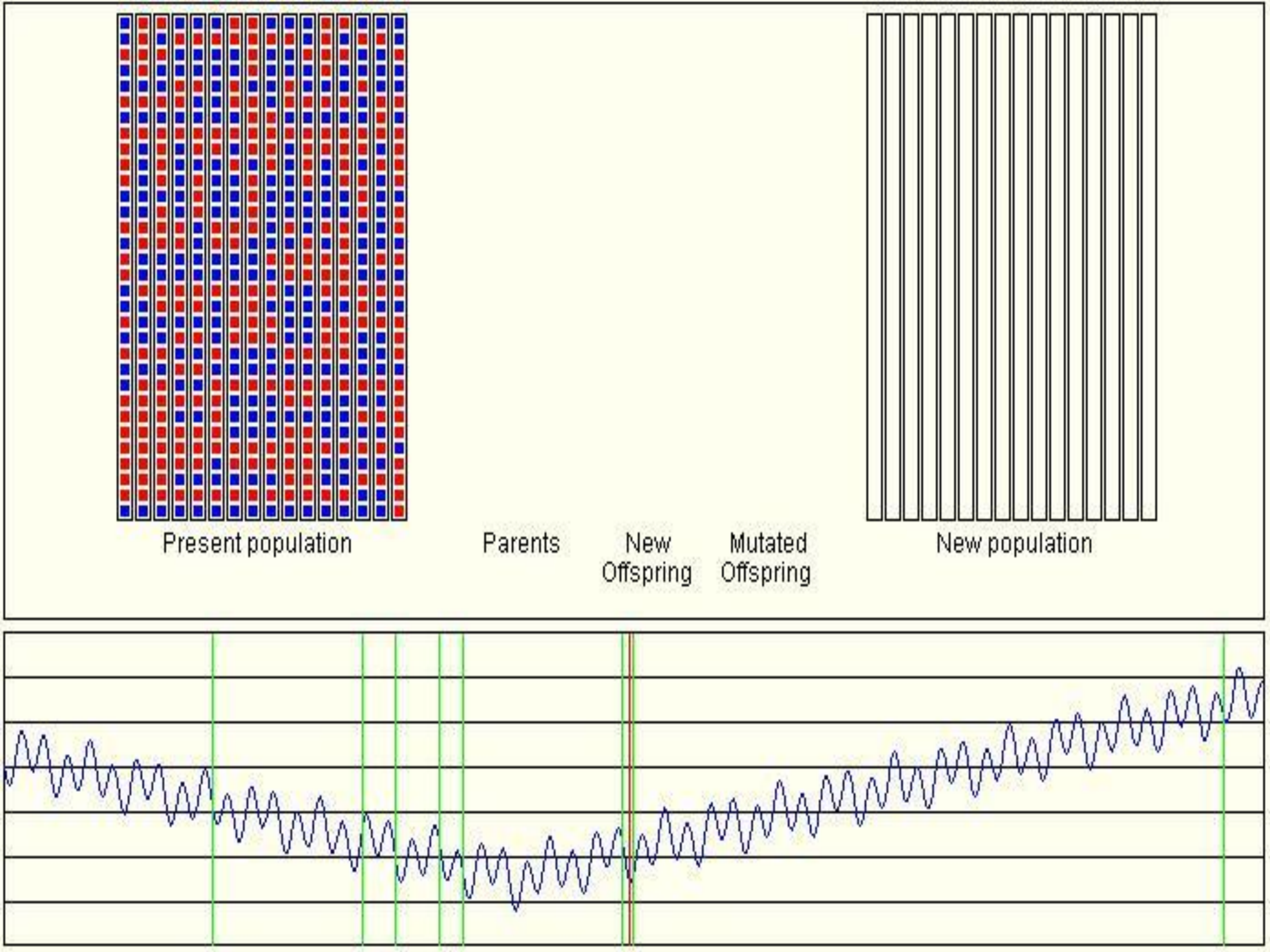
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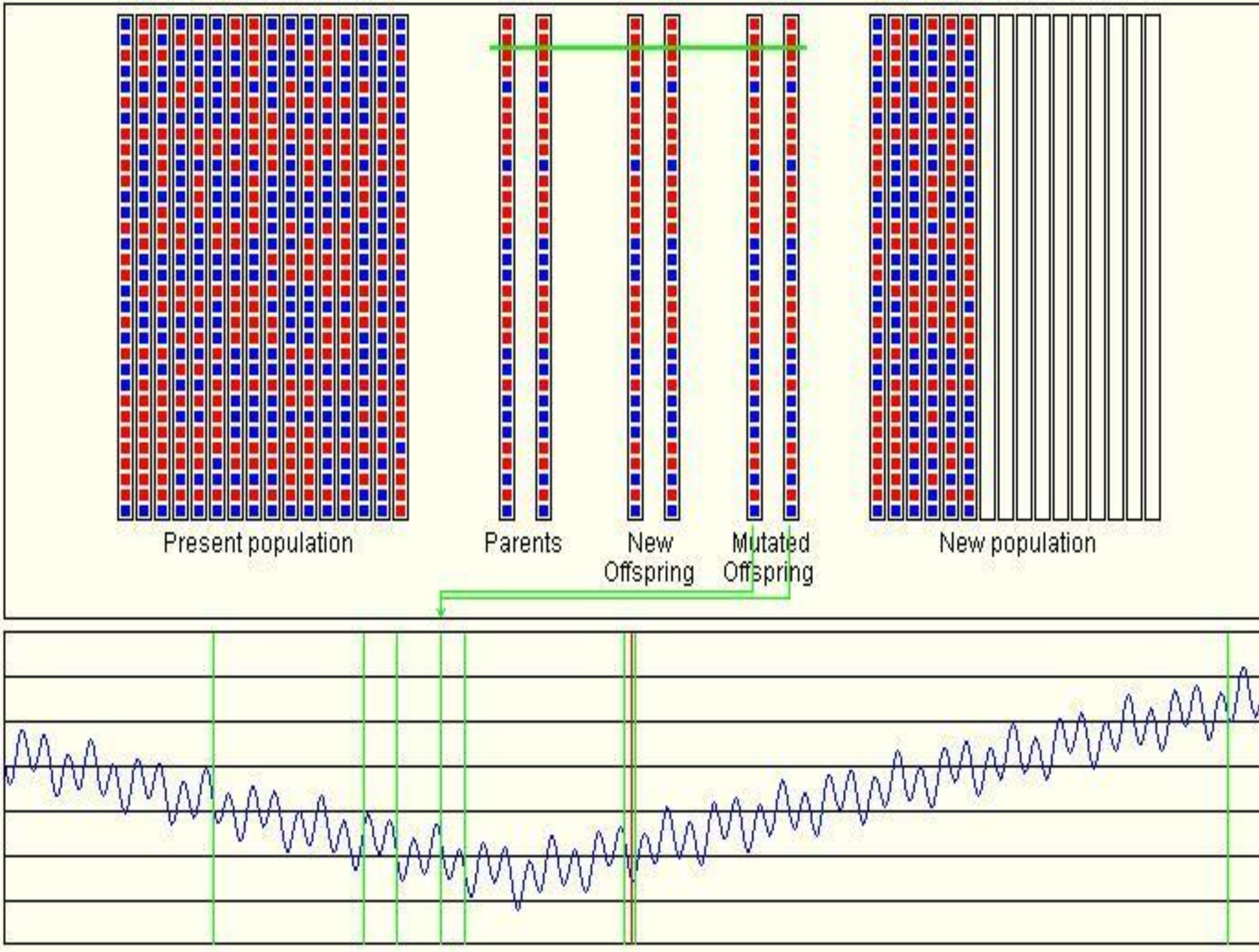
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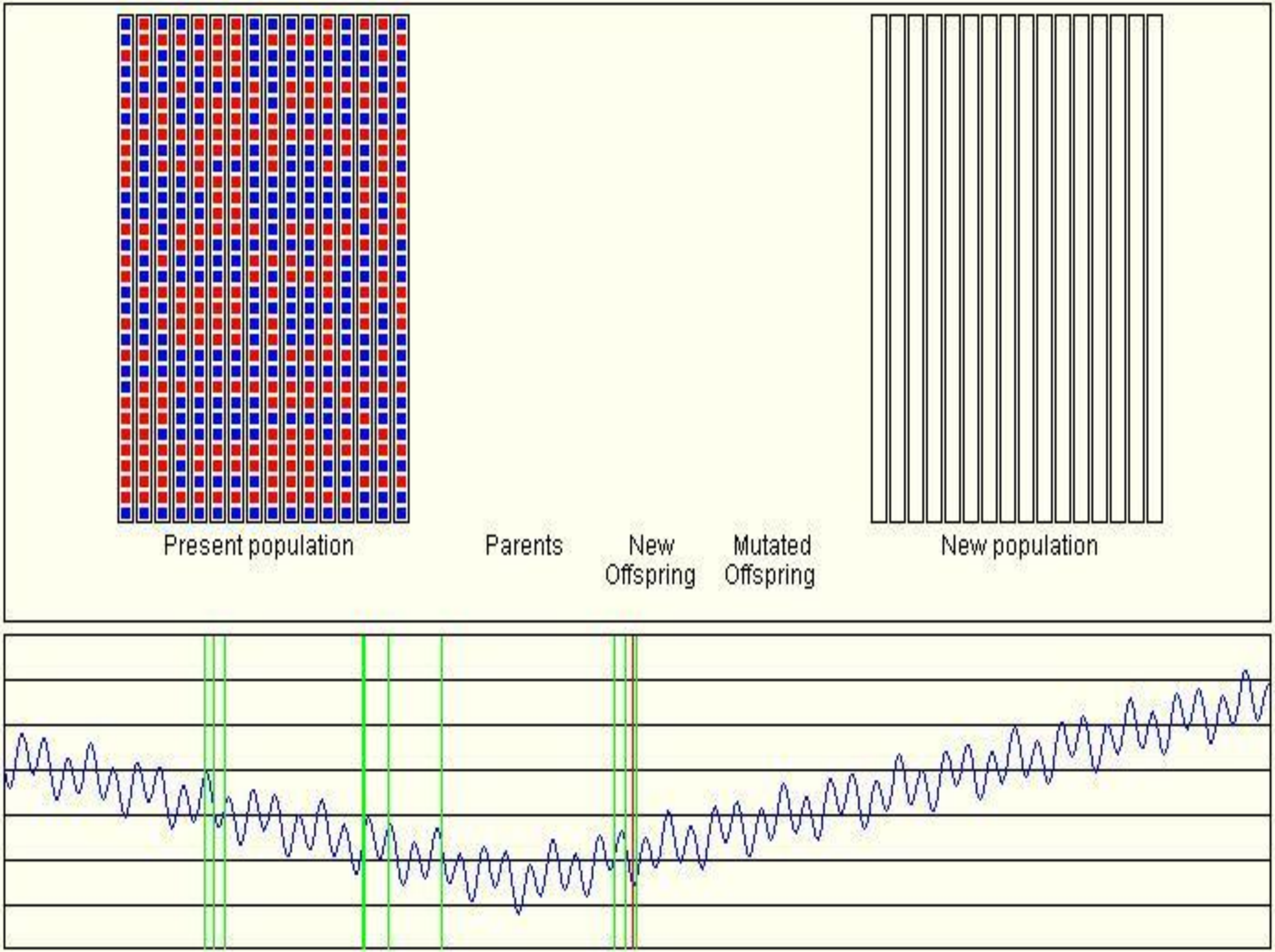
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Representation of genes (chromosome)

- Identify the simplest elements (Building block) found in a solution
- The number of these elements should be fixed and not very large
- X_i will be represented with a string of gene

We call it a string of chromosome.

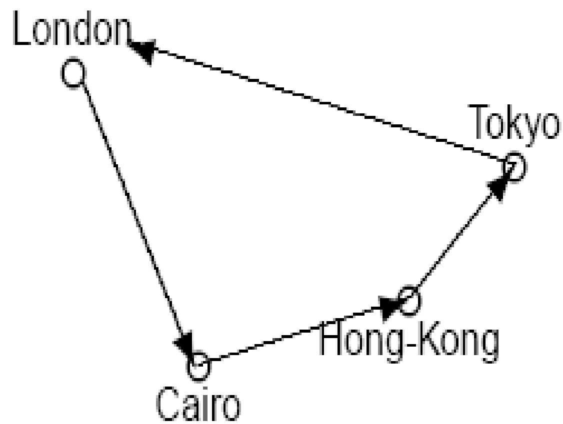
Example TSP

L London

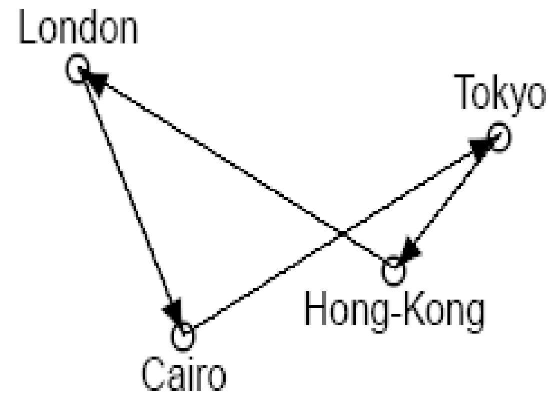
C Cairo

H Hong–Kong

T Tokyo



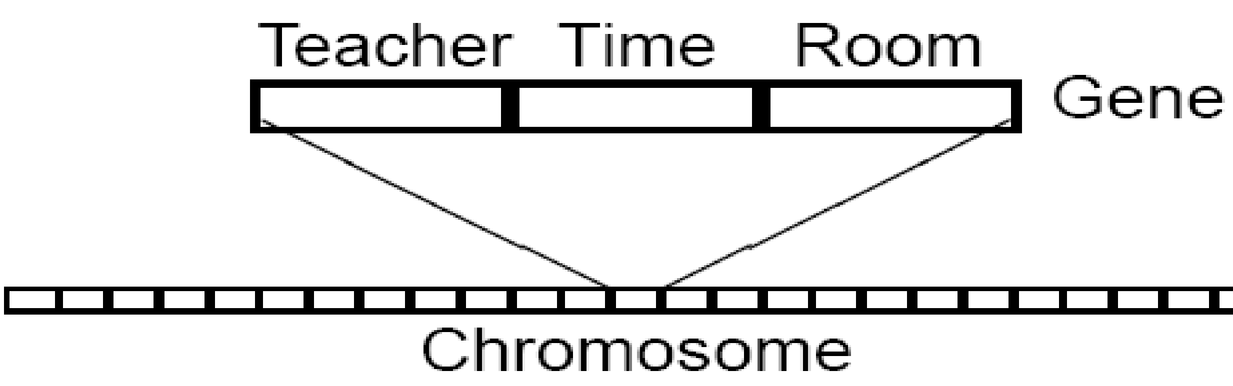
$$x_1 = LCHTL$$



$$x_2 = LCTHL$$

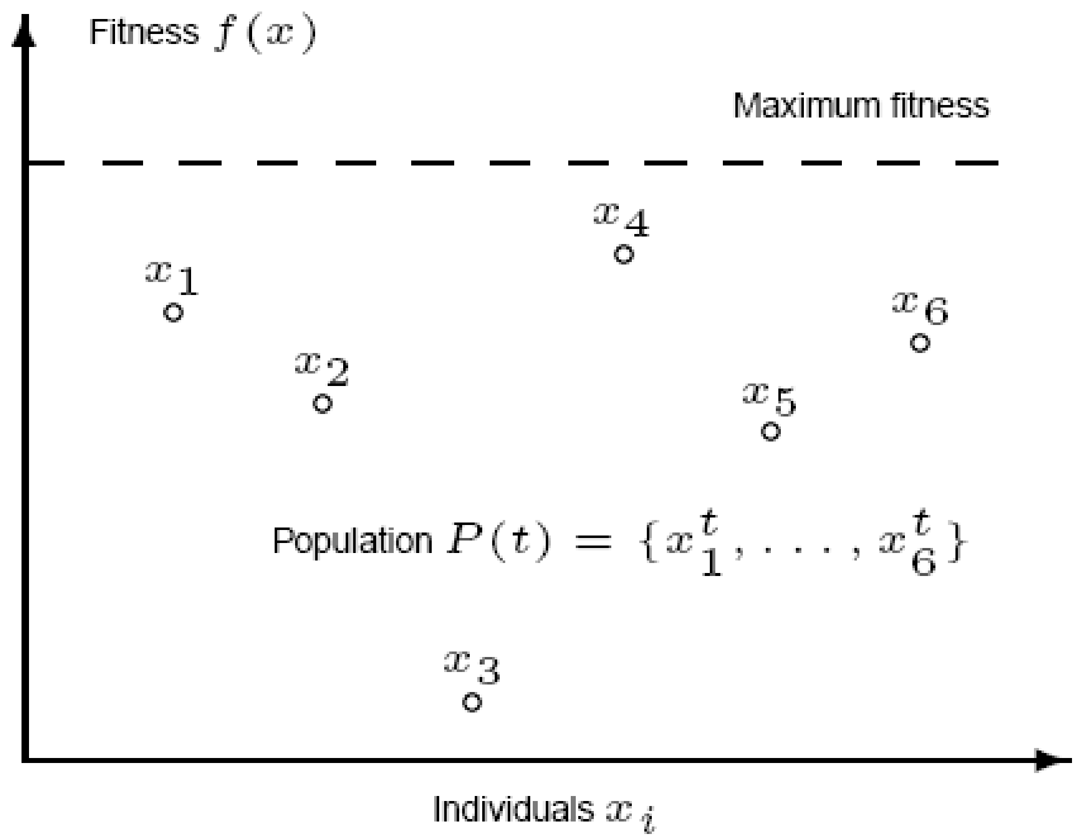
Example Time Table

Teacher	Time	Room
Prof. Newell	9:00am	Room B48
Dr. Ritter	11:00am	Room C52
Prof. Wood	1:00pm	
⋮	⋮	



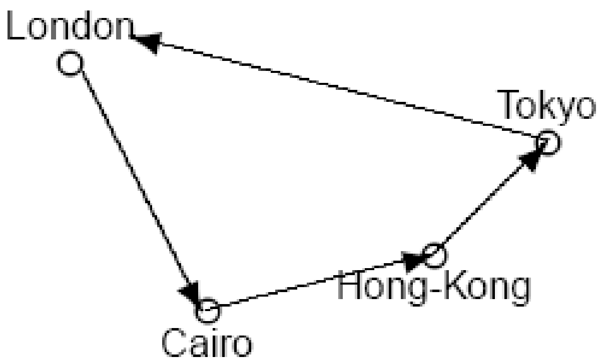
Fitness function

- A function that tell you how good the individual is.

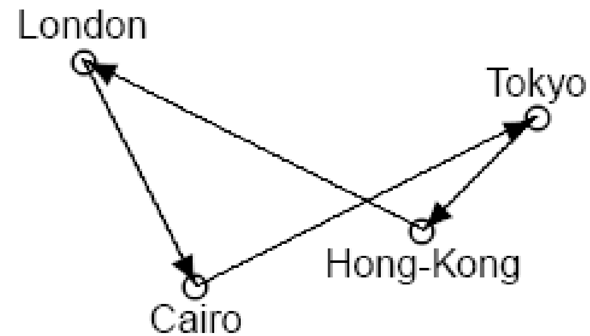


Example TSP

- X_1 better than X_2



x_1



x_2

$$\text{length}(x_1) \quad < \quad \text{length}(x_2)$$

$$f(x_1) \quad > \quad f(x_2)$$

SUMMARY OF GA

1. Choose the initial population
2. Select parent chromosomes
3. Perform crossover
4. Perform mutation
5. Evaluate fitness of the new population
6. Repeat 2 until satisfied

Pseudo-code algorithm

- Choose initial population
- Evaluate the fitness of each individual in the population
- Repeat
  - Select best-ranking individuals to reproduce
  - Breed new generation through crossover and mutation (genetic operations) and give birth to children
  - Evaluate the individual fitnesses of the children
  - Replace worst ranked part of population with offspring
- Until termination

Selection

- Select some of the population for reproduction:
  - Roulette Wheel selection: Probability selection from all population with probability proportional of their fitness
  - Ranked selection: few fittest individuals

Selection Methods

- Proportional (roulette) selection:
  - Probability of selection is proportional to the individual's fitness.

Fitness proportionate selection:

$$\Pr(h_i) = \frac{Fitness(h_i)}{\Sigma_{j=1}^{p} Fitness(h_j)}$$

- Ranking method:
  - All Individuals are sorted, and probabilities of their selection are according to their ranking rather than their fitness.
- Tournament selection:
  - Some number, e.g., 2, of individuals compete for selection
  - The competition step is repeated *popsize* times for each generation.
  - More diverse

CROSSOVER

- Replacing some genes in the parent by the corresponding genes of the other.

$$\begin{array}{rr|l} P_1 = & \mathbf{1\,0\,1} & \mathbf{0\,0\,1\,0} \\ P_2 = & 0\,1\,1 & 1\,0\,0\,1 \end{array} \Rightarrow \begin{array}{rr|l} O_1 = & \mathbf{1\,0\,1} & 1\,0\,0\,1 \\ O_2 = & 0\,1\,1 & \mathbf{0\,0\,1\,0} \end{array}$$

MUTATION

- Randomly chose gene and replace it with other gene
- Mutation help to add diversity to the population
- Help avoiding local maximum

$$O_1 = 1\,0\,\underline{1}\,1\,\underline{0}\,0\,1 \quad \Rightarrow \quad O_1 = 1\,0\,\underline{0}\,1\,\underline{1}\,0\,1$$

Why GA Work

- Why should one believe that this is going to result in an effective form of search or optimization?
  - Parallel search, since we check several solution at once
  - Fitness out bad solution from good one

GA: other applications

- Nurse Rostering with Genetic Algorithms
- Solving of the uncapacitated warehouse location problem
  - Shipping goods from warehouse to clients
  - Best solution : minimum cost (the sum of storage cost and cost of shipment)
- Volumetric Segmentation of Brain Images Using Parallel Genetic Algorithms (convert 2D pictures into 3D pictures to see abnormality in brain image)

GA: other applications (2)

- GA-based exam timetabling
- A Genetic Algorithm for Resource-Constrained Scheduling
- Using Genetic Programming To Evolve an Algorithm For Factoring Numbers
  - Modern cryptography is based on the assumption that factoring numbers takes a long time.

Research trends

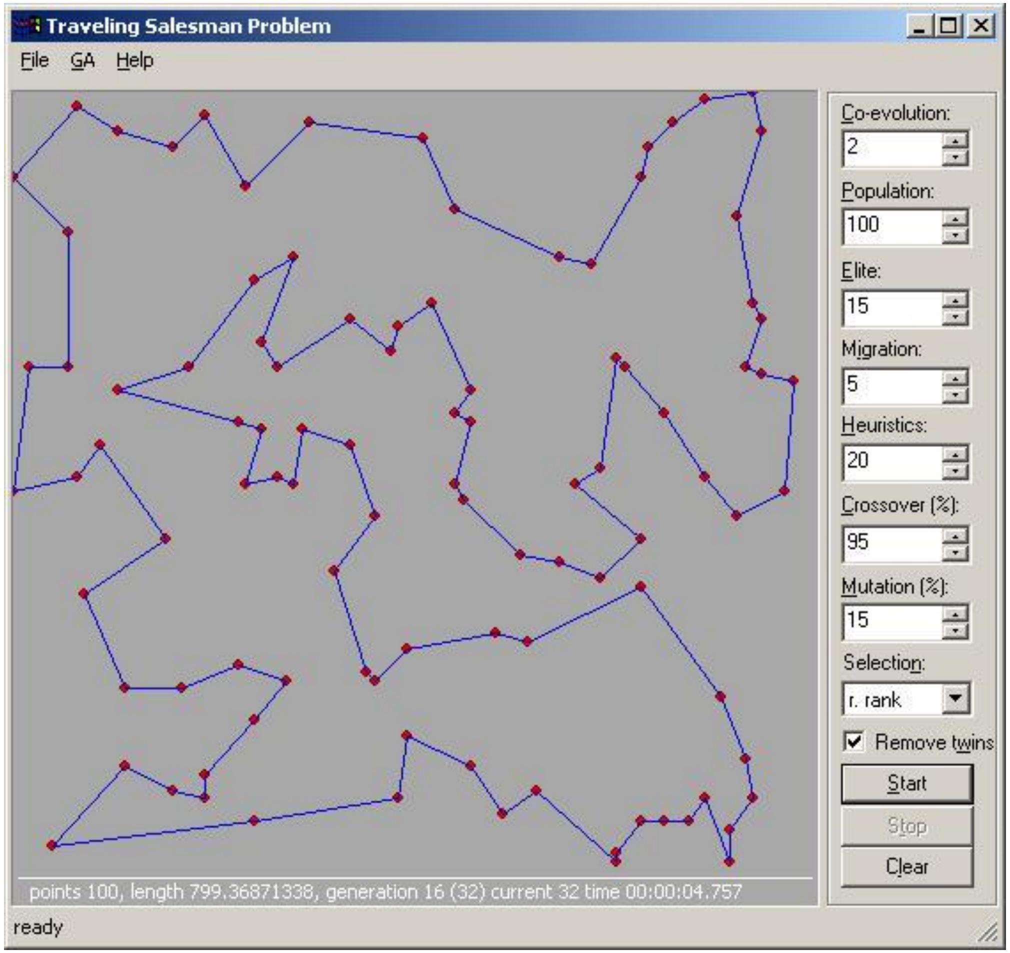
- Accelerating GA processing
  - using GRADIENT Search
  - Parallel GA
- Improve finding more optimized solutions

Other new technique

- **Ant colony optimization**
  - Advantage : the graph may change dynamically
- **Harmony search**
  - Does not need initial vector, and no hard calculations
- **swarm optimization**

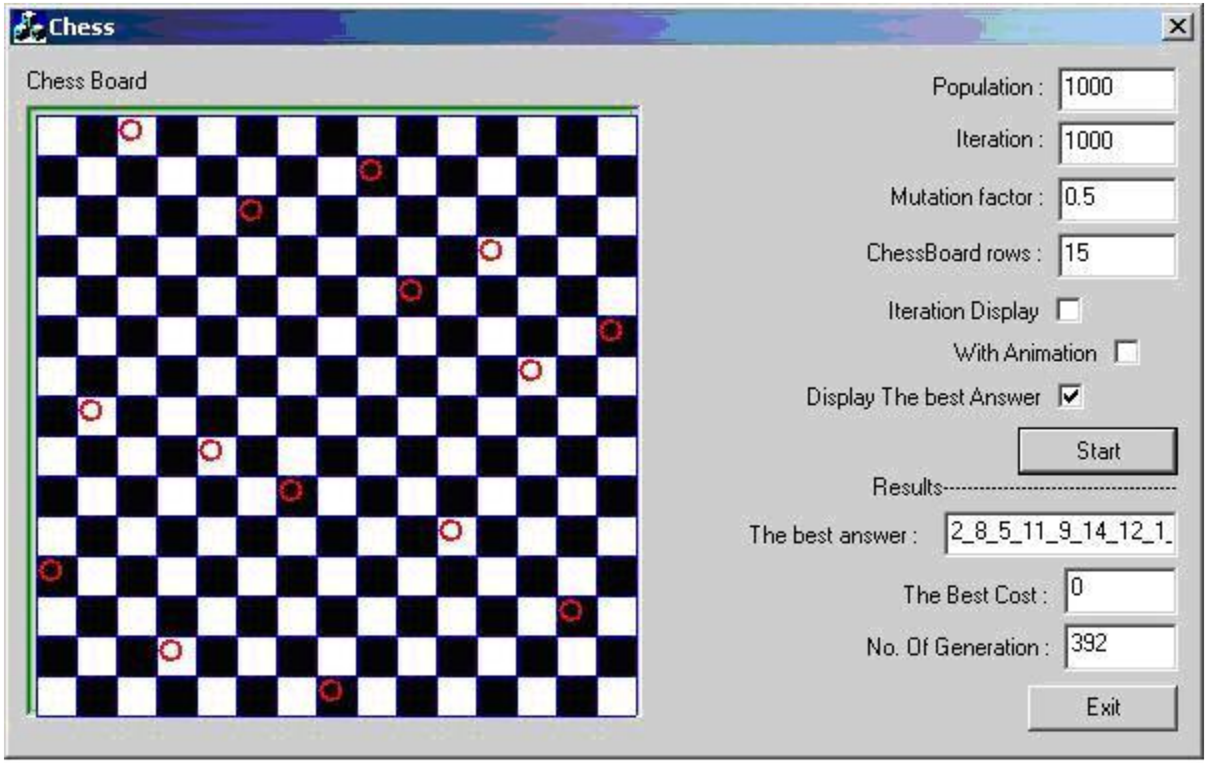
Examples

- VC++ Example on TSP



Examples

- how to place 8 queens on an ordinary chess board so that none of them can hit any other in one move



Networking & Security

- Immune System Model for Detecting Web Server Attacks using genetic algorithm

- Using Genetic Algorithm in Cryptanalysis

Cryptanalysis

- the practice of **codebreaking**
- this involves finding the secret key
  - *Cipher text-only*: the cryptanalyst has access only to a collection of cipher texts
  - *Known-plaintext*: the attacker has a set of ciphertexts to which he knows the corresponding plaintext
  - *Chosen-plaintext*: the attacker can obtain the ciphertexts (plaintexts) corresponding to an arbitrary set of plaintexts (ciphertexts) of his own choosing.

Methods of cryptanalysis

- **Brute force attack**：try all possible keys
- **Linear cryptanalysis**：finding affine approximations to the action of a cipher
- **Differential cryptanalysis**：study of how differences in an input can affect the resultant difference at the output
- **Timing attack**：analyzing the time taken to execute cryptographic algorithms
- …….