Thesis Presentation

Topic: Optimization of Travelling Salesman Problem (TSP) using Artificial Immune System (AIS)

Presenters

- Ziad Taher
  - 09.02.04.091
- Raghad Rowaida
  - 09.02.04.101
- Nusrat Jahan
  - 09.02.04.107
- Noshin Yeasmin
  - 09.01.04.001

Contents

- BIS
  - Components
  - Working process
  - Terms
  - Theories
- AIS
  - Definition
  - Significance
  - Application areas
  - Layered structure
- TSP
  - Problem definition
  - Mathematical representation
  - Background Study
  - Why use AIS
  - How to solve
- Our goal
- Work progress
- Future target

Biological Immune System (BIS)

The immune system is a very complex “hunt and destroy” mechanism that works at the cellular level in our bodies. There are two types of immunity.

- Innate Immune System
  - Prevents Immune System from attacking its own body cells. Only attacks previously known antigens.
- Adaptive Immune System
  - Can kill new unmet invading cells/pathogens. Can adapt with new situation.

Components of BIS

The BIS consists of a multitude of cells and molecules which interact in a variety of ways to detect and eliminate infectious agents (pathogens). Those are:

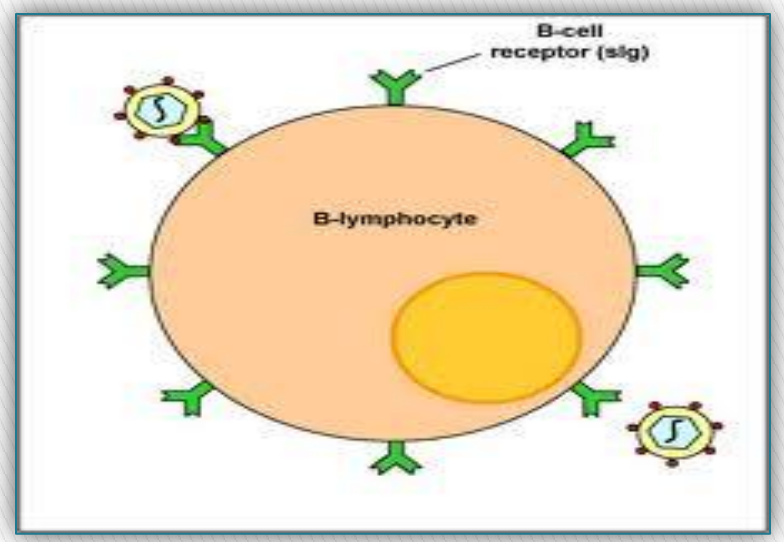
Immune components:

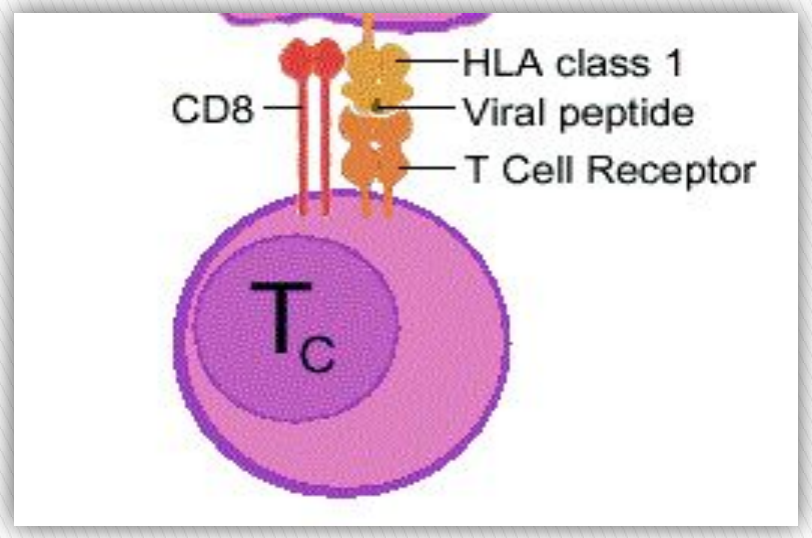
- B-cell
- T-cell
- Antibody/BCR
- TCR

Invading components:

- Pathogen
- Antigen

Components of BIS





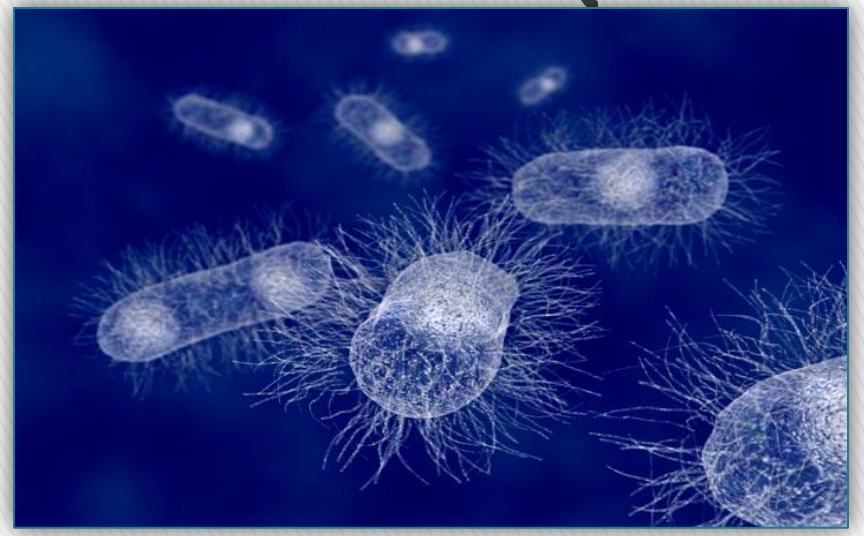
B-cell:

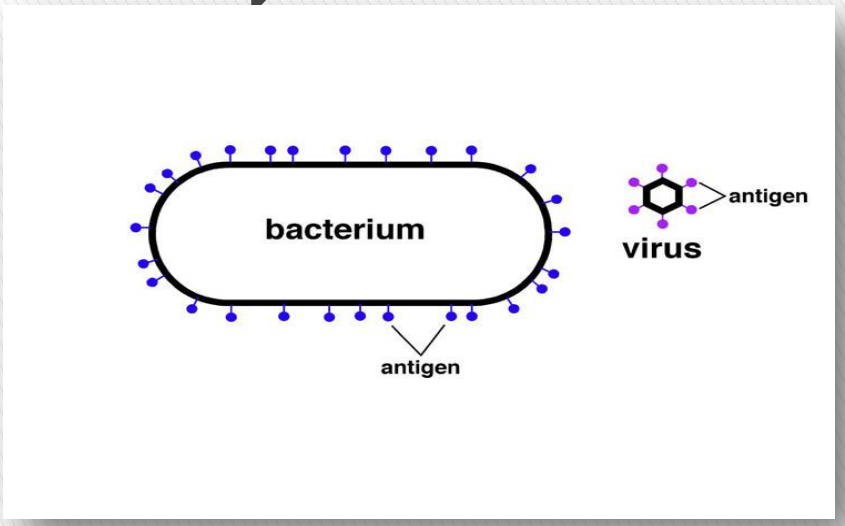
Fundamental Immune cell produced from bone marrow

T-cell:

Another fundamental Immune cell produced from bone marrow and migrates to Thymus

Components of BIS (continued)





Pathogen:

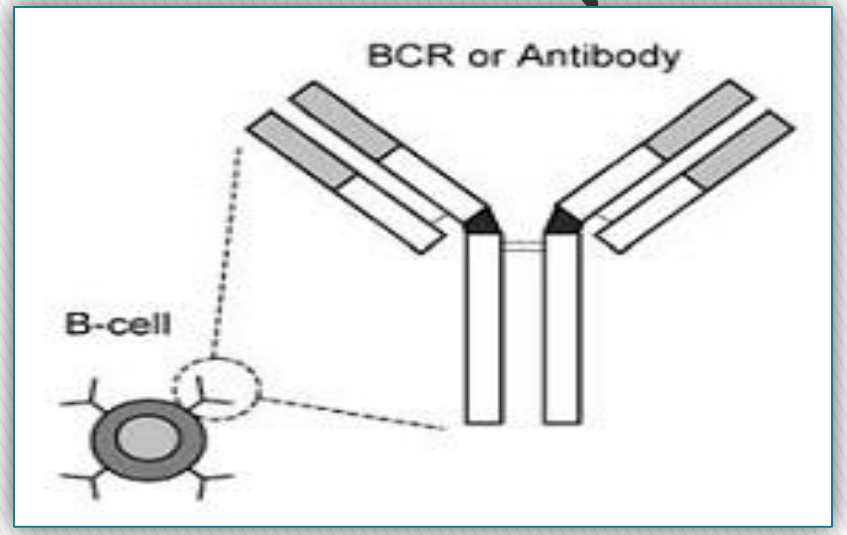
A bacterium, virus, or other microorganism that can cause disease. . Ex:

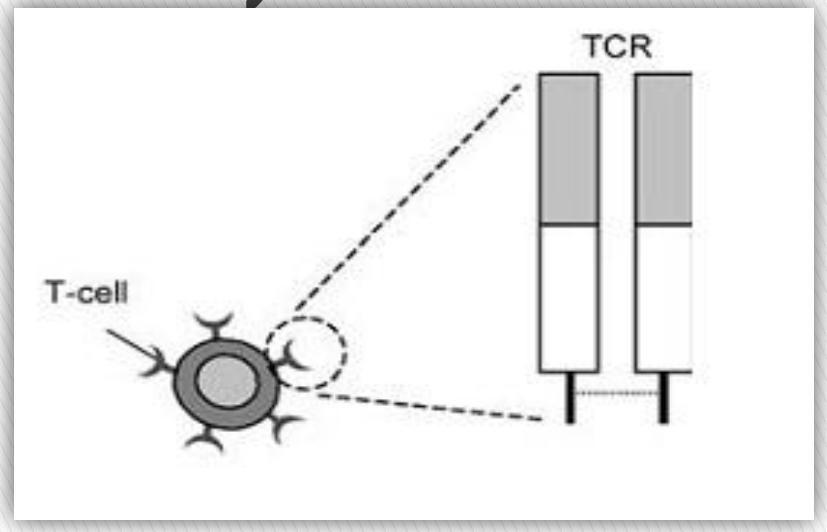
viruses, bacteria, fungi etc

Antigen:

Specific protein of pathogen which can be recognized by antigen.

Components of BIS (continued)





Antibody:

B-cell receptor that is a blood protein, produced in response to and counteracting a specific antigen.

TCR:

T-cell receptor that reacts upon antigens directly interact with pathogen MHC.

Important Terms of BIS

- Affinity mutation:

  It is the process by which B cells produce antibodies with increased affinity for antigen during the course of an immune response.

- Affinity:

  Antibody-antigen recognition and matching rate.

- Crossover:

  A characteristic resulting from the exchange of genetic material between homologous chromosomes during meiosis in antibody.

Important Terms of BIS (continued)

- Mutation:

  Changes in the DNA sequence which are usually caused by copying errors during replication that further lead to base substitution, insertion, or deletion of one or more base pairs.

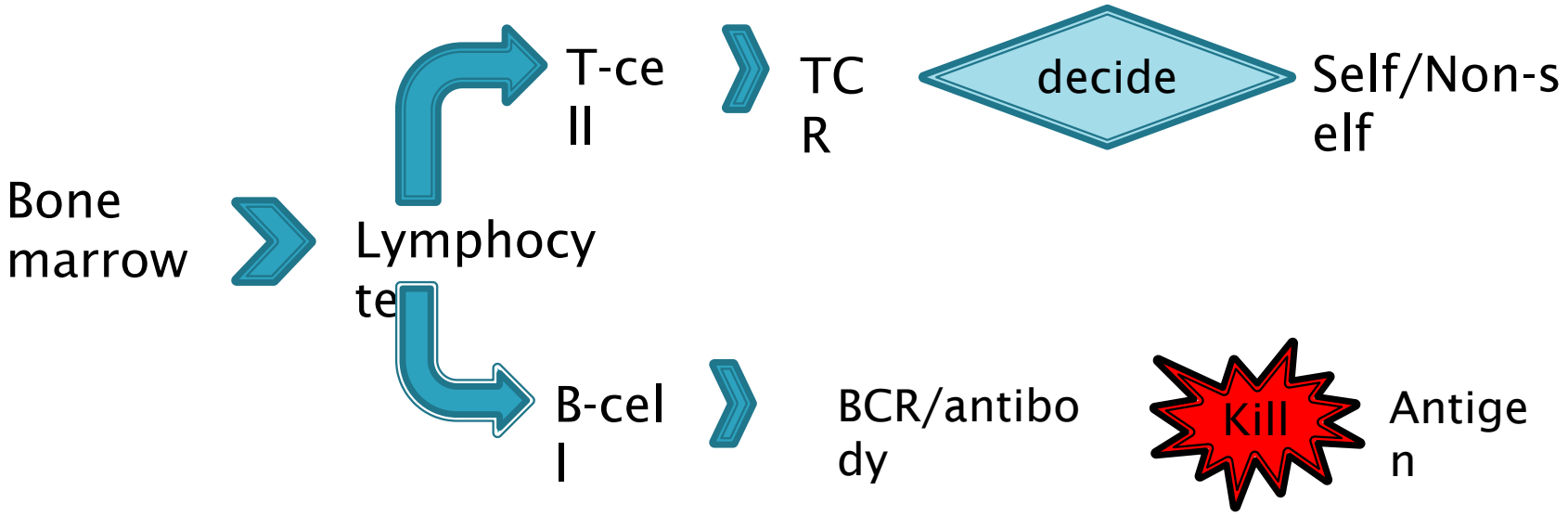
- Cloning:

  The process of creating an exact copy of a biological unit from which it was derived, especially by way of biotechnological methods.

General Working Process (BIS)

- It works by keeping track of all of the substances normally found in the body
- Any new substance in the body that the immune system does not recognize raises an alarm
- It causes the immune system to attack it

Flow Chart (BIS)



Biological Immune System

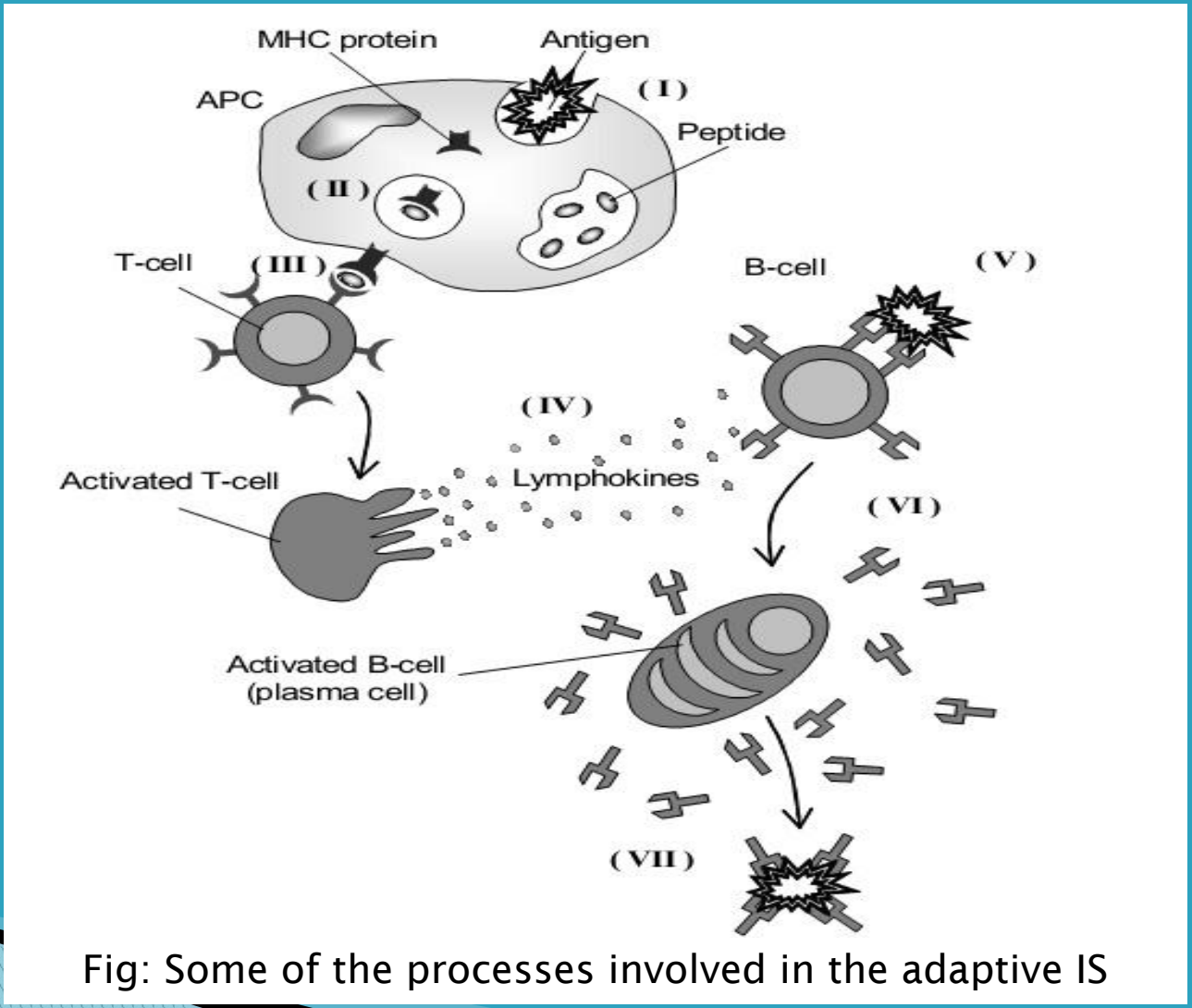


Fig: Some of the processes involved in the adaptive IS

Biological Immune Theories

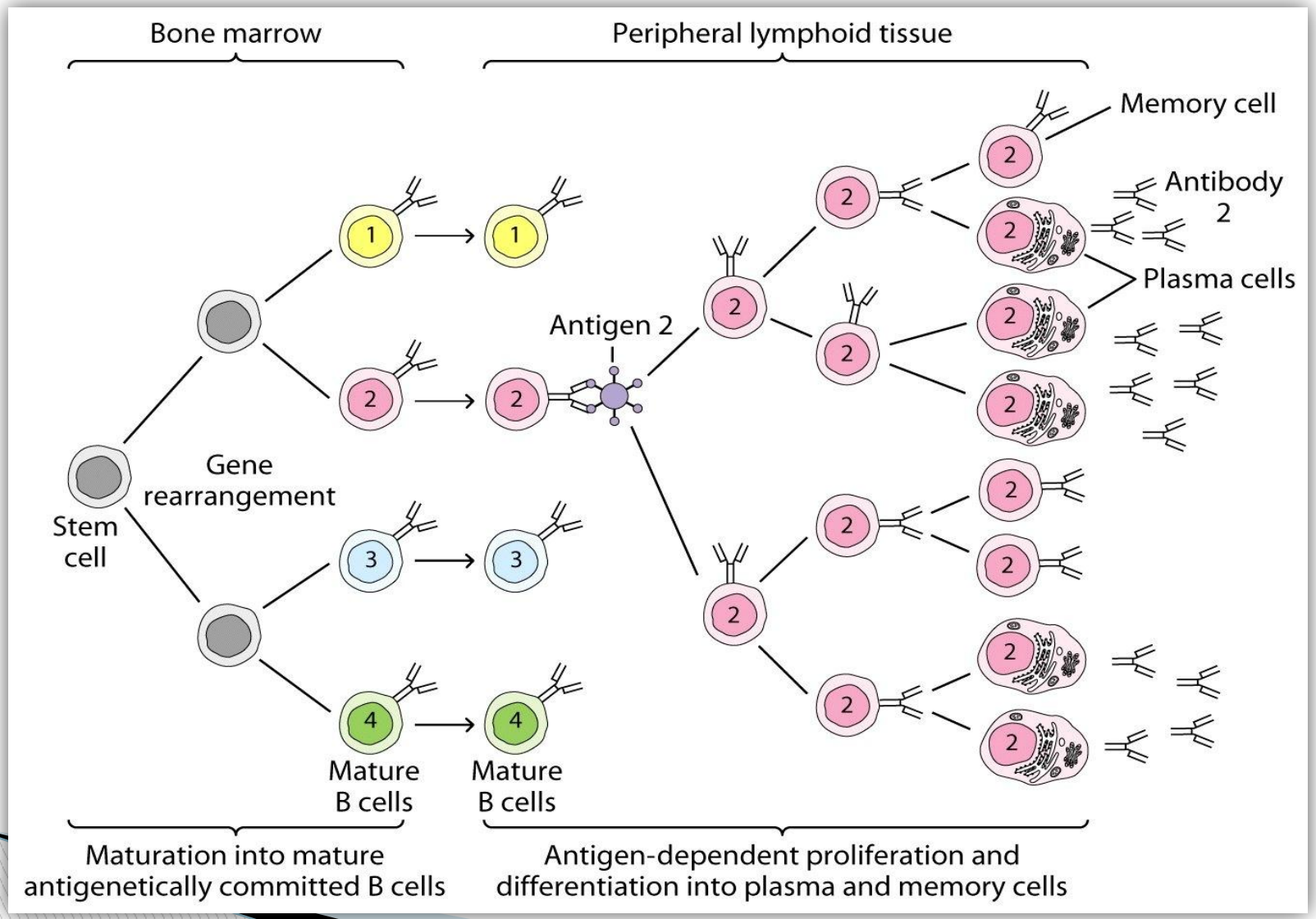
- Clonal Selection Theory
  - It says only those cells that recognize the antigen proliferate, thus being selected against those that do not.
- Negative Selection Theory
  - It deals with the BIS's ability to detect unknown antigens while not reacting to the self cells
- Idiotypic Network Theory
  - It says if two B cells are connected if the affinities they share exceed a certain threshold.

Clonal Selection Theory

Features of clonal selection:

- Selection of cells with higher affinity as parent cell and copying (clone) as new offspring;
- Crossover & mutation among new offspring according to their respective mutation factor;
- Elimination of newly differentiated lymphocytes carrying self-reactive receptors;

Clonal Selection Process



Artificial Immune System

- **Artificial immune systems** (AIS) are a class of computationally intelligent systems inspired by the principles and processes of the vertebrate immune system. The algorithms typically exploit the immune system's characteristics of learning and memory to solve a problem.

Significance Of AIS

- Easier application
- Robustness
- Memory
- Feature extraction
- Better parallel processing
- Highly adaptive and reactive

Application Fields

- Optimization
- Computer Security
- Data Mining & Retrieval
- Anomaly Detection
- Pattern Recognition
- Adaptive Control
- Robotics
- Autonomous Systems
- Engineering Design Optimization

Layered Structure of AIS

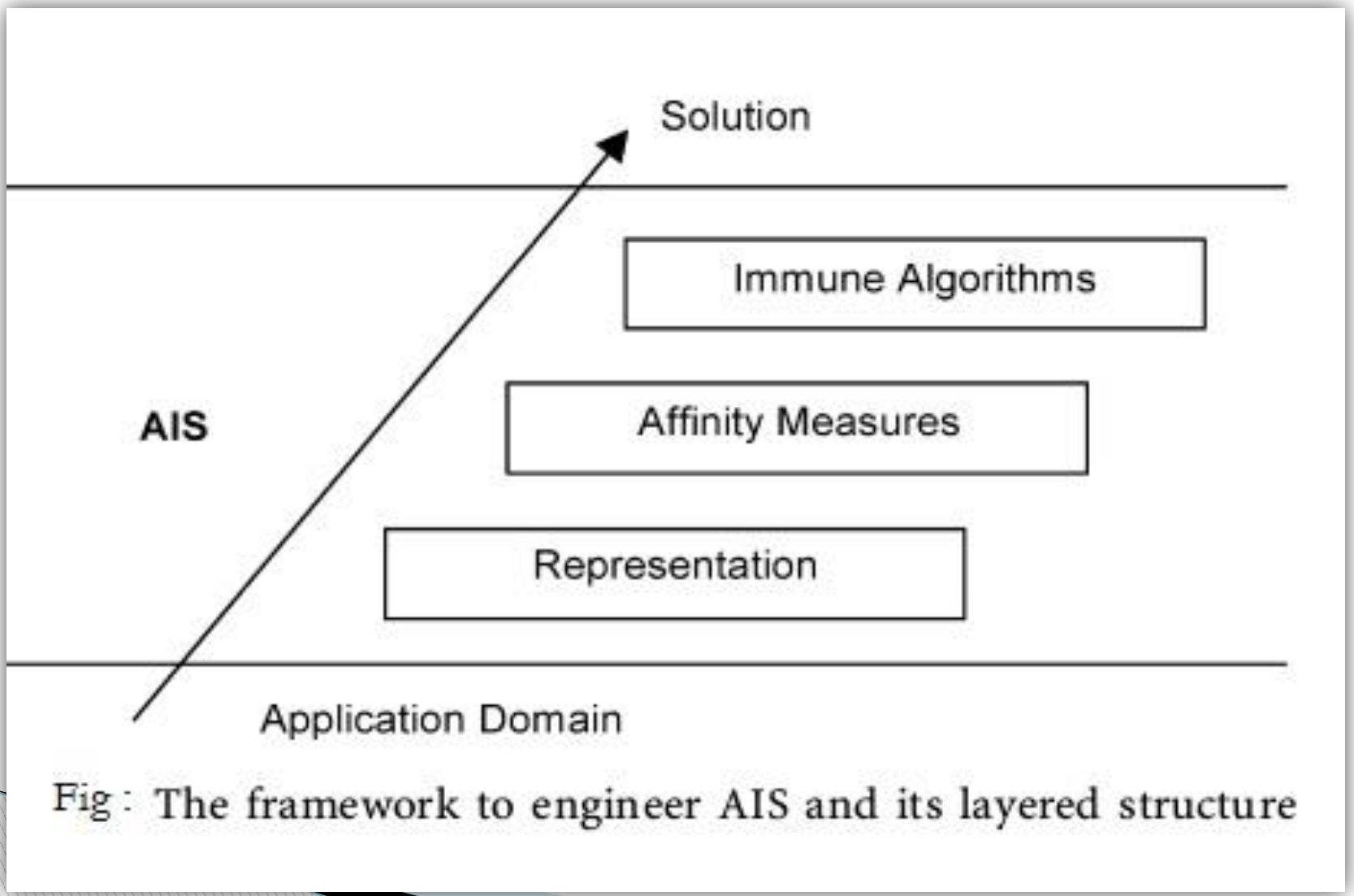
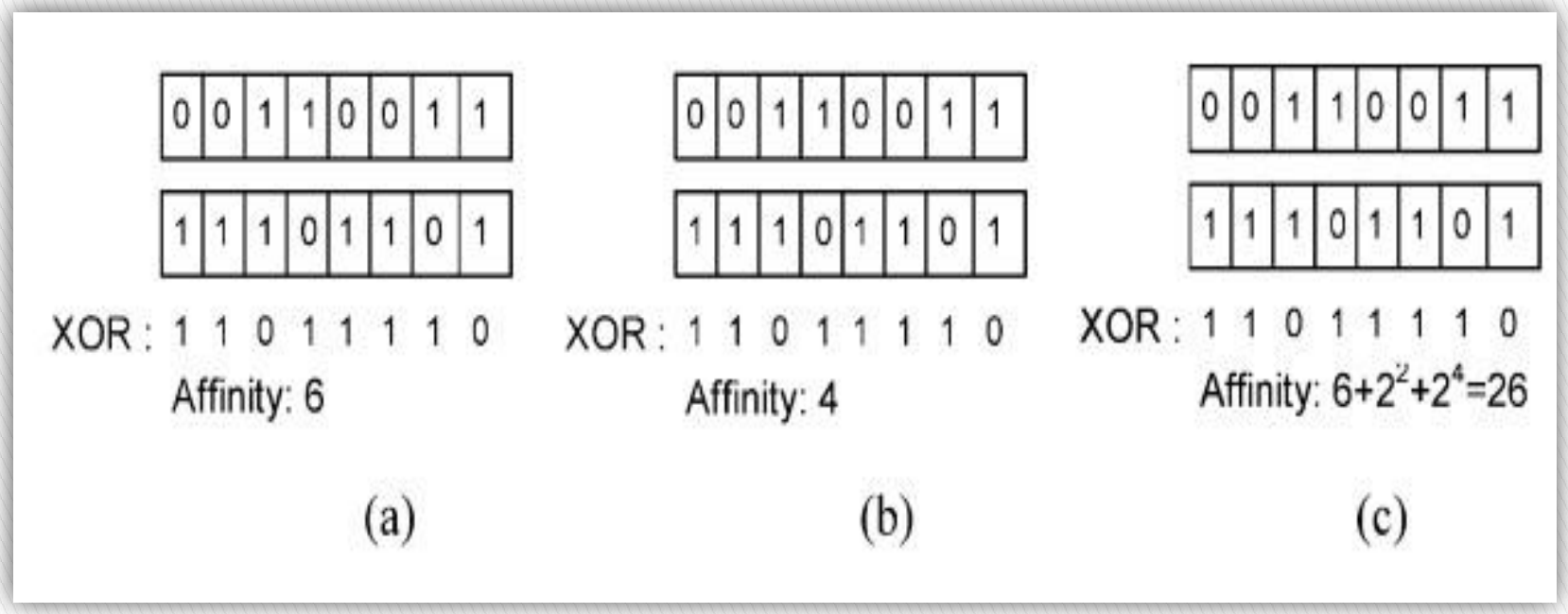


Fig : The framework to engineer AIS and its layered structure

BIS equivalent representation in AIS

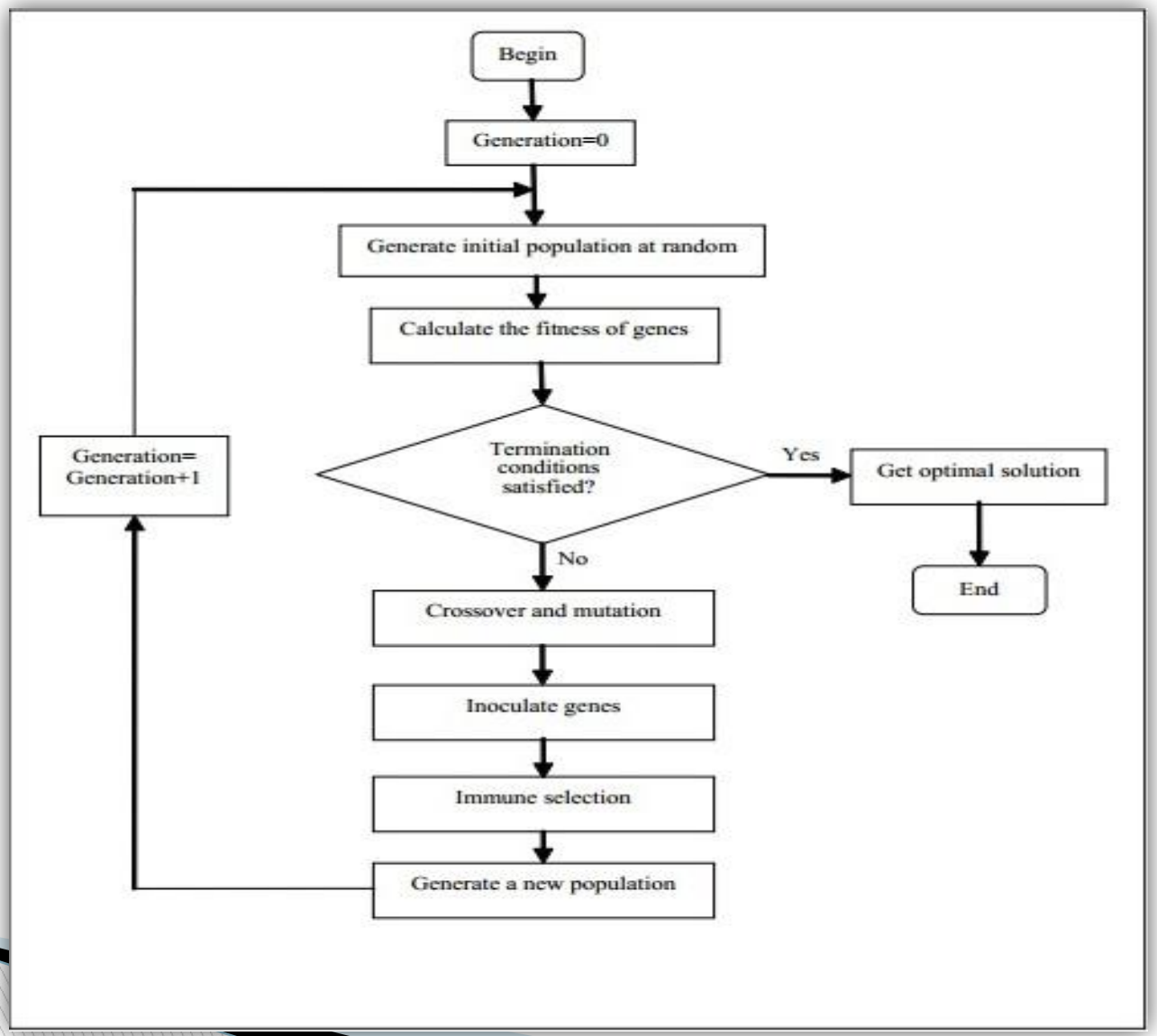
BIS components	AIS components
Antigen	Given problem
Antibody	Agent program
Affinity mutation	Fitness function
Clonal selection	Artificial clonal selection

Affinity Measurement In AIS



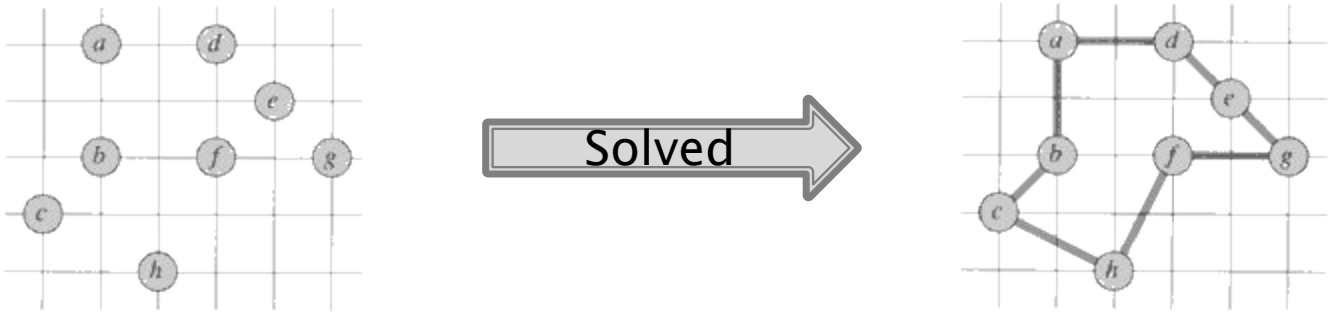
AIS assume a binary shape-space in which bitstring represent the molecules. The affinity between an antibody bitstring and an antigen bitstring can be determined by using Hamming distance(a), Total number of complementary region(b), r-contiguous bit rule(c).

AIS Algorithm



Travelling Sales-man Problem (TSP)

The idea of the traveling salesman problem (TSP) is to find a tour of a given number of cities, visiting each city exactly once and returning to the starting city where the length of this tour is minimized. Example:



TSP cost calculation

- Set of cities, C = {C1, C2, C3… Cn}
- The distance function of a pair of cities d(Ci,Cj)
- Sequence to visit/tour, (C1,C2,C3… Cn)

- $\text{Cost} = \sum_{i=1}^{n} \text{d}(\text{Ci}, \text{Ci} + 1) + \text{d}(Cn, C1)$

Background Study

- It’s an NP-Hard problem
- There is no such algorithm for solving TSP in polynomial time.
- The complexity grows exponentially with a growing number of cities.
- It is subject to meta heuristic algorithm.

Application of TSP

- **Planning**, **logistics**, and the **manufacture of microchips**.
- Modified sub-problem in many areas, such as **DNA sequencing**.
- Benchmark for **optimization techniques**.
- Building a **Mechanical arm.**
- Designing **Integrated circuit.**

Our Goal

- Finding a cost efficient relatively better suboptimal solution to solve TSP problem, which is an NP-hard problem using Artificial Immune System.

Why solving TSP using AIS

- TSP is a NP hard problem and its computational complexity grows exponentially with the growth of cities. So we need meta-heuristic approach.
- AIS provides sub optimal meta-heuristic result in a polynomial time.

Work Progress

- Studied several papers on the related field and gathered information.
- Established an idea to solve the problem using AIS
- Studied benchmark TSP problem from TSPLIB to test our proposed idea
- Created a simulator to calculate & visualize our proposed algorithm

TSP Equivalent AIS Representation

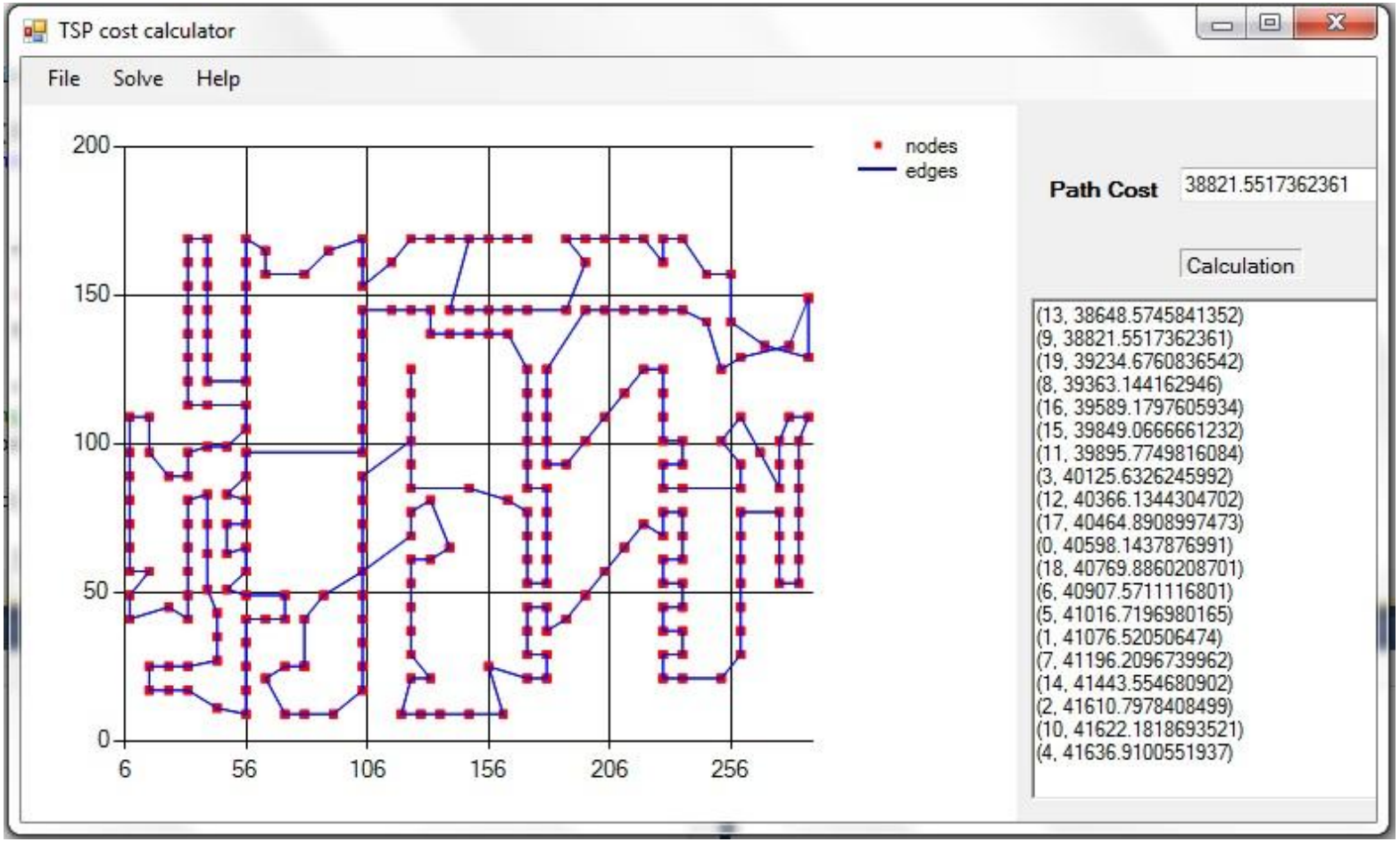
Immune system	Optimization problem
Pathogen	Problem (environment of antigens) (e.g., city graph wherein nodes represent antigens)
Immune response	Solution (e.g., shortest path)
Antibody	Agent program
Clonal selection	Creating new agents in order to explore the environment (i.e., proliferation)
Affinity mutation	Cost function evaluation

Our Proposed Method

```
1.  Init:   N = Initial_tour_generation();
2.  Eval:  Evaluate_tour_sequence(N, Cost);
3.  Cost_wise_sort(N, Cost);
4.  F = Select_M_fittest(N, Cost);
5.  Cloning(F, cl);
6.  Crossover(cl)
7.  Mutate(cl);
8.  Foreach(clone in cl)
9.  {
10.    Evaluate(clone, Clonal_cost);
11. }
12. Cost_wise_sort(cl, Clonal_cost);
13. If(Clonal_cost < Cost)
14. {
15.    Replace(N-F, cl)
16.    Goto  Eval;
17. }
18. Else
19.    Goto  Init;
```

Pseudo code for solving TSP

Our Simulation



Screen shot: Random solution of standard TSP problem

Future Work Proposal

- Establishing a full tested method to solve TSP
- Creating a TSP solver simulator

References

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   - U. Aickelin and D. Dasgupta
2. Artificial Immune System and Its Applications
   - Prof. Ying TAN
3. Artificial immune systems as a novel soft computing paradigm
   - L. N. de Castro, J. I. Timmis

Question?