Computational Intelligence

Artificial Immune System

Unit # 12

Artificial Immune Systems (Source: Wikipedia)

- Artificial Immune Systems (AIS) is a sub-field of Biologically-inspired computing that concerns with abstracting the structure and function of the immune system to computational systems, and investigating the application of these systems towards solving computational problems from mathematics, engineering, and information technology.

History

- AIS began in the mid 1980s with Farmer, Packard and Perelson's (1986) and Bersini and Varela's papers on immune networks (1990).
- However, it was only in the mid 90s that AIS became a subject area in its own right.

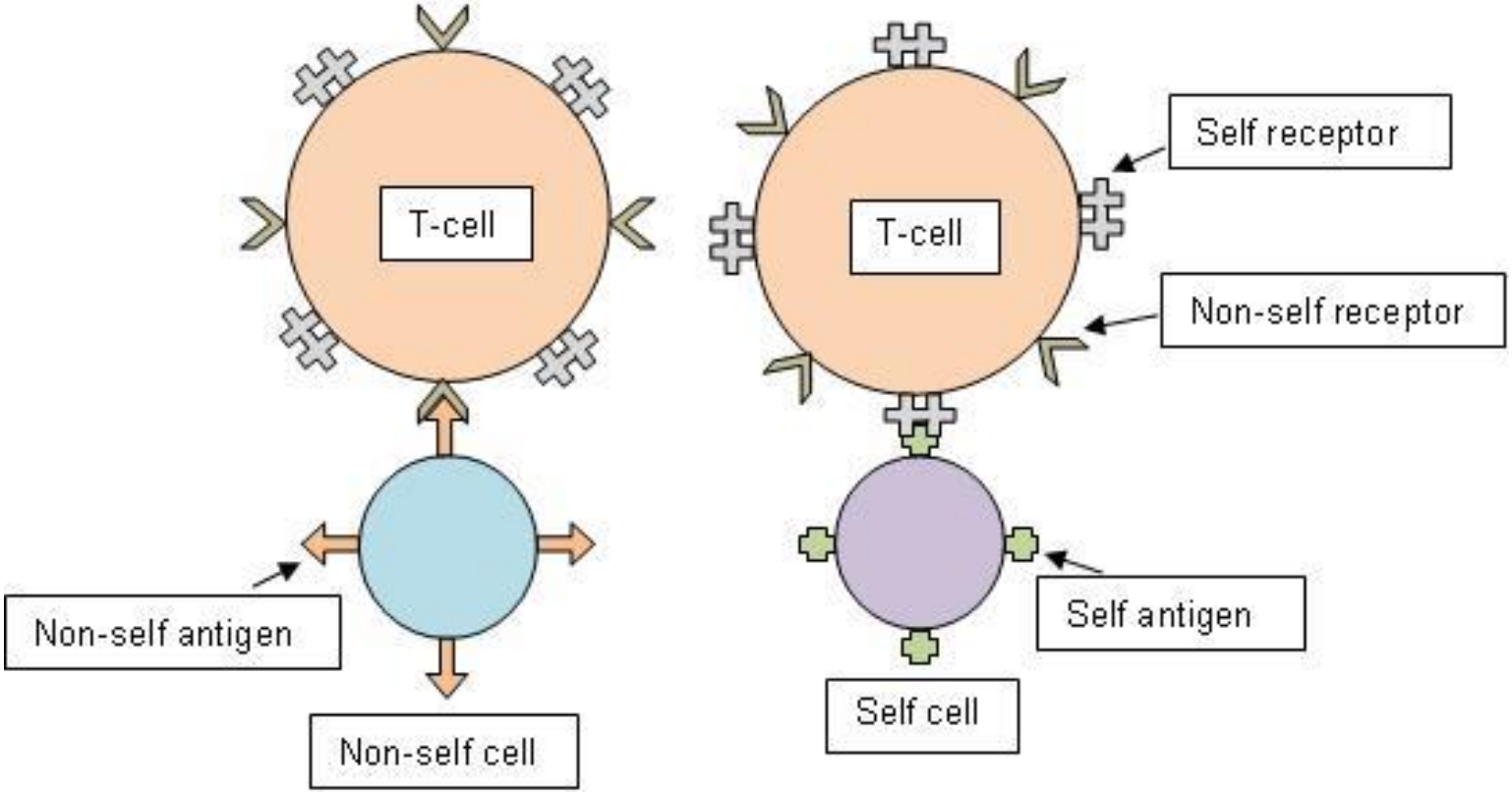
Inspiration

- AIS is inspired by the working of immune systems.
- The immune system is comprised of an intricate network of specialized tissues, organs, cells and chemical molecules.
- The capabilities of the natural immune system include the ability to **recognize, destroy and remember** an almost unlimited number of pathogens (foreign or non-self objects that enter the body, including viruses, bacteria, multi-cellular parasites, and fungi), and also to protect the organism from misbehaving cells in the body.

Working of Immune System

- To assist in protecting the organism, the immune system has the **capability to distinguish between self and non-self**.
- Critically, the system does not require exhaustive training with negative (non-self) examples to make these distinctions, but can identify a pathogen as being non-self even though it has never been encountered before.

Self vs Non-self



https://gravesimmunesystem.weebly.com/self-and-non-self.html

Working of Immune System (Cont'd)

- Both the innate and acquired immune systems are comprised of a variety of molecules, cells and tissues.
- The most important cells are leukocytes (white blood cells) which can be divided into two major categories: phagocytes and lymphocytes.
- Lymphocytes circulate constantly through the blood, lymph, lymphoid organs and tissue spaces.
- A major component of the population of lymphocytes is made up of B and T cells.

Working of Immune System (Cont'd)

- These cells are capable of recognizing and responding to certain antigen (foreign molecules) patterns presented on the surface of pathogens.
- Antigens are not the invading pathogens themselves, rather they are molecular signature expressed by the invading pathogen.

Key Terms

Component	Definition
Pathogens	Foreign bodies including viruses, bacteria, multi-cellular parasites, and fungi.
Antigens	Foreign molecules expressed by a pathogen that trigger an immune system response.
Leukocytes	White blood cells, including phagocytes and lymphocytes (B and T cells) for identifying and killing pathogens.
Antibodies	Glycoproteins (protein+carbohydrate) secreted into the blood in response to an antigenic stimulus that neutralise the antigen by binding specifically to it.

Destruction Process

- Antigen-secreting pathogen enters the body.
- B-cells are activated by the foreign antigen.
- With help of T-cells, B-cells undergo cloning and mutation.
- Plasma B-cells secrete immunoglobulins which attach to the antigen.
- Marked antigens are attacked by the immune system.
- Memory of the antigen is maintained by B memory cells.

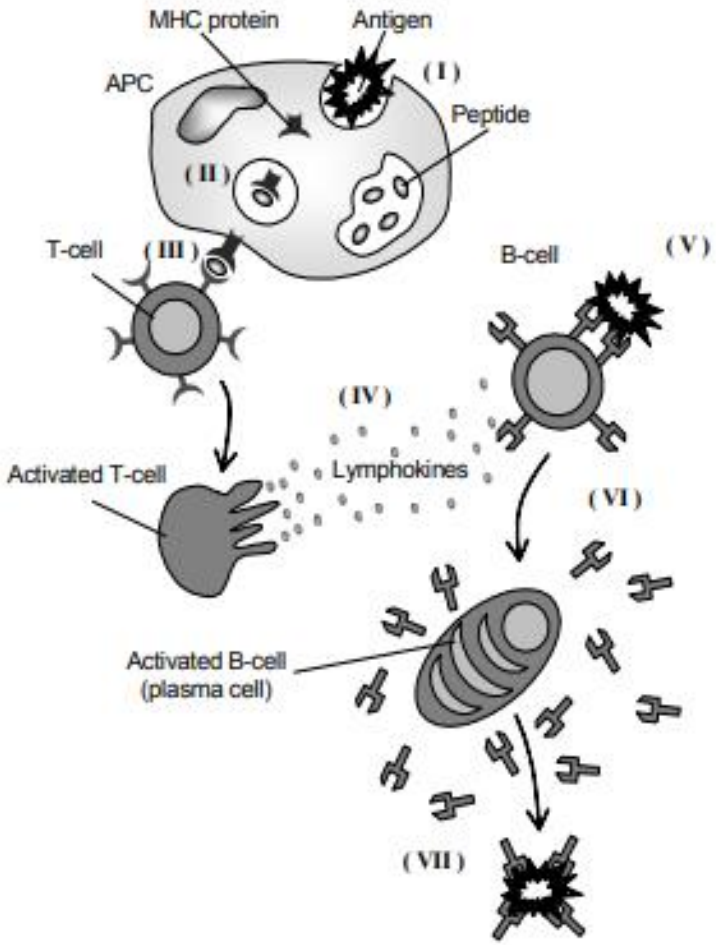


Figure -1. Pictorial representation of the essence of the acquired immune system mechanism (taken from de Castro and van Zuben (1999): I-II show the invade entering the body and activating T-Cells, which then in IV activate the B-cells, V is the antigen matching, VI the antibody production and VII the antigen's destruction.

Reading

How your Immune System Works

Clonal Selection – for Optimization

1. ***Initialization***: create an initial population of antibodies
2. ***Fitness Evaluation***: determine the fitness of each element of P.
3. ***Clonal Selection and expansion***: select n1 highest fitness elements of P and generate clones of these antibodies proportionally to their fitness: the higher the fitness, the higher the number of copies and vice versa.
4. ***Affinity maturation***: mutate all these copies with a rate that is inversely proportional to their fitness. Higher the fitness, smaller the mutation rate and vice versa. Add these mutated individuals to population P.
5. ***Metadynamics***: replace a number n2 of low fitness individuals by (randomly generated) new ones.
6. ***Cycle***: repeat step 2 – 5 until a certain stopping criterion is met.

Clonal Selection Algorithm

input : S = set of patterns to be recognised, n the number of worst elements to select for removal
output: M = set of memory detectors capable of classifying unseen patterns
begin
  Create an initial random set of antibodies, A
  forall *patterns in* S **do**
    Determine the affinity with each antibody in A
    Generate clones of a subset of the antibodies in A with the highest affinity. The number of clones for an antibody is proportional to its affinity
    Mutate attributes of these clones inversely proportional to its affinity. Add these clones to the set A, and place a copy of the highest affinity antibodies in A into the memory set, M
    Replace the n lowest affinity antibodies in A with new randomly generated antibodies
  end
end

http://www0.cs.ucl.ac.uk/staff/p.bentley/teaching/L9_AIS.pdf

AIS – CLONALG-OPT

```
Procedure P = CLONALG_OPT(max_it, n1,n2)  Initialize P
        t = 1
        while t < max_it do,
                f  ← eval(P)
                P1 ← select(P,n1,f)
                C  ← clone(P1,f)
                C1 ← mutate(C,f)
                f1 ← eval(C1)
                P1 ← select(C1,n1,f)
                P  ← replace(P,n2)
                t  ← t+1
        end while
End procedure
```

About AIS

- Where is exploration and exploitation happening?
- How does it ensure diversity?
- Where do you see knowledge sharing?

References

- Engelbrecht, Chapter 19
- The innate and adaptive immune systems - InformedHealth.org - NCBI Bookshelf (nih.gov)
- http://www0.cs.ucl.ac.uk/staff/p.bentley/teaching/L9_AIS.pdf

Thanks