# SCS5107 Computational Intelligence Unit IV

# Artificial Immune System

Novel paradigms are proposed and accepted not necessarily for being faithful

to their sources of inspiration, but for being useful and feasible.

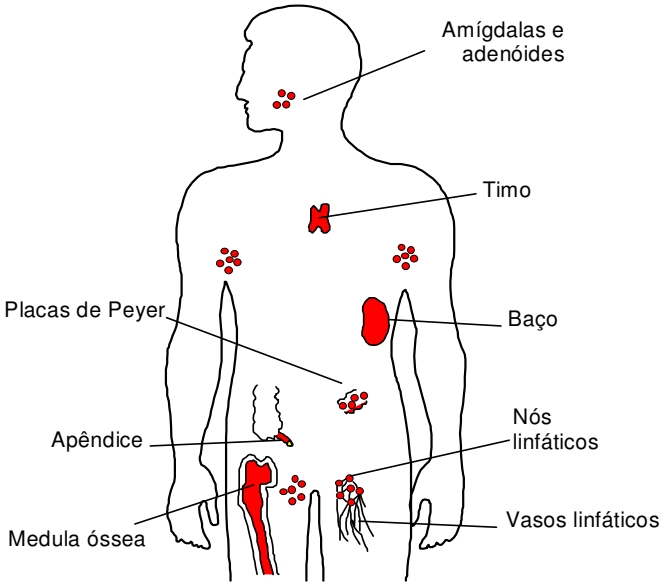
Give you a taster of what AIS is all about

- Define an AIS
- Why do we find the immune system useful?
- Explain what AIS are
- Show you where they are being used
- Some high level case studies
- Comments for the future

AIS are adaptive systems inspired by theoretical immunology and observed immune functions, principles and models, which are applied to complex problem domains.

- Developed from the field of theoretical immunology in the mid 1980's.
  - Suggested we 'might look' at the IS
- 1990 – Bersini first use of immune algos to solve problems
- Forrest et al – Computer Security mid 1990's
- Hunt et al, mid 1990's – Machine learning

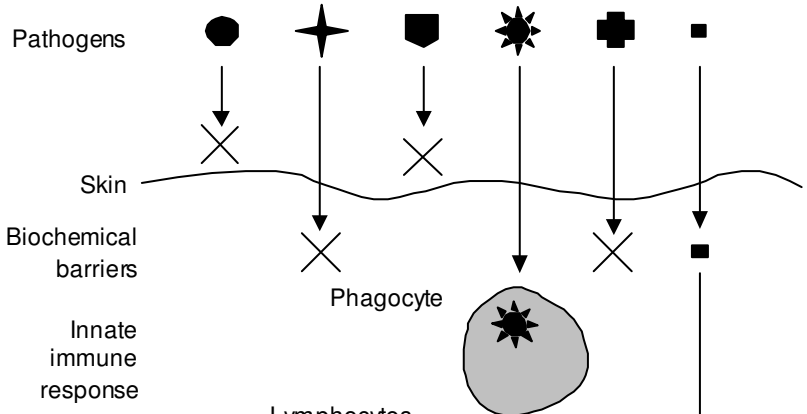
**Where is it?**



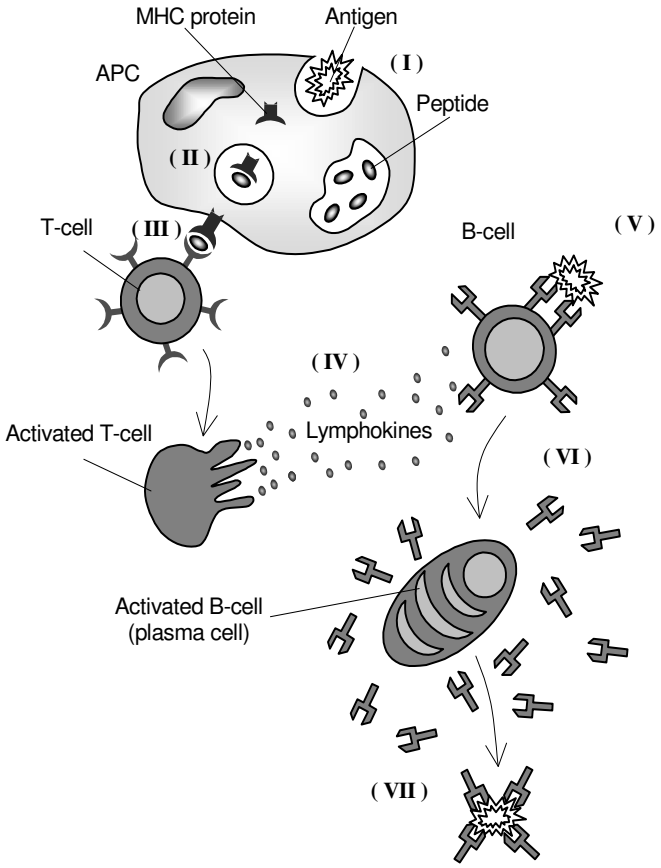

Protect our bodies from pathogen and viruses

- Primary immune response
  - Launch a response to invading pathogens
- Secondary immune response
  - Remember past encounters
  - Faster response the second time around

## Multiple layers of the immune system



**Immune cells**




- There are two primarily types of lymphocytes:
  - B-lymphocytes (B cells)
  - T-lymphocytes (T cells)
- Others types include macrophages, phagocytic cells, cytokines, etc.

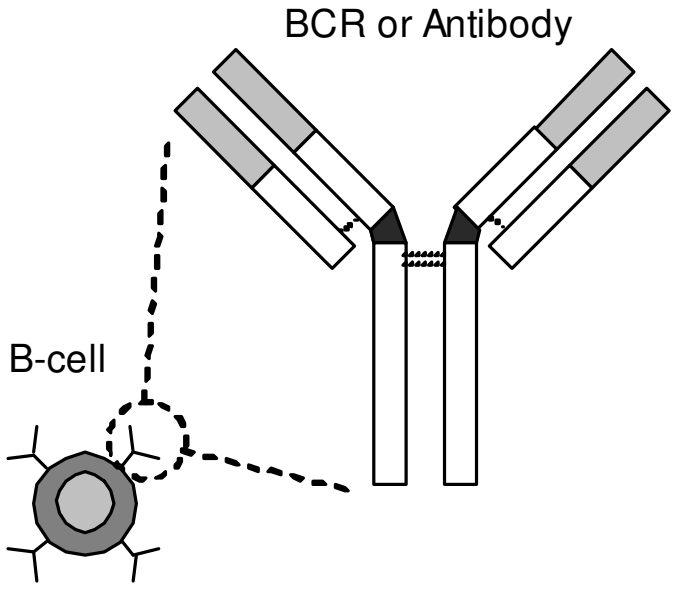
**Immune system needs to be able to differentiate between self and non-self cells**

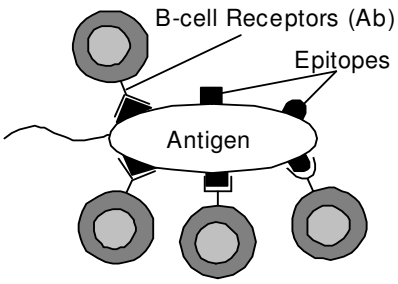
- Antigenic encounters may result in cell death, therefore
- Some kind of positive selection
- Some element of negative selection

**Antigen**

- Substances capable of starting a specific immune response commonly are referred to as **antigens**
- This includes some pathogens such as viruses, bacteria, fungi etc .

**Immune Pattern Recognition**

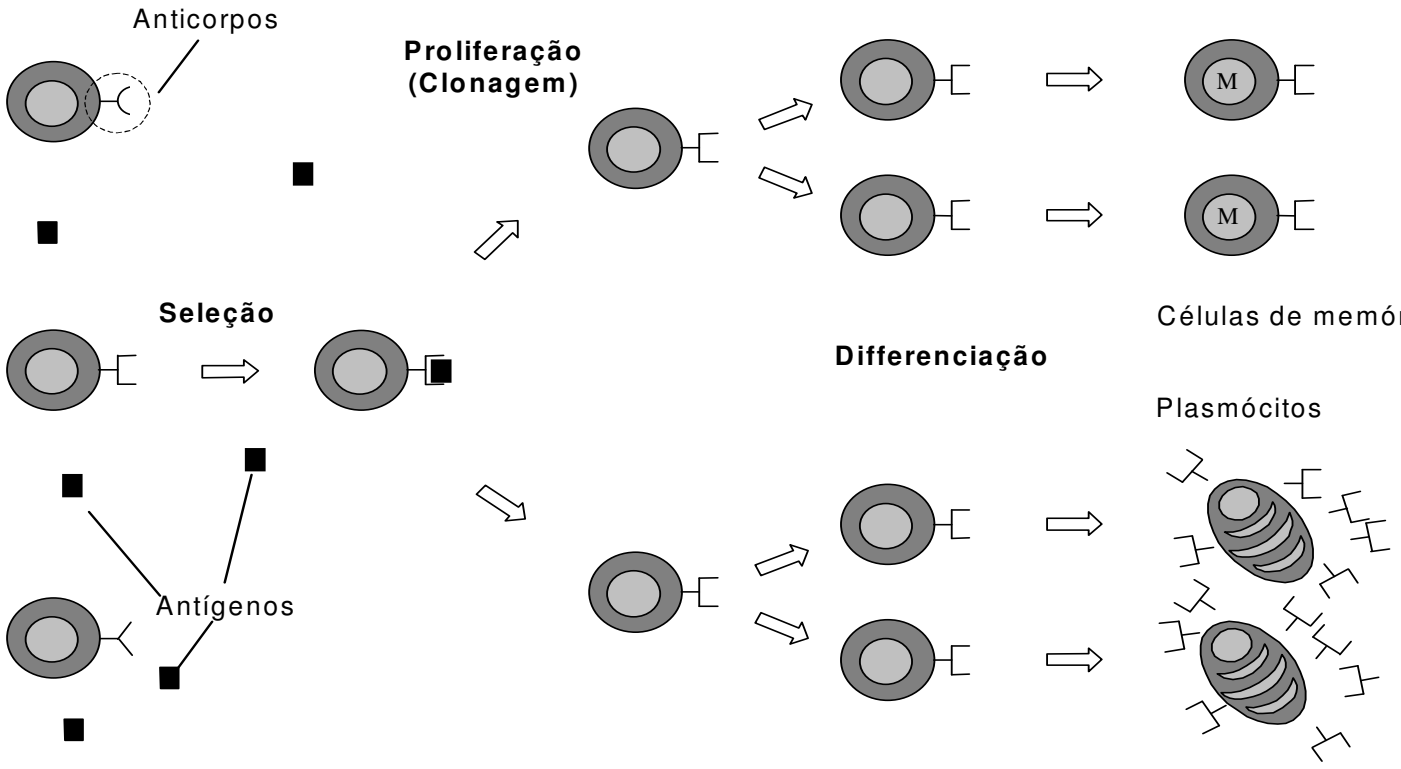



- The immune recognition is based on the *complementarity* between the binding region of the receptor and a portion of the antigen called *epitope*.

- Antibodies present a single type of receptor, antigens might present several epitopes.
  - This means that each antibody can recognize a single antigen

## Clonal Selection



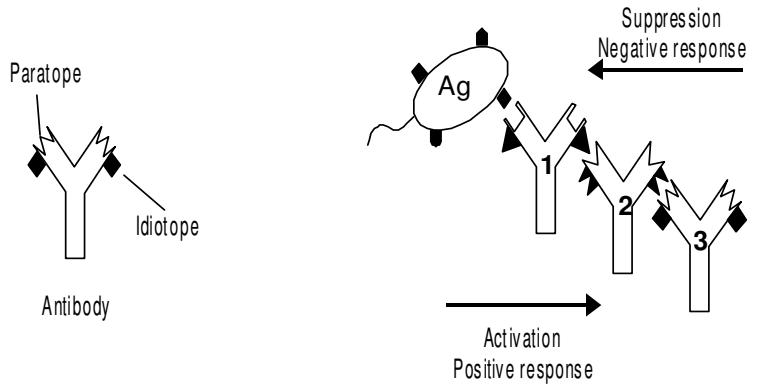

**Main Properties of Clonal Selection**

- **Elimination of *self antigens***
- **Proliferation and differentiation on contact of mature lymphocytes with antigen**

- **Restriction of one pattern to one differentiated cell and retention of that pattern by clonal descendants;**
- **Generation of new random genetic changes, subsequently expressed as diverse antibody patterns by a form of accelerated somatic mutation**

## Immune Network Theory

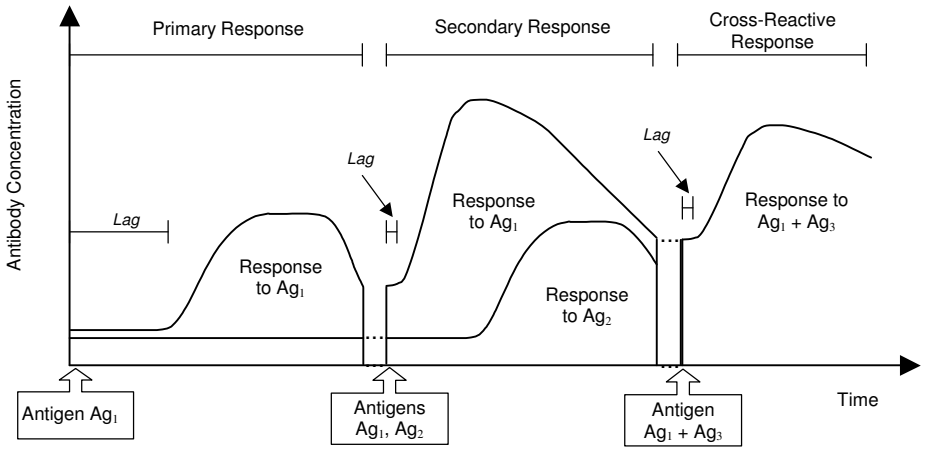
- Idiotypic network (Jerne, 1974)
- B cells co-stimulate each other
  — Treat each other a bit like antigens
- Creates an immunological memory




## Reinforcement Learning and Immune Memory

- Repeated exposure to an antigen throughout a lifetime
- Primary, secondary immune responses
- Remembers encounters
  - No need to start from scratch
  - Memory cells

- Continuous learning




**Representation of Antigens**

**Ab** = $\langle Ab_1, Ab_2, ..., Ab_L \rangle$

**Ag** = $\langle Ag_1, Ag_2, ..., Ag_L \rangle$

- Real-valued shape-space
- Integer shape-space
- Binary shape-space
- Symbolic shape-space
- Define the term **Affinity**
- Distance measures such as Hamming, Manhattan etc. etc.
- Affinity Threshold

**Basic Immune Models and Algorithms**

- Negative Selection Algorithms
- Clonal Selection Algorithm

- Immune Network Models

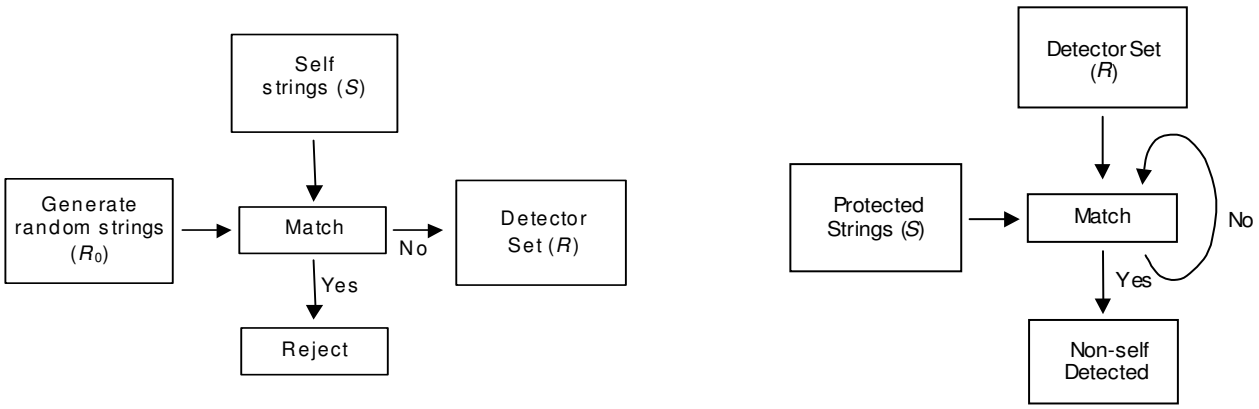
**Negative Selection (NS) Algorithm**

Forrest 1994: Idea taken from the negative selection of T-cells in the thymus

Applied initially to computer security

Split into two parts:

- Censoring
- Monitoring




## Clonal Selection Algorithm

1. *Initialisation*: Randomly initialise a population (P)

2. *Antigenic Presentation*: for each pattern in Ag, do:

2.1 *Antigenic binding*: determine affinity to each P'

2.2 *Affinity maturation*: select *n* highest affinity from P and clone and mutate prop. to affinity with Ag, then add new mutants to P

3. *Metadynamics*:

3.1 select highest affinity P to form part of M

3.2 replace *n* number of random new ones

4. *Cycle*: repeat 2 and 3 until stopping criteria

## Immune Network Models

1. *Initialisation*: create an initial network from a sub-section of the antigens
2. *Antigenic presentation*: for each antigenic pattern, do:

   *2.1 Clonal selection and network interactions*: for each network cell, determine its stimulation level (based on antigenic and network interaction)

   *2.2 Metadynamics*: eliminate network cells with a low stimulation

   *2.3 Clonal Expansion*: select the most stimulated network cells and reproduce them proportionally to their stimulation

   *2.4 Somatic hypermutation*: mutate each clone

   *2.5 Network construction*: select mutated clones and integrate

*3. Cycle*: Repeat step 2 until termination condition is met.