What is the immune system?

SFB 1335 Aberrant Immune Signals in Cancer

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Our body is made of cells
The cells of the immune system help us fight dangerous viruses, bacteria and parasites. Without an immune system we wouldn’t be able to survive!

These are the cells of the immune system:

- Macrophage
- Dendritic cell
- B cell
- T cell
- Granulocyte
- Mast cell

Dangerous viruses, bacteria and parasites are called “pathogens”.
This is how the immune response is organized:

1. Recognize that something dangerous entered the body
2. Tell other cells
3. Do something against it
The immune system has two arms:

The innate immune system

- Macrophage
- Dendritic cell
- Granulocyte

The adaptive immune system

- B cell
- T cell

We respond very quickly!

We can respond to any pathogen and we can remember previous infections!
<table>
<thead>
<tr>
<th>Innate immune response</th>
<th>Adaptive Immune response</th>
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</thead>
<tbody>
<tr>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Recognizes only the most common pathogens</td>
<td>Can recognize basically any pathogen</td>
</tr>
<tr>
<td>No “immune memory” (= responds equally fast to a second infection)</td>
<td>“immune memory” (= responds faster if a pathogen infects a second time)</td>
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The innate immune system

- Recognize that something dangerous entered the body
- Tell other cells
- Do something against it
The most difficult job of the immune system is to recognize what is a pathogen and what is not a pathogen.

The cells of the immune system don’t have eyes and ears. They need to use something else to "see" pathogens.
Cells have “receptors”, which help them to figure out what is around them.

A structure on the pathogens surface (can be a protein, lipid, sugar structure)

Receptor recognizing the structure

An immune cell knows that a pathogen is close, if the receptor binds to the structure it is made to recognize.
Innate immune system

How the cells recognize pathogens:

Cells of the innate immune system use “pattern recognition receptors” = These receptors recognize structures that are common on pathogens

Example:
All the different bacteria below have “LPS” on their surface (in purple) a cell of the innate immune system with the “TLR4” receptor can “bind LPS” and therefore is able to tell that a bacterium is close.
The innate immune system

Recognize that something dangerous entered the body

Tell other cells

Do something against it
Some cells can simply swallow whole pathogens.

I’m a macrophage. I remove bacteria by eating them.
The adaptive immune system

Recognize that something dangerous entered the body

Tell other cells

Do something against it
The adaptive immune system

Hi! I am a B cell. I have a B cell receptor.

This part is different on individual B cells and is important for recognizing structures on pathogens.

Hi! I am a B cell. I have a B cell receptor.
Every B cell has a different B cell receptor and recognizes different structures. We have many B cells in our body and can therefore recognize any pathogen in the world.

In this example the B cell with the “yellow” BCR recognizes the bacterium with the red spikes but not the one with the blue bumps. The bacterium with the blue bumps is recognized by the B cell with the “green” BCR.
The adaptive immune system

Recognize that something dangerous entered the body

Tell other cells

Do something against it
B cells can become plasma cells and make antibodies

Once a B cell recognizes a pathogen, it gets activated and can become a plasma cell. Plasma cells produce large amounts of antibodies that are released into the blood stream. Antibodies then bind to pathogens.
This virus can enter the cell and make it sick.

This virus can not enter the cell because antibodies are sticking to it.

Antibodies can prevent pathogens from entering cells. Pathogens often need to bind to a specific receptor on a cell to be able to get inside. If antibodies are sticking to the virus, the virus cannot interact with the receptor and cannot enter the cell. The cell then doesn't get sick.
What are antibodies good for

Antibodies make it easier for the cells of the innate immune system to recognize dangerous things. Macrophages have receptors that recognize antibodies. Once they bind antibodies they eat the pathogen that is covered by them.
The adaptive immune system

Recognize that something dangerous entered the body

Tell other cells

Do something against it
T cells have a T cell receptor

This part is different on individual T cells and is important for recognizing structures on pathogens.

Similar to B cells, T cells have a receptor that is unique for every individual T cell.
T cells don’t recognize whole pathogens, they need other cells to show them pieces of the pathogen. These pieces are called peptides. The other cells have molecules on their surface called MHC to show peptides to T cells. There are two types of MHC molecules: MHC-II and MHC-I.
Only some cells have MHC-II molecules. These cells often eat pathogens, cut them into pieces and show the pieces on MHC-II molecules to T cells.

We are good at eating pathogens and showing pieces to T cells.
This is what happens inside the cell

A pathogen or a protein from a pathogen is taken up by the cell.

1.
2. The protein is cut into pieces = peptides
3. The peptides are loaded on MHC-II molecules
4. The MHC-II molecules travel to the surface of the cell to show peptides to T cells.
All cells have MHC-I molecules. MHC-I molecules show peptides from the inside of the cell to T cells. This is important if a cell is infected with a virus, it will make virus proteins and show these to T cells to tell them it has been infected.

We also have MHC-I molecules, but so does any other cell.
This is what happens inside the cell

1. A pathogen e.g. a virus infects the cell and forces it to make virus proteins.
2. The protein is cut into pieces = peptides
3. The peptides are loaded on MHC-I molecules
4. The MHC-II molecules travel to the surface of the cell to show peptides to T cells.
MHC-II

- Only present on cells that like to eat pathogens.
- Show peptides from proteins that come from outside the cell.
- This is meant to tell T cells that pathogens are present in the body

MHC-I

- Present on all cells.
- Show peptides from proteins that come from inside the cell.
- This is meant to tell T cells that the cell is infected or has become a cancer cell
What are T cells good for?

T cells can kill infected cells or cancer cells. If an infected cell is killed this can stop the disease because many pathogens can only replicate in cells. If the first infected cells die, new virus is not made and the body does not get sick.

T cells can also help B cells to better do their work.

T cells can make proteins which make holes into other cells and kill them.
Immune cells need to make tough decisions

B cell binds a structure

Is it something **foreign**?

- YES
- NO

Is it something **dangerous**?

- YES
- NO

Is the infection resolved?

- YES
- NO

STOP

GO

STOP
What happens is immune cells make the wrong decision?

B cell binds a structure

Is it something **foreign**?

- YES
- NO

Is it something **dangerous**?

- YES
- NO

Is the infection resolved?

- YES
- NO

Autoimmunity
What happens if immune cells make the wrong decision?

B cell binds a structure

Is it something **foreign**?

- **YES**
- **NO**

Is it something **dangerous**?

- **YES**
- **NO**

Is the infection resolved?

- **YES**
- **NO**

**Allergy**
What happens if immune cells make the wrong decision?

Is it something foreign?
- YES
- NO

Is it something dangerous?
- YES
- NO

Is the infection resolved?
- YES
- NO

B cell binds a structure
What happens if immune cells make the wrong decision?

- **Cancer**

  - Is the infection resolved? 
    - NO
    - YES: **GO**

  - Is it something **dangerous**? 
    - NO
    - YES: **GO**

  - Is it something **foreign**? 
    - NO
    - YES: **GO**

- B cell binds a structure
Vaccination

During vaccination, pieces of the pathogen are shown to cells of the immune system making it easier for them to fight once they see the real pathogen.
Our immune system is awesome