Immunology & Vaccines

At home learning resources

Provided by GSBS Immunology Program Students
Introduction to Immunology
How does our body fight disease?

- System to detect foreign invaders (pathogens)
- Diagram on left shows major immune organs
- Immune organs contain various types of immune cells with unique functions
General Overview of Immune Cells

- **White blood cells (WBCs)**
  - Eat pathogens
  - Take parts of pathogens to send a message to other immune cells
  - Kill infected cells
  - Learn & remember what a pathogen looks like
  - Secrete products that aid in fighting infections
  - Provide both short and long term protection to guard your health
2 Arms of the Immune System

- **Innate immunity**
  - Microbe
  - Epithelial barriers
  - Phagocytes
  - Complement
  - NK cells

- **Adaptive immunity**
  - B lymphocytes
  - Antibodies
  - T lymphocytes
  - Effector T cells

**Time after infection**

- 0 hours
- 6 hours
- 12 hours
- 1 day
- 3 days
- 5 days

Copyright © 2001 Elsevier Inc. All rights reserved.
Innate Immunity

- Definition of innate: “natural, unlearned, untaught”
- Occurs early (minutes to hours)
- “Non-specific” response to foreign molecules (pathogens)
- Consists of:
  - Molecules that attack bacteria cells (complement system)
  - Cells that attack bacteria (granulocytes)
  - Cells that eat or engulf bacteria (phagocytes)
  - Cells that recruit or activate additional immune cells (antigen presenting cells = APCs)

Main Function: To rapidly respond to foreign invaders, and recruit other immune cells to activate the adaptive immune system
4 Major Innate Immune Cell Types

**Neutrophil**
- 1st cell to site of infection
- **Phagocyte**: eats bacteria
- **Granulocyte**: Use granules to kill bacteria
- Polymorphonuclear cell: Has a segmented, multi-lobed nucleus
- [https://youtu.be/p1_B6zRdpEM](https://youtu.be/p1_B6zRdpEM)

**Natural Killer (NK) cell**
- **Granulocyte**: Releases small toxic **granules** that directly kill infected or tumor cells
4 Major Innate Immune Cell Types

Antigen Presenting Cells (APCs)

**Macrophage**
- Arise from monocytes (shown in early figure)
- **Phagocyte**: Eats pathogens & dead cells
- Repairs wounds
- [https://youtu.be/vgRZeBpgbt8](https://youtu.be/vgRZeBpgbt8)

**Dendritic cell (DC)**
- Phagocyte
- Break down and present parts of bacteria, viruses, cancer cells (peptides) to adaptive immune cells
- “Bridge” between innate & adaptive immunity
- [https://youtu.be/eutHTBQYoeY](https://youtu.be/eutHTBQYoeY)
Adaptive Immunity

- Slower response (days)
- Activated in immune organs
- Recognize antigen specific to the threat
  - **Antigen**: Small piece of a protein (peptide)
- Need help from innate cells to see pathogen-related proteins
- Make tools to target the specific threat
- Build immunologic memory to respond faster if you see the threat again
Major Adaptive Immune Cell Types: B cells

- APCs
- Produce antibodies
- Antibodies help the immune system to identify & neutralize foreign bacteria or viruses
- An antibody recognizes an antigen, a unique part of the foreign target
- https://youtu.be/DaB54Dw_SWU

http://ruo.mbl.co.jp/bio/e/support/method/antibody.html
Major Adaptive Immune Cell Types: T cells

Killer (Cytotoxic) T cells
- Directly bind with and kill cells
- https://youtu.be/kYNIAZ5HunI

Helper T cells
- Release soluble proteins (cytokines) to help killer T cells and B cells
- https://youtu.be/-_s2bVi2qy0

Suppressor T cells
- Type of helper T cell, sometimes termed “T regulatory cell”
- Prevent autoimmunity by suppressing killer T cells
- Cause problems by suppressing immune cell activity in tumors
Overview of Antigen Presentation

1. An innate immune cell travels to an organ dedicated to immune activation,

2. where it shows its piece of a bacterium to many T cells

3. until it finds a T cell that specifically recognizes that piece.

4. The T cell makes many copies of itself, which become armed to fight the infection.

Figure: https://yourimmunology.wordpress.com/tag/adaptive-immunity/
1. Antigen Detection & Presentation

Detection

bacteria

Internalization (Phagocytosis)

Presentation
2. Antigen Presentation to T cells

- Certain T cells express a T cell receptor specific to the antigen presented by the DC.
- The T cell receptor (TCR) recognizes both the antigen, and the antigen presentation molecule.

![Diagram showing the antigen presentation to T cells](image_url)


2. Antigen Presentation to T Cells

- Certain T cells express a T cell receptor specific to the antigen presented by the DC.
- The T cell receptor (TCR) recognizes both the antigen, and the antigen presentation molecule (MHC).
- Close up of the TCR and antigen:MHC interaction (notice how the TCR shape matches that of the antigen:MHC molecule).
3. Specific T Cell Activation

- If the T cell is specific to the antigen & antigen presentation molecule, the T cell and DC bind together
- Additional molecules bind the T cell and DC together strongly
- When bound together, the APC provides important activation signals to the T cell

Antigen presentation molecule
(official term: major histocompatibility complex, MHC)
4. T Cell “Clonal” Proliferation

- Activated T cell begins dividing (*proliferating*)
- Process makes exact copies (*clones*) of the antigen-specific T cell
- New T cell clones go out to fight the infection!
Summary of an Immune Response

1. Pathogen entry into body
2. Detection of pathogen by innate immune cells
3. Pathogen processed & presented as antigen
4. Antigen detected by B & T cells
5. Activation of B & T cells
Quiz 1: Intro to Immunology

1. The function of the immune system is to detect foreign invaders, termed ________________

2. Which of the following is not a foreign invader to your immune system? Bacteria, your kidney, viruses, parasites

3. What are immune cells? __________ ___________ __________

4. Name two organs of the immune system.

5. The immune system has 2 main arms, the ____________ system, which occurs early, often within minutes of encountering a pathogen, and the adaptive system, which occurs within __________.
### Quiz 1: Intro to Immunology

6. Fill in the chart below: Innate vs. Adaptive Immune system

<table>
<thead>
<tr>
<th></th>
<th>Innate</th>
<th>Adaptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Response (specific or general)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form Memory?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immune cell types</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Quiz 1: Intro to Immunology

7. This cell is 1st to the site of infection: ________________
8. This cell produces antibodies: ________________
9. These types of cells are termed ________________ because they eat bacteria. They include neutrophils, macrophages, and dendritic cells (DCs)
10. This innate immune cell can heal wounds after an immune response has occurred: ________________
11. These two cells are capable of directly killing infected or tumor cells: ________________, ________________. (Hint: one is an innate immune cell, and one is an adaptive immune cell)
12. Macrophages, dendritic cells, and B cells are all what types of cells? ________________ ________________ ________________
13. Match the TCR with the antigen and antigen presentation molecule (MHC) on the APC.
Quiz 1: Intro to Immunology

14. This type of T cell produces factors that prevent autoimmune reactions.
_____________ ______ ______

15. Why do you think it is important that both an innate and an adaptive immune cell are capable of killing infected or tumor cells?

16. What do you think happens if a T cell expressing a T cell receptor cannot recognize the antigen and antigen presentation molecule on the APC?

Answers to Quiz 1 may be found in slides at the end of the presentation.
Vaccines
Vaccines create immunological memory

When you get a vaccine, it sparks your immune response to help your body fight off and remember the germ.

Creating this “memory” enables the immune system to attack a germ when it invades again.

Watch this video to learn more: http://www.youtube.com/watch?v=lXMc15dA-vw
Vaccine Specifics

- Vaccines contain substances designed to stimulate an immune response.
- Vaccination reduces the risk of a detrimental condition such as disease or death.

There are 4 main types of vaccines:
  - Live-attenuated
  - Inactivated
  - Subunit, recombinant, polysaccharide, & conjugate
  - Toxoid

http://www.youtube.com/watch?v=rb7TVW77ZCs
Live-Attenuated Vaccines

- Weakened (or attenuated) form of the germ that causes a disease.
- Create a strong and long-lasting immune response since they are so similar to the natural infection.
- Just 1 or 2 doses of most live vaccines can give you a lifetime of protection against a germ and the disease it causes.

Child with Smallpox in Bangladesh
Live-Attenuated Vaccines

Limitations:
- Unavailable for people with weakened immune systems, long-term health problems, or people who’ve had an organ transplant.
- They need to be kept cool so they can’t be used in countries with limited access to refrigerators.

Protect against:
- Measles, mumps, rubella (MMR combined vaccine)
- Rotavirus
- Smallpox
- Chickenpox

Small child with measles rash after 4 days. Source: CDC.
Inactivated Vaccines

- Uses the killed version of the germ that causes the disease.
- Killing the germ decreases its infectivity, compared to live vaccines.

**Limitations:**
- Usually does not provide as strong immunity (protection) as live vaccines.
- May require several doses over time (booster shots) to achieve ongoing immunity against diseases.

Children with Polio in Nigeria
Inactivated Vaccines

Protects against:

• Hepatitis A
• Flu
• Polio
• Rabies

Illustration of US flu cases from 2018-2019. Highlights the benefit for annual vaccination to help decrease illness, hospitalization, and death.

Source: www.cdc.gov.
Subunit, Recombinant, Polysaccharide, and Conjugate Vaccines

- Use **specific pieces of the germ** — like its protein, sugar, or capsid (a casing around the germ).
- Stimulates a very strong immune response targeted to key parts of the germ.
- Can also be used on almost everyone who needs them, including people with weakened immune systems and long-term health problems.
Subunit, Recombinant, Polysaccharide, and Conjugate Vaccines

**Limitations:** May need booster shots to achieve long-lasting protection against diseases.

**Protects against:**
- Hepatitis B
- HPV (Human papillomavirus)
- Whooping cough (part of the DTaP combined vaccine)
- Meningococcal disease
- Shingles

Source: www.cdc.gov
Toxoid Vaccines

- Toxoid vaccines use a toxin (harmful product) made by the germ that causes a disease.
- They create immunity to the parts of the germ that cause a disease instead of the germ itself.
- That means the immune response is targeted to the toxin instead of the whole germ.
Toxoid Vaccines

Limitation: May need booster shots to achieve ongoing protection against diseases.

Protect against:
- Diphtheria
- Tetanus

How a new vaccine is developed, approved and manufactured

The Food and Drug Administration (FDA) sets rules for the three phases of clinical trials to ensure the safety of the volunteers. Researchers test vaccines with adults first.

**PHASE 1**
- **20-100 healthy volunteers**
  - Is this vaccine safe?
  - Does this vaccine seem to work?
  - Are there any serious side effects?
  - How is the size of the dose related to side effects?

**PHASE 2**
- **several hundred volunteers**
  - What are the most common short-term side effects?
  - How are the volunteers’ immune systems responding to the vaccine?

**PHASE 3**
- **hundreds or thousands of volunteers**
  - How do people who get the vaccine and people who do not get the vaccine compare?
  - Is the vaccine safe?
  - Is the vaccine effective?
  - What are the most common side effects?

**FDA licenses the vaccine only if:**
- It’s safe and effective
- Benefits outweigh risks

Vaccines are made in batches called lots.

Manufacturers must test all lots to make sure they are safe, pure and potent. The lots can only be released once FDA reviews their safety and quality.

The FDA inspects manufacturing facilities regularly to ensure quality and safety.

**FOR MORE INFORMATION, VISIT HTTPS://WWW.FDA.GOV/CBER**

Video describing vaccine development process: https://youtu.be/Fcvg6gNh6o
If the FDA licenses a vaccine, experts may consider adding it to the recommended immunization schedule.

How a vaccine is added to the U.S. Recommended Immunization Schedule

The Advisory Committee on Immunization Practices (ACIP) is a group of medical and public health experts. Members of the American Academy of Pediatrics (AAP) and American Academy of Family Physicians (AAFP) are among some of the groups that also bring related immunization expertise to the committee. This group carefully reviews all available data about the vaccine from clinical trials and other studies to develop recommendations for vaccine use. The ACIP continues to monitor vaccine safety and effectiveness data even after the vaccine’s routine use and may change or update recommendations based on that data.

When making recommendations, ACIP considers:

- How safe is the vaccine when given at specific ages?
- How well does the vaccine work at specific ages?
- How serious is the disease this vaccine prevents?
- How many children would get the disease the vaccine prevents if we didn’t have the vaccine?

ACIP recommendations are not official until the CDC Director reviews and approves them and they are published. These recommendations then become part of the United States official childhood immunization schedule.

New vaccine to protect your child against a disease is added to the schedule.

For more information, visit https://www.cdc.gov/vaccines
How a vaccine’s safety continues to be monitored

FDA and CDC closely monitor vaccine safety after the public begins using the vaccine.

The purpose of monitoring is to watch for adverse events (possible side effects). Monitoring a vaccine after it is licensed helps ensure that possible risks associated with the vaccine are identified.

Vaccine Adverse Event Reporting System (VAERS)

VAERS collects and analyzes reports of adverse events that happen after vaccination. Anyone can submit a report, including parents, patients and healthcare professionals.

Vaccine Safety Datalink (VSD) and Post-Licensure Rapid Immunization Safety Monitoring (PRISM)

Two networks of healthcare organizations across the U.S.

- **VSD** can analyze healthcare information from over 24 million people.
- **PRISM** can analyze healthcare information from over 190 million people.

Scientists use these systems to actively monitor vaccine safety.

Clinical Immunization Safety Assessment Project (CISA)

CISA is a collaboration between CDC and 7 medical research centers.

- Vaccine safety experts assist U.S. healthcare providers with complex vaccine safety questions about their patients.
- CISA conducts clinical research studies to better understand vaccine safety and identify prevention strategies for adverse events following immunization.

Vaccine recommendations may change if safety monitoring reveals new information on vaccine risks (like if scientists detect a new serious side effect).

For more information, visit https://www.cdc.gov/vaccinesafety
Vaccines Provide Herd Immunity

- **Herd Immunity**: When majority of the population is vaccinated, this helps prevent the spread of infectious diseases throughout a community (herd)
- Helps keep you protected while preventing spread to individuals who cannot receive vaccines, or those who have weakened immune systems.
- Graphic from pbs.org
Vaccine Questions or Misconceptions

- **Do vaccines cause autism? NO.** The original paper in 1994 by Dr. Andrew Wakefield describing a link between the MMR vaccine and autism contained falsified (fake) data. The paper was retracted based on non-scientific findings. Since then, numerous independent scientific studies have not found a link between autism and vaccination. More recent studies suggest other factors, such as mothers health status (having type 1 or type 2 diabetes), may have a stronger link with their children developing autism.

- **Will getting a vaccine give me the illness?** No. Many people may experience pain, swelling, or redness (inflammation) at the injection site, as well as mild fever, headache, or chills. This is your immune system reacting to the vaccine, and learning what the germ is, to help you in future. Some serious side effects do occur (1-2 people per 1 million people) due to severe allergic reactions; discussing these potential risks with your doctor is important to ensure your safety.
Vaccine Questions or Misconceptions

- Are adjuvants used in vaccines dangerous? Adjuvants help stimulate the immune response to the germ in the vaccine. Common adjuvants include aluminum, emulsions (oil and water), or bacterial or viral genetic material.
  - Aluminum salts are safe, and are commonly found in nature, including foods, air, water, and breast milk
  - The emulsions are used in only a few specific vaccines. The oils (lipids) are derived from bacteria, plants, or are naturally found in humans or other animal cells.
  - The genetic material is specifically DNA that mimics bacteria or viral genetical material. This material helps further stimulate innate immune cells to become activated and present the vaccine antigens to activate T and B cells. Our bodies naturally encounter these signals daily.
Formaldehyde is a cancer-causing agent, yet it is used to inactivate vaccines. Is this dangerous? Formaldehyde is a natural byproduct of metabolism found in our bodies, and we frequently come in contact with formaldehyde containing items (carpets, car exhaust, etc). The residual amount of formaldehyde in a vaccine is far less that what is normally found in our bodies, and does not pose any safety concerns. Repeated exposure to aerosolized formaldehyde, usually due to work-related hazards, is the main risk of developing cancer.

Follow these links to find additional information on vaccine ingredients:
- [https://www.cdc.gov/vaccines/vac-gen/additives.htm](https://www.cdc.gov/vaccines/vac-gen/additives.htm)
Vaccine Questions or Misconceptions

- Why is it important for me to receive vaccines? If you are healthy, receiving a vaccine means you can become protected from highly contagious, infectious, or deadly diseases. Moreover, when enough people are vaccinated, we build herd immunity to protect those who cannot receive vaccines, or people with weakened immune systems that cannot easily fight off infections. High levels of vaccination help prevent the spread of illness within communities.
Quiz 2: Vaccines

True or False: If False, describe what would make the statement true.

1. True or False: Vaccines educate our immune system to fight diseases without giving us the disease.

2. True or False: Everyone should be vaccinated.

3. True or False: Vaccines only protect us from viral infections.

4. This type of vaccine uses killed portions of the germ: __________ __________

5. This type of vaccine often does not require a booster shot because it mimics the natural infection and induces strong immunity: _______ _______ ______
6. Fill in the chart below: Innate vs. Adaptive Immune system

<table>
<thead>
<tr>
<th>Type of Vaccine</th>
<th>A Disease the Vaccine helps prevent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flu or polio</td>
<td>flu or polio</td>
</tr>
<tr>
<td>Toxoid</td>
<td></td>
</tr>
<tr>
<td>Meningococcal disease or whooping cough</td>
<td>meningococcal disease or whooping cough</td>
</tr>
<tr>
<td>Live-attenuated</td>
<td></td>
</tr>
</tbody>
</table>
Quiz 2: Vaccines

7. This type of vaccine uses specific portions of the germ: ________, ________,
   ________, and ________ vaccines

8. Do vaccines provide short-term or long-term benefits?

9. Last year in your class of 25 students, 22 of you received the flu vaccine. This
   year, in your class of 30 students, only 10 of you receive the flu vaccine.
   Which year were people in your class more protected, and why?
Quiz 2: Vaccines

10. What are some reasons for including adjuvants in vaccines?

11. My friend has Severe Combined Immune Deficiency (SCID), a disease which causes her to have no T cells and non-functional B cells. Should she receive vaccines and why?
Extra Content

- Link to a video that complies many of the concepts of basic immunology and vaccines covered in these slides: https://youtu.be/4LwYOYZyPzw
- Links to websites to learn more about vaccines in the US:
  - https://www.cdc.gov/vaccines/index.html
  - https://www.vaccines.gov/
  - https://www.fda.gov/vaccines-blood-biologics/vaccines
- Link to the National Institutes of Allergy and Infectious Diseases page on immune-related diseases: https://www.niaid.nih.gov/diseases-conditions
- Additional questions? Email us at GSBS_OutreachProgram@uth.tmc.edu
Quiz
Answers
Quiz 1: Intro to Immunology Answers

1. The function of the immune system is to detect foreign invaders, termed pathogens.

2. Which of the following is not a foreign invader to your immune system? Bacteria, your kidney, viruses, parasites

3. What are immune cells? White blood cells

4. Name two organs of the immune system. Spleen, LN, thymus, etc.

5. The immune system has 2 main arms, the innate system, which occurs early, often within minutes of encountering a pathogen, and the adaptive system, which occurs within days.
6. Fill in the chart below: Innate vs. Adaptive Immune system

<table>
<thead>
<tr>
<th></th>
<th>Innate</th>
<th>Adaptive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Response (specific or general)</td>
<td>General</td>
<td>Specific</td>
</tr>
<tr>
<td>Form Memory?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Immune cell types</td>
<td>DC, Macrophage, Neutrophil, NK cell</td>
<td>T and B cells</td>
</tr>
</tbody>
</table>
Quiz 1: Intro to Immunology Answers

7. This cell is 1st to the site of infection: Neutrophil
8. This cell produces antibodies: B cell
9. These types of cells are termed phagocytes because they eat bacteria. They include neutrophils, macrophages, and dendritic cells (DCs)
10. This innate immune cell can heal wounds after an immune response has occurred: Macrophage
11. These two cells are capable of directly killing infected or tumor cells: NK cells, T cells. (Hint: one is an innate immune cell, and one is an adaptive immune cell)
12. Macrophages, dendritic cells, and B cells are all what types of cells? Antigen Presenting Cells (APCs)
13. Match the TCR with the antigen and antigen presentation molecule (MHC) on the APC.
14. This type of T cell produces factors that prevent autoimmune reactions. **Suppressive T cell –OR– T regulatory cell**

15. Why do you think it is important that both an innate and an adaptive immune cell are capable of killing infected or tumor cells? The timing (kinetics) of the immune response. Redundancy allows the NK cells of the innate immune system to kill infected or cancerous cells while the adaptive immune system learns how to fight the threat (antigen presentation and T cell activation). An analogy would be like putting a bandage on a cut (innate system) while waiting to get the cut properly cleaned and stitched back together (adaptive). Both steps prevent you from loosing blood, but play unique and tailored roles.

16. What do you think happens if a T cell expressing a T cell receptor (TCR) cannot recognize the antigen and antigen presentation molecule on the APC? The T cell receptor MUST match both the antigen and antigen presentation molecule. A non-specific TCR will not bind with the APC, will not receive critical activation signals, and will not undergo clonal proliferation.
Quiz 2: Vaccines Answers

True or False: If False, describe what would make the statement true.
1. **True** or False: Vaccines educate our immune system to fight diseases without giving us the disease.
2. True or **False**: Everyone should be vaccinated. Majority of healthy people should be, except for those with weakened immune systems, organ transplants, chronic health conditions, or known allergies to vaccine ingredients.
3. True or **False**: Vaccines only protect us from viral infections. Vaccines protect us from viral, bacterial, and parasitic infections.
4. This type of vaccine uses killed portions of the germ: **inactivated vaccine**
5. This type of vaccine often does not require a booster shot because it mimics the natural infection and induces strong immunity: **Live-attenuated vaccine**
6. Fill in the chart below: Innate vs. Adaptive Immune system

<table>
<thead>
<tr>
<th>Type of Vaccine</th>
<th>A Disease the Vaccine helps prevent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactivated</td>
<td>Flu or polio</td>
</tr>
<tr>
<td>Toxoid</td>
<td>Diphtheria or Tetanus</td>
</tr>
<tr>
<td>Subunit, recombinant, polysaccharide, &amp; conjugate</td>
<td>Meningococcal disease or whooping cough</td>
</tr>
<tr>
<td>Live-attenuated</td>
<td>Small pox, chicken pox, measles, mumps, rubella, rotavirus</td>
</tr>
</tbody>
</table>
7. This type of vaccine uses specific portions of the germ: **Subunit**, **recombinant**, **polysaccharide**, and **conjugate** vaccines.

8. Do vaccines provide short-term or long-term benefits? **Once your body learns the germ, it forms immunological memory, which often persists for your lifetime. With weaker vaccines, long-term benefits are sustained by receiving booster shots.**

9. Last year in your class of 25 students, 22 of you received the flu vaccine. This year, in your class of 30 students, only 10 of you receive the flu vaccine. Which year were people in your class more protected, and why? **Last year, more people were protected. This is based on the decreased chance of spread from person to person by herd immunity.**
10. What are some reasons for including adjuvants in vaccines? Adjuvants help activate the innate immune system to alert that the body has encountered a foreign germ, the vaccine. This helps activate an appropriate adaptive immune response to induce immunity to the germ.

11. My friend has Severe Combined Immune Deficiency (SCID), a disease which causes her to have no T cells and non-functional B cells. Should she receive vaccine and why? She should not receive the vaccine because she lacks a functioning adaptive immune system. This means upon vaccination, her body cannot learn the germ or build memory, and can be easily infected if re-exposed to the pathogen.