The Big, Wonderful Immune System

Basics of Immunology

Heidi Gurov, RN, BSc, BSN, CMSRN
Nurse Consultant
2025 Wyoming Immunization Conference

Wyoming Department of Health
PUBLIC HEALTH DIVISION
IMMUNIZATION UNIT

Today we'll learn…

- General anatomy and function of the human immune system
- Types of immunity
- Immune system dysfunctions
- Basics of vaccinology

Definitions

Definitions

- **Immunology: t**he study of molecules, cells, organs, and the system responsible for the recognition and disposal of nonself (foreign) substances.
  - Relatively new area of science that branched off from microbiology
  - Louis Pasteur is considered the “father of immunology”
  - Immunology “took off” in the 1960s and 1970s

- **Immunity:** a condition of being able to resist a particular disease, especially through preventing development of a pathogenic microorganism or by counteracting the effects of its products
  - Concept of immunity from disease dates back to Greece in the 5th century BCE

Definitions

- **Vaccine:** a preparation that is used to stimulate the body's immune response against a specific disease

- **Vaccination:** the act of introducing a vaccine into the body to produce protection from a specific disease

- **Immunization:** the process by which a person becomes immune to an infectious disease
  - This term is often used interchangeably with vaccination

The Immune System

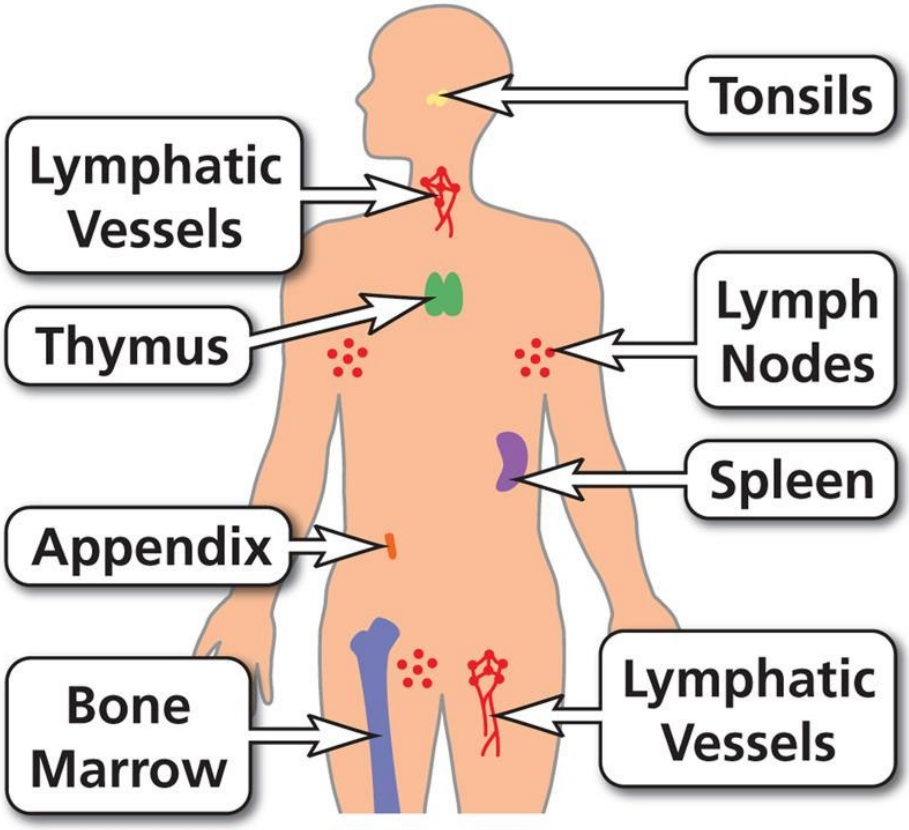
What is the immune system?

The immune system is awesome!!!

What is the immune system?

- A complex system of interacting cells that identifies foreign substances (“antigens”) and develops a defense against those substances

Immune System



Antigen

- Substance capable of producing an immune response
- Recognized as “non-self,” or foreign
- Two types:
  - Exogenous
    - Come from outside of the cell or body
      - Examples: pollen, transplanted organs, microorganisms
  - Endogenous
    - Produced within our own cells
      - Examples: viruses, products from normal cell metabolism

Immunity

Immunity

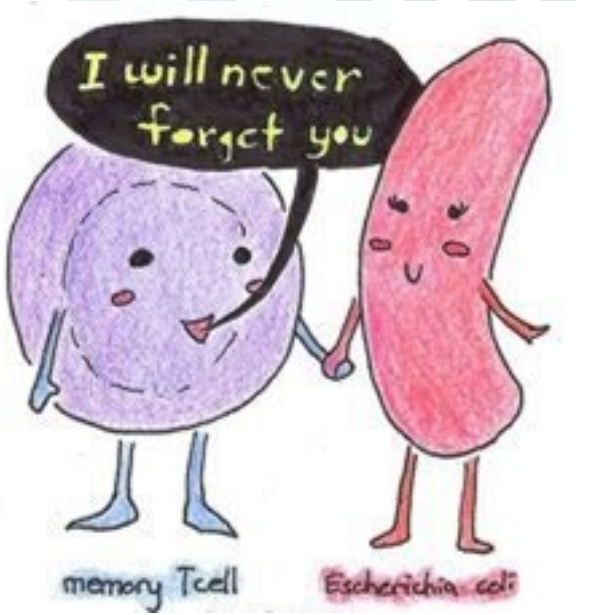
- Two key principles:
  - Specificity
  - Memory
- Two types of immunity:
  - Innate
  - Adaptive
    - Passive & active

Innate Immunity

- Anatomical barriers
  - Can be physical or chemical barriers
  - Examples: skin, mucous membranes, saliva, and tears
- Cellular responses
  - Phagocytic, dendritic, and natural killer cells
- Soluble proteins
  - Complement components, cytokines, lysozyme, and interferons
- Inflammatory responses
  - Fever
- Cough reflex, sneezing

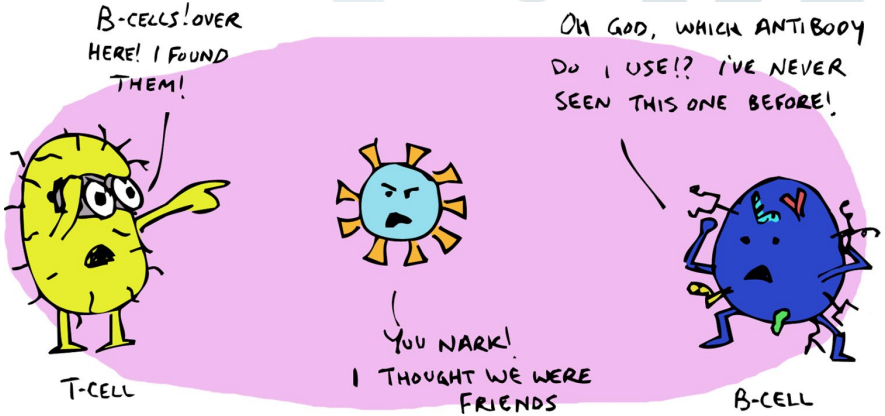
Adaptive immunity

- Types:
  - Humoral & cell-mediated
  - Active & passive
- High degree of specificity with memory
- Self/non-self recognition
- Not independent from innate immunity
  - In fact, poorly effective without innate immunity components

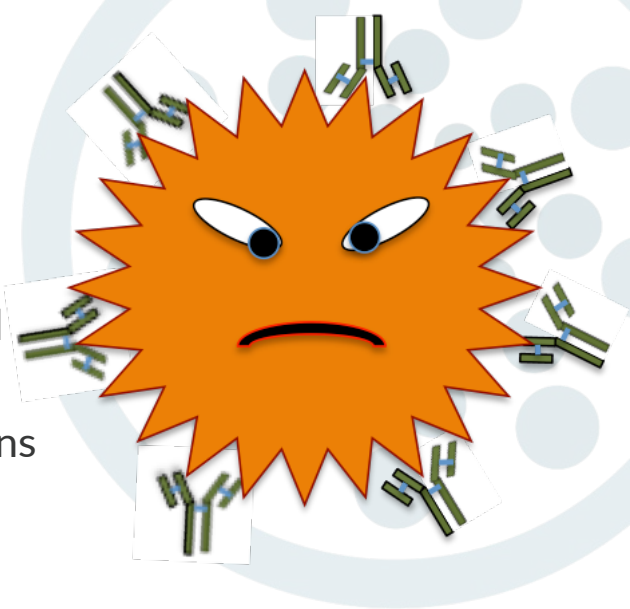


Humoral immunity

- Important against bacteria, parasites, toxins, and extracellular virus particles
- B lymphocytes
  - Mature in the bone marrow
  - Memory B cells
    - Long lifespan
    - Membrane-bound antibodies
  - Effector B cells (plasma cells)
    - Antibodies are secreted
    - Live only a few days
- Antibodies
  - Also called immunoglobulins
  - A Y-shaped protein with antigen binding sites
  - 5 types



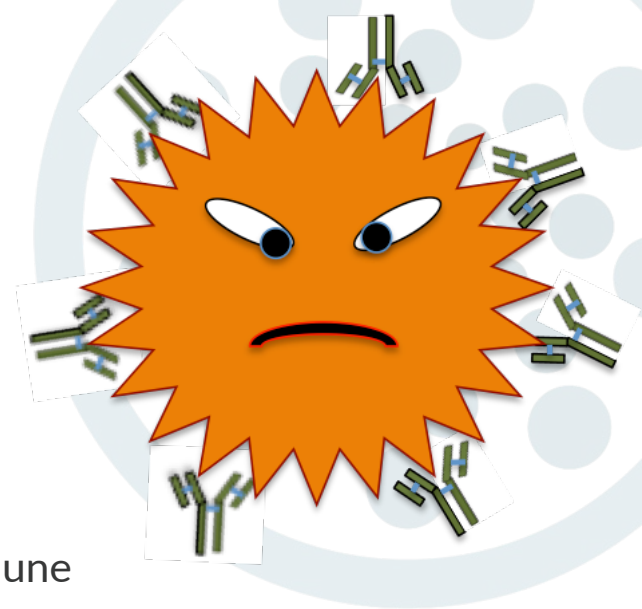
Antibodies



- IgA
  - Found on mucous membranes, and in saliva, tears, and breastmilk
  - Important first line of defense against certain pathogens
- IgD
  - Antigen receptor found on mature B cells
  - Activates basophils and mast cells to produce antimicrobial factors
- IgE
  - Important in parasitic worm infections
  - Key in hypersensitivity reactions and triggers histamine release

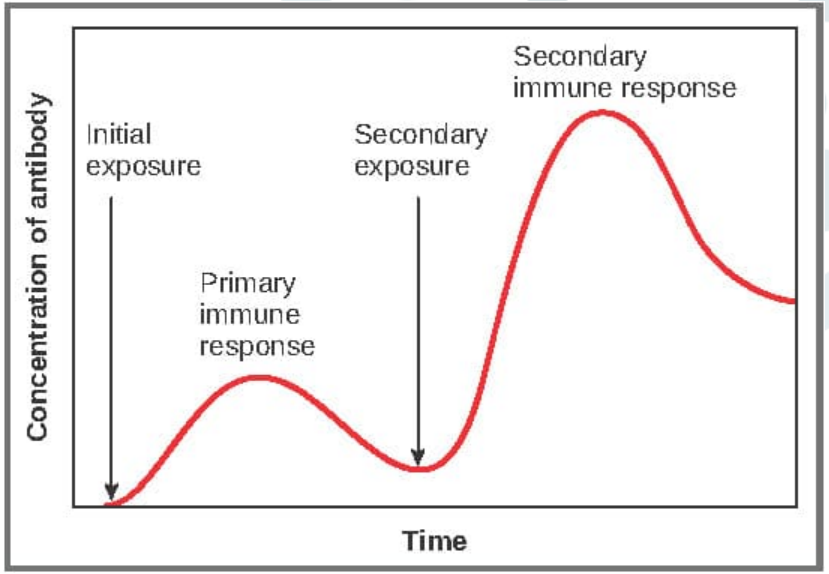
Antibodies

- IgG
  - Most abundant type of antibody
  - Forms majority of antibody-based immunity
  - Crosses the placenta during pregnancy
- IgM
  - First type of antibody produced during a primary immune response



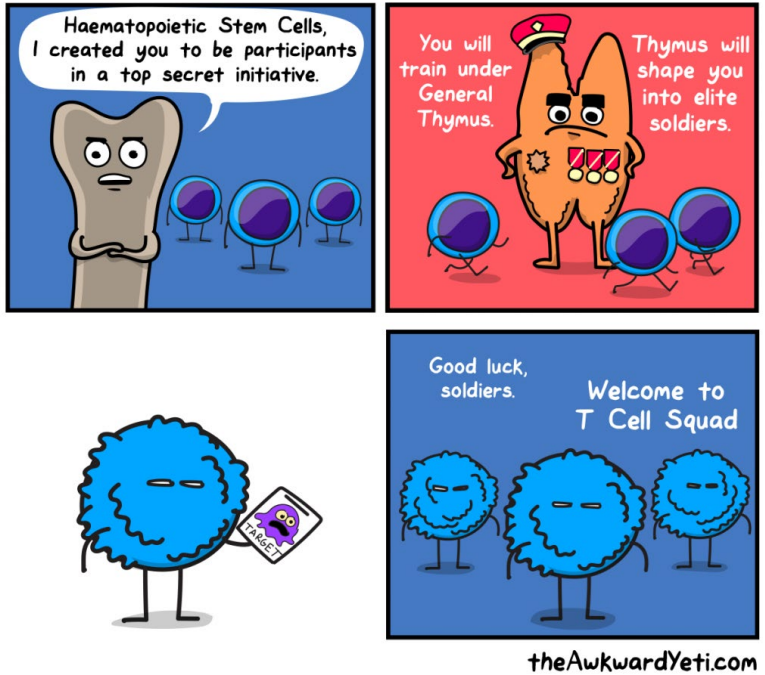
Primary vs. secondary immune response

- Primary response
  - Initial encounter with an antigen
  - 5-7 days for response
- Secondary response
  - Later contact with an antigen
  - Immune system recognizes antigen and responds swiftly and specifically
  - 1-2 days for response
  - Antibody levels are higher and sustained for longer than primary response



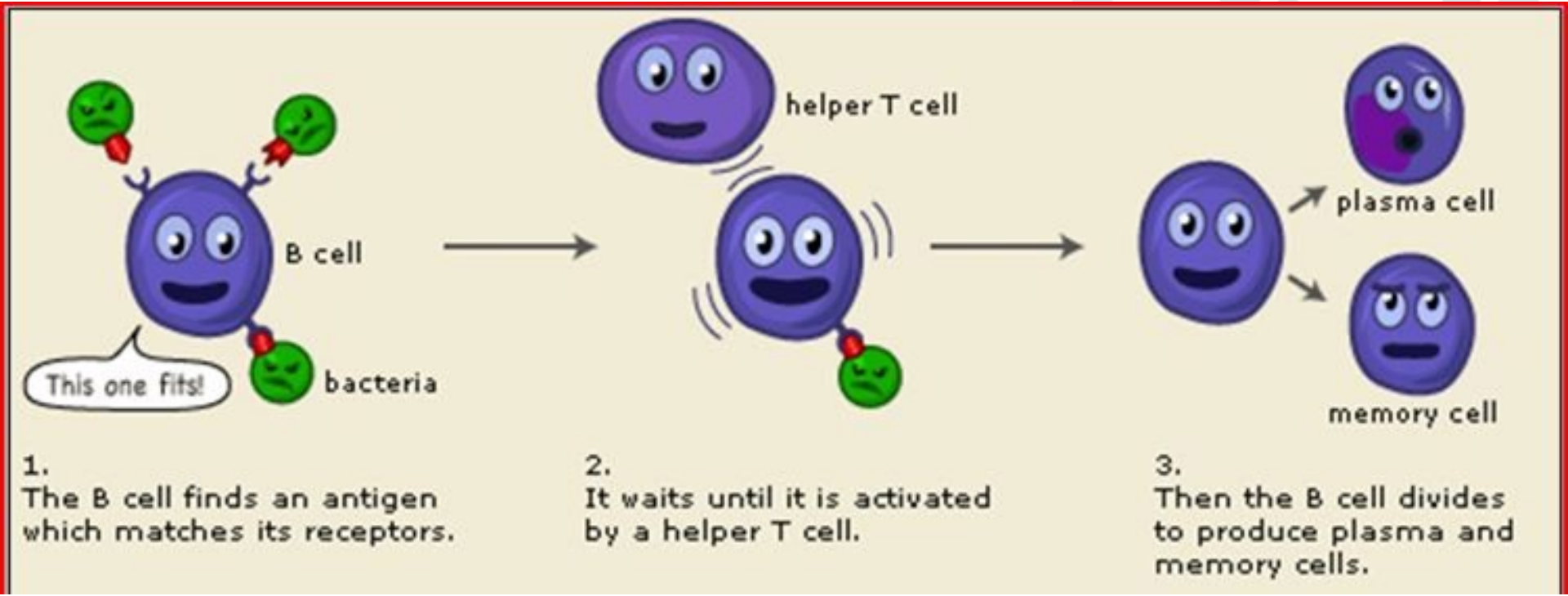
Cell-mediated immunity

- Important against virus-infected cells, cancer cells, and transplanted cells
- Does not involve antibodies, but instead the activation of various immune cells in response
- T-lymphocytes
  - Arise in the bone marrow, but mature in the thymus
  - T-helper CD4 cells
    - Recognizes and interacts with antigen-molecule complexes
      - B cells and an antigen, for example
    - Becomes activated and secretes cytokines
  - T-cytotoxic CD8 cells
    - Exhibit cell-killing activity once activated

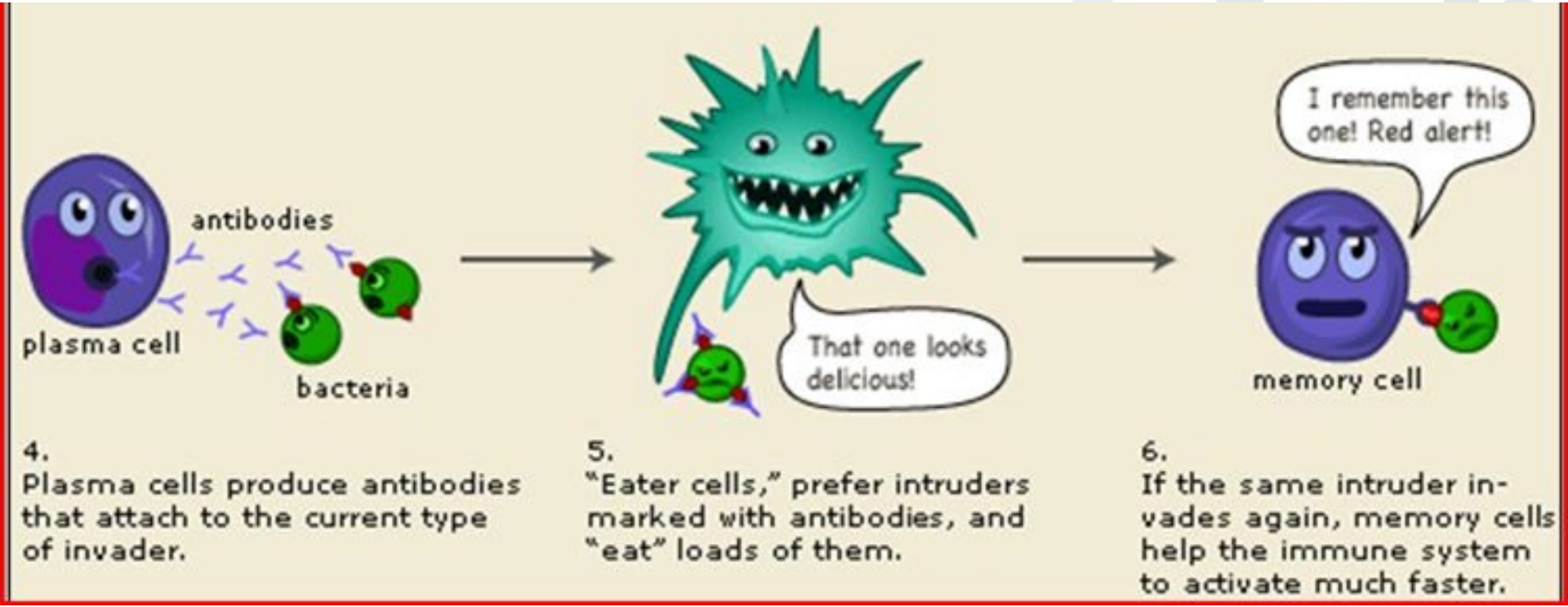


Putting it all together…

Humoral response: Part 1



Humoral response: Part 2

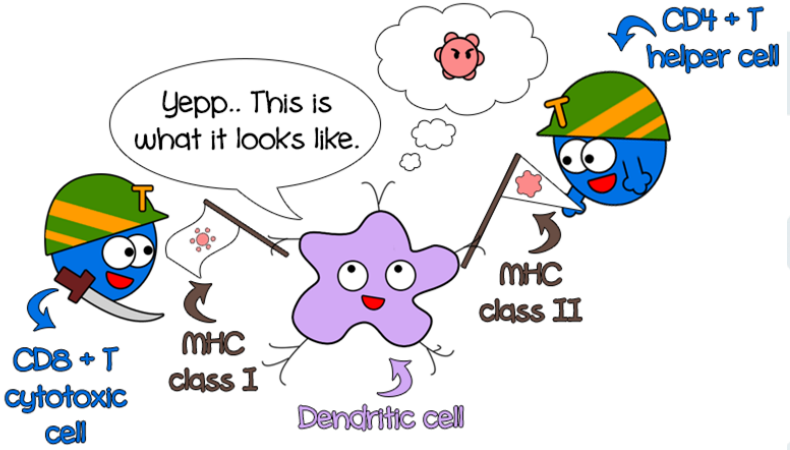


4.
Plasma cells produce antibodies that attach to the current type of invader.

5.
"Eater cells," prefer intruders marked with antibodies, and "eat" loads of them.

6.
If the same intruder invades again, memory cells help the immune system to activate much faster.

Cell -mediated response



- Antigen presenting cells
  - B cells
  - Macrophages
  - Dendritic cells
  - Langerhans cells
- Major Histocompatibility Complexes (MHC)
  - Class I: found on the surface of all nucleated cells
    - CD8 T-cytotoxic cells
      - Kills virus-infected cells, cancer cells, and intracellular bacteria
  - Class II: found on the surface of antigen presenting cells
    - CD4 T-helper cells
      - Extracellular antigens

Passive vs. active immunity

- Passive immunity
  - Protection derived from products by an animal or human that are transferred to another human
  - Protection wanes, often within a few weeks to months
  - Most common forms:
    - Maternal antibodies
    - Blood products
    - Pooled antibodies
    - Antitoxins
    - Monoclonal antibodies
      - Example: nirsevimab for RSV

Passive vs. active immunity

- Active immunity
  - Protection produced by your own immune system
  - Lasts for many years, sometimes a lifetime
    - Memory B cells circulate in blood and reside in bone marrow
- Two types:
  - Survive the infection from the disease-causing organism
  - Vaccination

Immune System Dysfunction

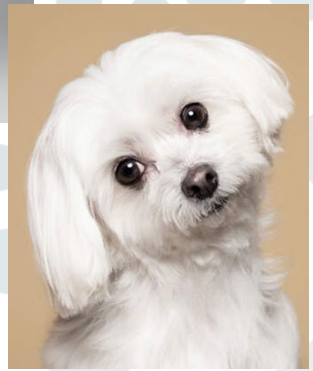
When things go wrong…

- Immune system dysfunction
  - Hypersensitivities
  - Immunodeficiencies
  - Autoimmune disorders
- Play a role in immunization
  - Inability to receive a particular vaccine (contraindication)
  - Reduce immune response
  - Vaccine recommendations due to health condition or immunodeficiency

Hypersensitivities

- Commonly known as an “allergy”
- Occurs when the immune system mistakenly identifies a generally harmless substance as harmful
- Is not necessarily a “heightened” response, but is an inappropriate immune response to an antigen
- 4 types

Type 1 hypersensitivities



- Also called IgE-mediated hypersensitivity
- Causes an immediate response after exposure to the triggering antigen
- Immune system responds by producing IgE antibodies
  - These IgE antibodies binds to tissue mast cells and basophils
- Reaction can be systemic or localized
- Antigens
  - Examples: foods, animal sources (ex: cats, dogs, bee stings), mold, latex, and dust
- Two stages:
  - Sensitization stage
    - Person encounters the antigen but does not experience any symptoms
  - Effect stage
    - The person has a repeat exposure to the antigen and symptoms occur that are typical of allergic reactions
- Treatments include epinephrine, systemic glucocorticoids, antihistamines, immunotherapy, anti-IgE monoclonal antibodies

Type 2 hypersensitivities

- Also called antibody-mediated cytotoxic hypersensitivity
- Causes cytotoxic reactions, meaning healthy cells die as antibodies activate the complement system
- Can cause long-term damage to cells and tissues
- Transfusion reactions, hemolytic disease of the newborn, and drug-induced hemolytic anemia
- Treatment usually involves:
  - Immunosuppressants
  - Systemic glucocorticoids
  - IV immunoglobulin infusions
  - Plasmapheresis

Type 3 hypersensitivities

- Also called immune complex-mediated hypersensitivity
- Antigens and antibodies form complexes in the skin, blood vessels, joints, and kidneys, leading to tissue damage due to complement activation and inflammatory response
- Common causes:
  - Drugs that contain foreign serum, such as antivenom, antitoxins, and anti diphtheria serum
  - Certain infectious diseases
  - Insect stings or tick bites
- Can lead to serum sickness, lupus, rheumatoid arthritis, small-vessel vasculitis, poststreptococcal glomerulonephritis, among others
- Treatment options typically involves controlling the underlying condition

Type 4 hypersensitivities

- Also called delayed-type hypersensitivity
- Reaction is cell-mediated
- Reaction begins with a sensitization phase, 1-2 weeks after primary contact with an antigen
  - Subsequent exposure to the antigen induces a response about 24 hours after contact
  - In many cases, tissue damage is limited and may be protective
- Three types:
  - Contact dermatitis
  - Tubercular lesions
  - Graft rejection
- Common causes:
  - Poison ivy & oak
  - Nickel
  - Hair dye
  - Intracellular bacteria, fungi, parasites, and viruses
- Treatment depends on cause

Immunodeficiency

- The immune system's ability to fight infections and cancer is compromised or entirely absent
- Two types:
  - Primary
  - Secondary
- A person who has an immunodeficiency is said to be "immunocompromised"
  - May be more vulnerable to opportunistic infections
  - May be vulnerable to routine infections that can affect anyone, with greater possibility of severe complications
  - Decreased cancer immunosurveillance
  - Reduced protection from vaccines

Primary immunodeficiency

- Disorders in which part of the immune system is missing or does not function properly
- Not caused by secondary factors such as disease, drug treatment, or environmental exposures
- Most are genetic disorders
- About 1 in 500 people in the U.S. are born with a primary immunodeficiency
- Can result in persistent or recurring infections, autoinflammatory disorders, tumors, and disorders of various organs

Secondary immunodeficiencies

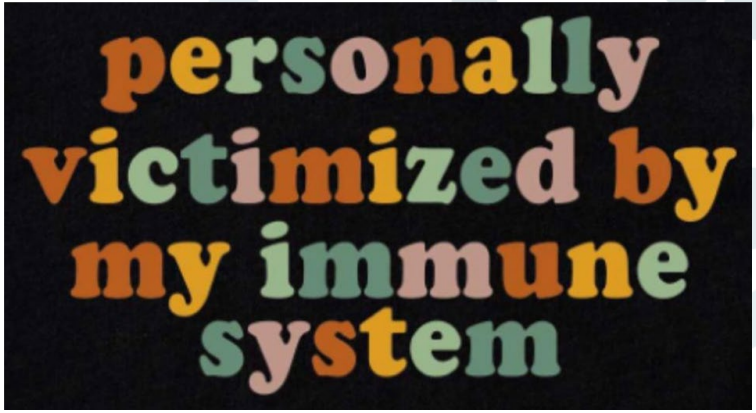
- Also called acquired immunodeficiency
- Causes include:
  - Malnutrition
  - Aging
  - Medications
    - Chemotherapy, disease-modifying therapies (DMTs), anti-rejection immunosuppressants, and glucocorticoids
  - Toxins
    - Heavy metals, mercury, pesticides, petrochemicals
  - Cancers of the bone marrow and blood cells
    - Leukemia, lymphoma, multiple myeloma
  - Certain infections such as HIV
  - Smokers, alcoholism, and drug abuse

Managing & treating immunodeficiencies

- Managing & preventing infections
  - Antibiotic therapy
  - Vaccination
    - Live vaccines may be contraindicated
  - Immunoglobulin (IVIG) replacement therapy
- Hematopoietic stem cell transplantation (HSCT) and gene therapy
  - Primary immunodeficiencies
- In secondary immunodeficiency, removing or resolving the underlying cause if possible

Autoimmune disorders

- Immune system is more active than it should be and attacks the body's own healthy tissues and organs
- Can be mediated by autoantibodies, T cells, antigen-antibody complexes, or immune complexes
- Chronic conditions
- More than 100 different autoimmune disorders have been identified
    - Examples: rheumatoid arthritis (RA), lupus, psoriasis, Crohn's disease, celiac disease, ulcerative colitis (UC), type 1 diabetes, Hashimoto's thyroiditis, multiple sclerosis (MS), and myasthenia gravis
- 1 in 15 people in the U.S. has an autoimmune disorder



Autoimmune disorders

- Exact cause is unknown
  - Triggers may include:
    - Viral infections (including COVID-19 and Epstein-Barr virus)
    - Female
      - 80% of those living with an autoimmune disorder are female
    - Having biological relatives with autoimmune disorders
    - Having another autoimmune disease
    - Exposure to chemicals, pollution, or other environmental factors
    - Smoking
    - Vitamin deficiencies (such as vitamin D)
    - Geographical location (such as higher latitudes)

Autoimmune disorders

- Treatment depends on the particular condition
  - For example, type 1 diabetes need insulin therapy and people with celiac disease need a gluten-free diet
  - Common treatments to manage symptoms and progression of disease include:
    - Pain relievers
    - Immunosuppression
      - DMTs, glucocorticoids
        - Secondary immunodeficiency may occur
    - Physical and occupational therapy
    - IVIG infusions
- Most autoimmune diseases have no cure and require lifelong management

Vaccines

Vaccination

- Active immunity without the risk of the actual disease
- Two types of vaccines
  - Inactivated
  - Live, attenuated
- General rule
  - The more similar a vaccine is to the disease-causing form of the pathogen, the better the immune response is to the vaccine
- Factors influencing the immune response to vaccines
  - Maternal antibodies
  - Dose of antigen
  - Route of administration
  - Use of adjuvants
  - Host factors

How do vaccines work?

- Introduces the body to an ingredient that mimics the appearance or behavior of a pathogen
  - The “antigen”
- Antibodies are created
- If the pathogen is encountered, the immune system can quickly respond as it will recognize the antigen

Inactivated vaccines

- Cannot cause any form of disease
- Less affected by circulating antibody
- Always require multiple doses to induce an immune response
- Mostly a humoral response
- Antibody titers will diminish with time in most cases
    - This is called “waning”

Types of inactivated vaccines

- Whole cell: contains whole bacteria or viruses that have been killed through a physical or chemical process
  - Polio, hepatitis A, rabies, and whole-cell pertussis
- Subunit, recombinant, polysaccharide, and conjugate: use specific pieces of the pathogen, like its protein, sugar, or capsid
  - Create a strong immune response that is targeted to key parts of the germ
  - May need boosters for ongoing protection
  - Hib, hepatitis B, HPV, acellular pertussis, pneumococcal disease, meningococcal disease, COVID-19, and shingles

Types of inactivated vaccines

- Toxoid: use a toxin made by the pathogen that causes a disease that has been made harmless
  - Immune response is targeted at the toxin
  - May require booster shots for ongoing protection
  - Diphtheria and tetanus
- Messenger RNA (mRNA): mRNA created in a laboratory teaches cells how to make a protein that triggers an immune response
  - The mRNA is broken down within a few days after vaccination
  - COVID-19, RSV
- Viral vector: use a modified version of a different virus as a vector to deliver instructions to stimulate an immune response
  - Ebola Zaire

Live, attenuated vaccines

- A virus or bacteria is weakened using laboratory techniques
- Must grow and replicate in a vaccinated person
  - Fragile
- Humoral and cell-mediated response occurs
- Usually produces immunity with one dose
- Vulnerable to interference from circulating antibodies
- Cannot be used in immunocompromised persons

Live, attenuated vaccines

- Measles, mumps, rubella (MMR)
- Varicella
- Rotavirus
- Intranasal influenza
- Yellow fever
- Vaccinia (smallpox - ACAM2000)
- Oral typhoid
- Oral polio

What's in a vaccine?

Vaccine components

- Antigens
  - Stimulates the immune response towards the specific pathogen
  - As vaccine technology advances, vaccines contain less and less antigen
- Stabilizers
  - Maintains effectiveness in storage
  - $MgCl_2$, $MgSO_4$, lactose-sorbitol
  - Gelatin
    - Most is porcine in origin, but may be bovine
- Antibiotics
  - Help prevent bacterial contamination during the manufacturing process
  - Neomycin, streptomycin, polymyxin B, chlortetracycline, and amphotericin B
    - Rarely cause human allergies

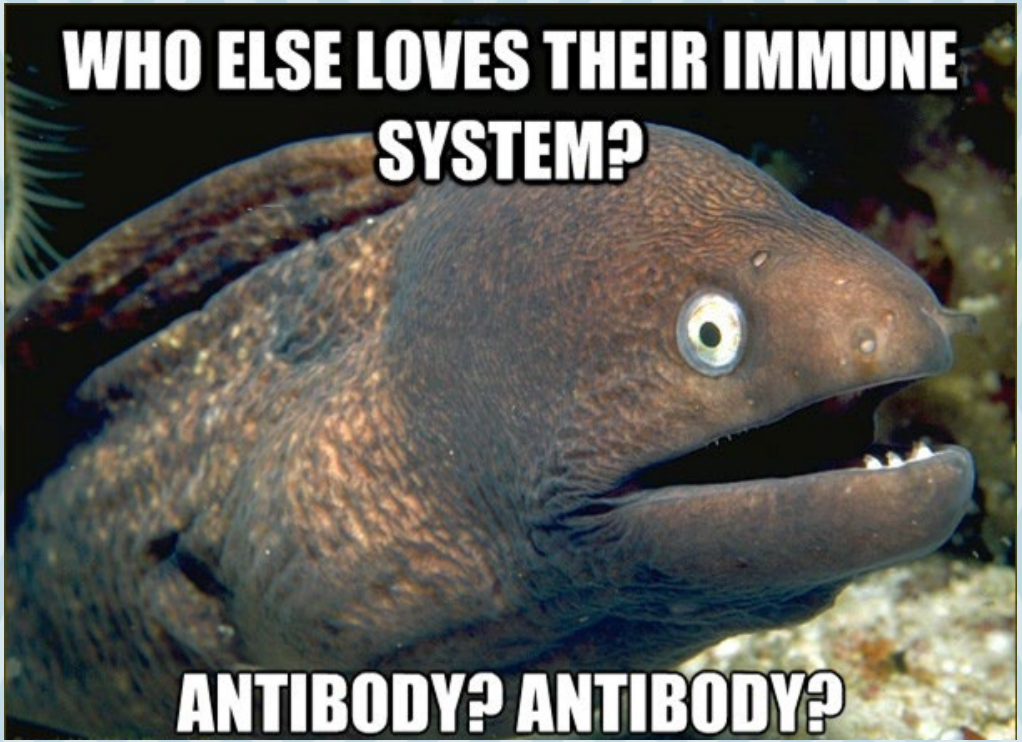
Vaccine components

- Adjuvants
  - Help stimulate the production of antibodies against the antigen
  - Makes vaccines more effective by enhancing, accelerating, and prolonging the immune response
  - Allows for fewer doses of the vaccine to be given
    - Important in inactivated vaccines
  - Several hundred different types
    - Aluminum
    - Monophosphoryl A
    - QS21
    - Squalene

Vaccine components

- Preservatives
  - Added to multi-dose vials to prevent microbial growth
  - Phenol, benzethonium chloride, 2-phenoxyethanol currently used in the U.S.
  - Thimerosal has not been in routine childhood vaccines since the late 1990s
- Formaldehyde
  - Used to inactivate viruses and detoxify bacterial toxins

Questions?



Thank you!

Heidi Gurov, RN, BSc, BSN, CMRN
heidi.gurov@wyo.gov
307-777-8981

Wyoming Department of Health | PUBLIC HEALTH DIVISION | IMMUNIZATION UNIT