The Science Behind Vaccines and the Immune Response

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Outline of Talk

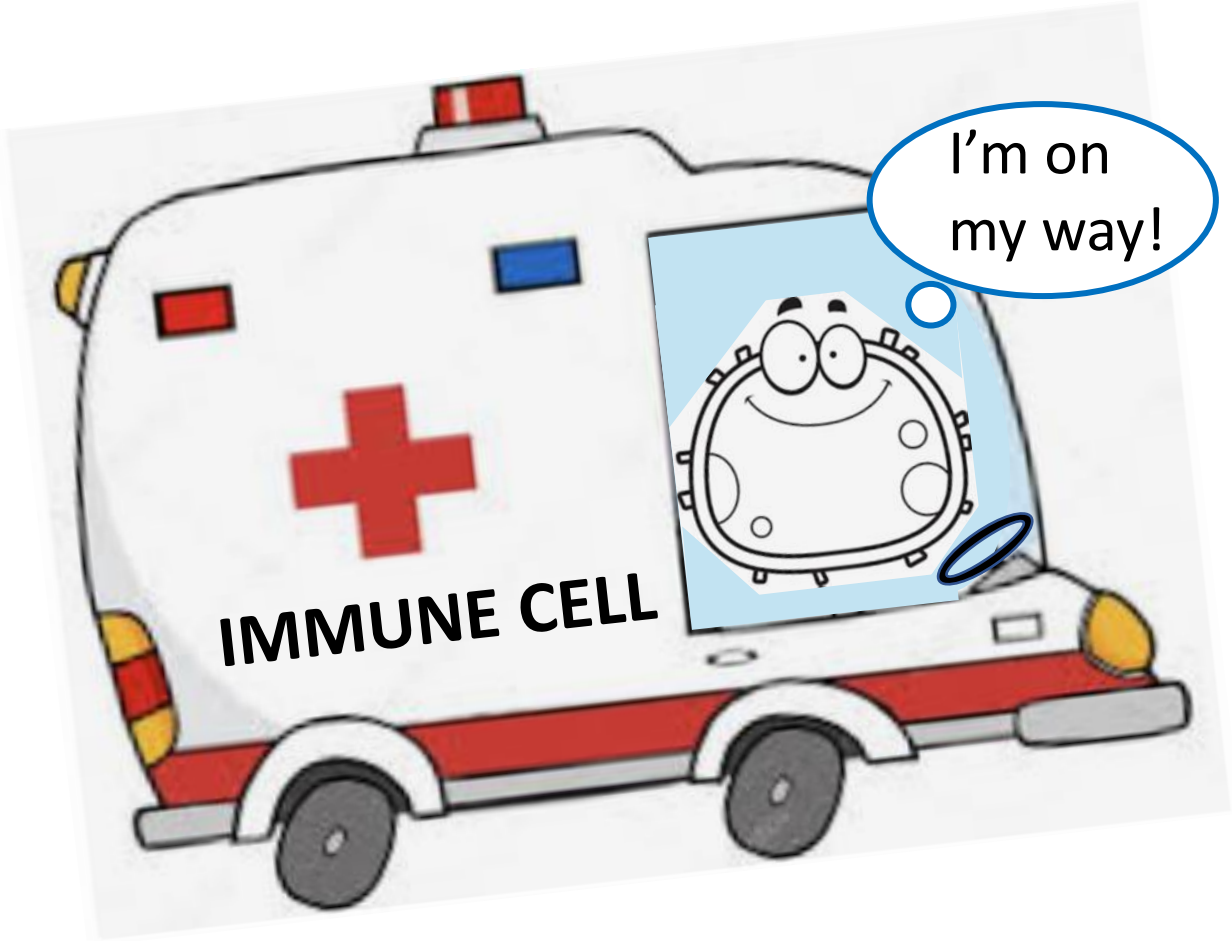
- The immune system is a mobile defense system *and* your personal TSA
- Overview of Innate and Adaptive Immunity
- Comparison of Passive and Active Immunity
- B cells, T cells, and Immunologic Memory
- Immune System Capacity (aka 'clonal selection theory')
- Vaccines – immune response to different formulations
  - mRNA
  - live, attenuated
  - subunit
  - conjugate
  - inactivated
- Concept of Herd or Community Immunity
- Immunization Schedules and Altered Immunocompetence

Learning Objectives

- **Compare** and **contrast** innate and adaptive immunity
- **Describe** the role of B cells and T cells in the adaptive immune system
- **Compare** and **contrast** passive immunity and active immunity
- **Evaluate** vaccines in relation to formulation and immune response
- **Describe** the role of the adjuvant in vaccines
- **Explain** the concept of herd immunity
- **Discuss** the use of vaccines in populations with immunodeficiency or an immunocompromised state (aka ‘altered immunocompetence’)
- **Review** clonal selection in relation to immunization
- **Explain** the capacity of the immune system in the context of the number of antigens that can be combated at any given time

The immune system is a mobile defense system

– like an ambulance – made up of lots of different cells that travel to the site of an injury



Much of immune function relies on getting the right cells to the right place at the right time

The immune system is your personal Transportation Security Administration (TSA)

Function of the TSA

○ Scan passengers for possible security threats	✓ **TSA**
○ Early detection of security threat	✓ **TSA**
○ Gather information about threat	✓ **TSA**
○ Rapid containment of local threat	✓ **TSA**
○ Initiate identification of larger threat	✓ **TSA**
○ Neutralization/elimination of local and disseminated threat	✓ **FBI/CIA/armed forces**
○ After resolution, better prepared for next possible threat	✓ **TSA/FBI/CIA/armed forces**

Function of the Immune System

○ Scan tissues for infectious threats	✓ **Innate immunity**
○ Early detection of infection threat	✓ **Innate immunity**
○ Gather information about infection	✓ **Innate immunity**
○ Rapid containment of local infection	✓ **Innate immunity**
○ Initiate identification of infection	✓ **Innate/adaptive immunity**
○ Neutralization/elimination of local and disseminated infection	✓ **Adaptive Immunity**
○ After resolution, better prepared for next possible infection	✓ **Adaptive immunity**

Two basic types of immunity

Attribute	Innate Immunity	Adaptive Immunity
Response time	Minutes/hours	Days
Specificity	Specific for molecules and molecular patterns associated with pathogens	Highly specific; discriminates even minor differences in molecular structure; details of microbial or nonmicrobial structure recognized with high specificity
Diversity	A limited number of germ line–encoded receptors	Highly diverse; a very large number of receptors arising from genetic recombination of receptor genes
Memory responses	None	Persistent memory, with faster response of greater magnitude on subsequent infection
Soluble components of blood or tissue fluids	Many antimicrobial peptides and proteins	Antibodies
Major cell types	Phagocytes (monocytes, macrophages, neutrophils), natural killer (NK) cells, dendritic cells	T cells, B cells

first encounter (primary) takes 7-14 days
subsequent encounter (secondary) 1-3 days

- **Innate** immunity is **non-specific**
  - first line of defense
  - recognize 'patterns' associated with categories of pathogen
- **Adaptive** immunity is **specific** in response to each pathogen
  - Recognizes highly specific, unique molecules of each pathogen

Hematopoiesis is the formation and development of red and white blood cells in our bone marrow

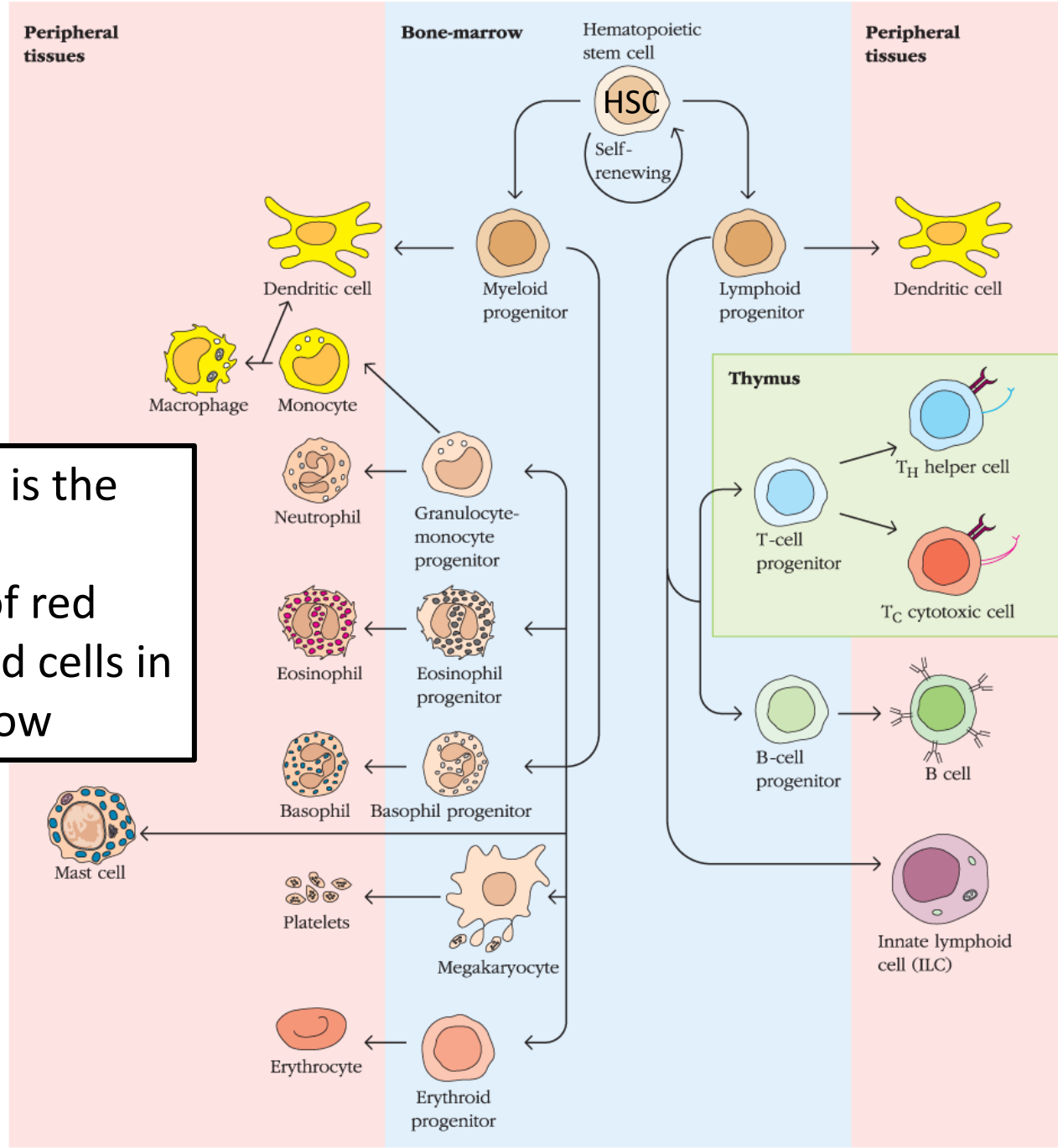


Figure 2-1
Punt, *Kuby Immunology*, 8e, © 2018 W. H. Freeman and Company

- All blood cells arise from the hematopoietic stem cell (HSC), which differentiates along one of **two pathways** - lymphoid progenitor cell or myeloid progenitor cell
- **Myeloid** progenitors give rise to innate cells
- **Lymphoid** progenitors give rise to adaptive cells (B & T)

Initiating host defense (aka TSA)

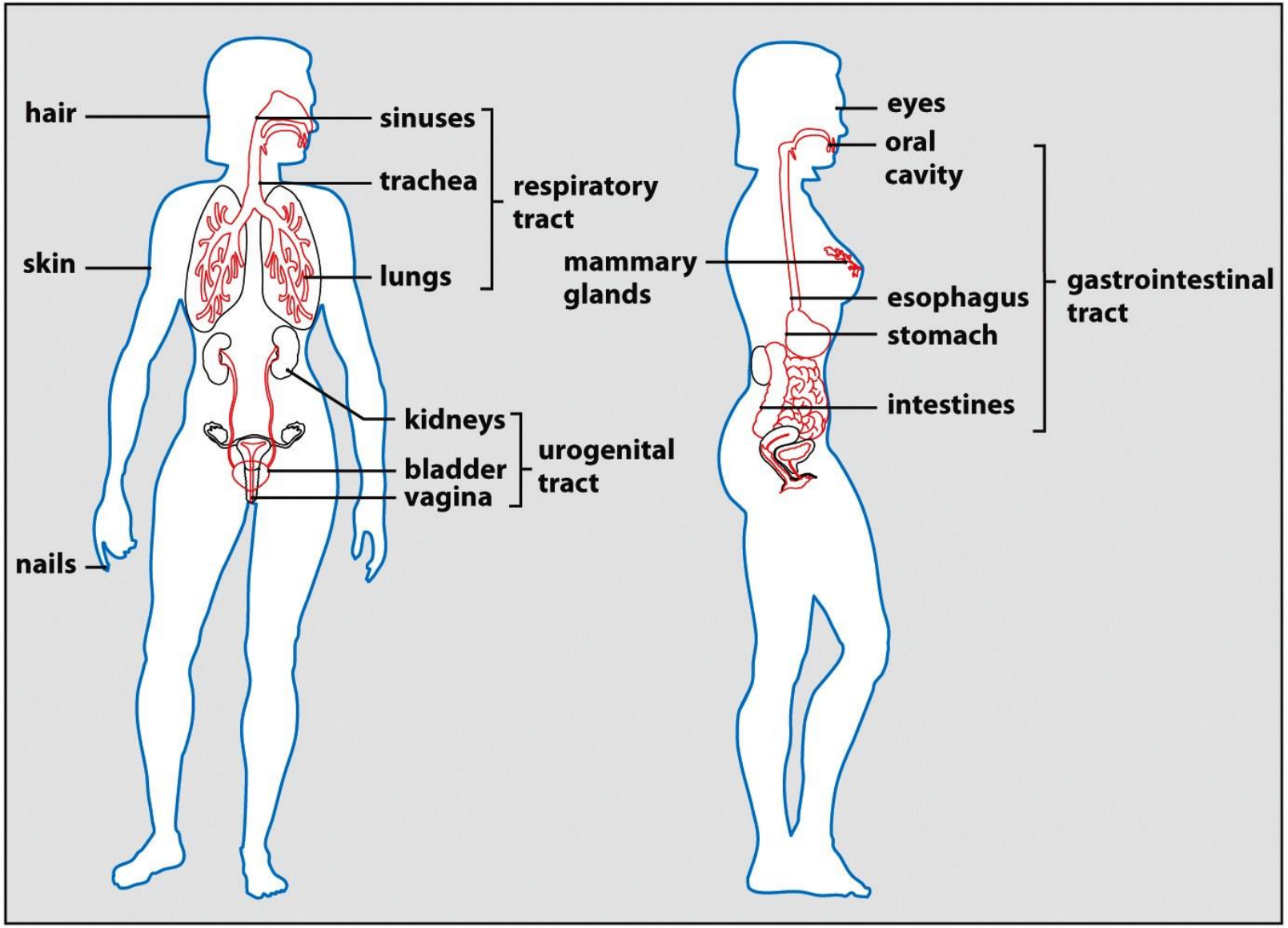
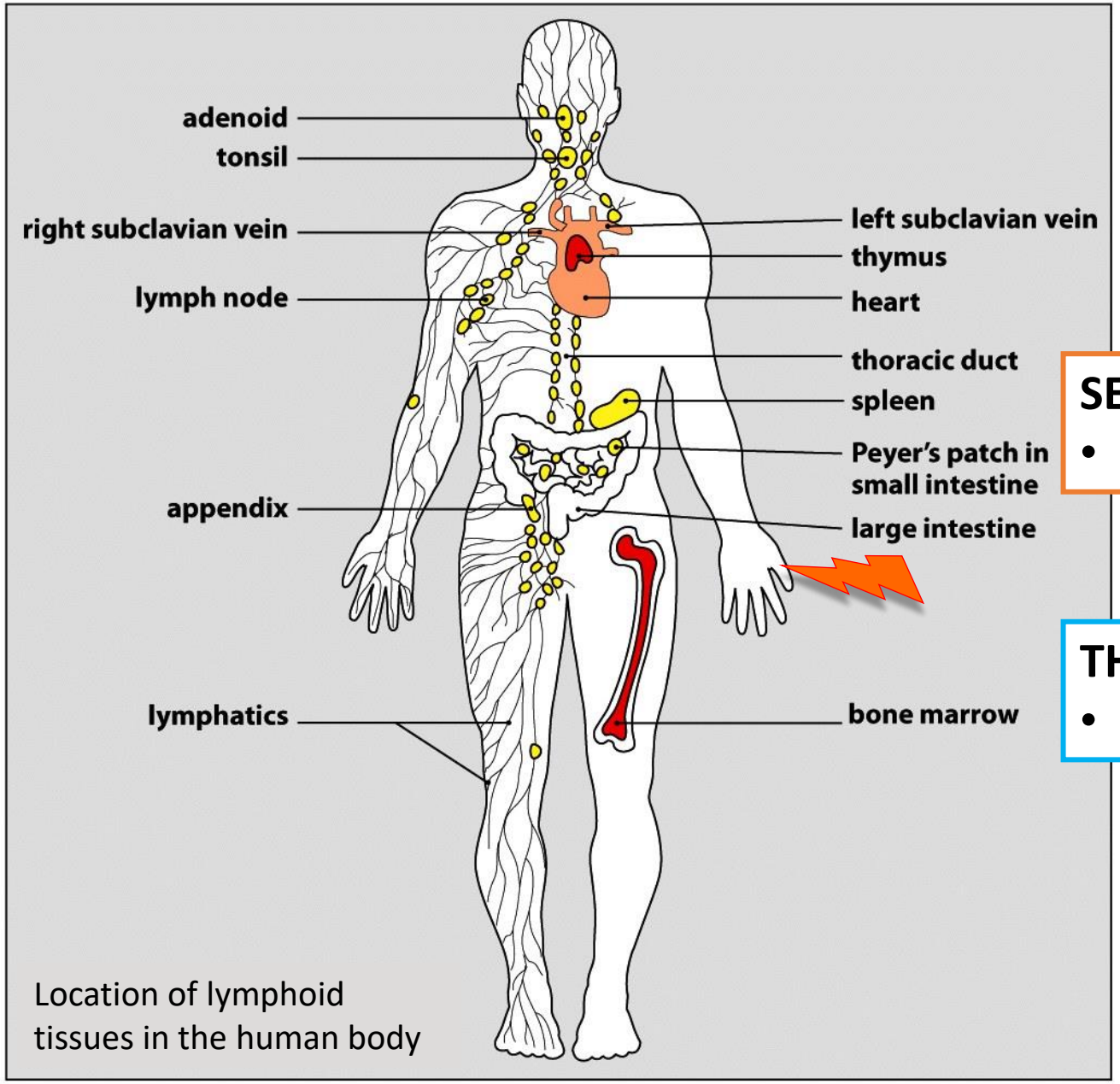


Figure 1.5 The Immune System, 3ed. (© Garland Science 2009)

FIRST LINE OF DEFENSE. physical barriers and epithelial surfaces that separate the body from the external environment

Continuing host defense (aka TSA)



Location of lymphoid tissues in the human body

Figure 1.18 The Immune System, 3ed. (© Garland Science 2009)

Innate Immune system

- First Barrier (skin, mucous membranes)
- Rapid, First Responders
- No Memory
- Containment of infection

SECOND LINE OF DEFENSE. Innate immune response

- Local, rapid response at site of infection

THIRD LINE OF DEFENSE. Adaptive immune response

- Slow, specific, centralized response to infection

Adaptive Immune system

- T cells and B cells
- Delayed, targeted response… highly specific
- Long-term immune **memory**
- Elimination of infection

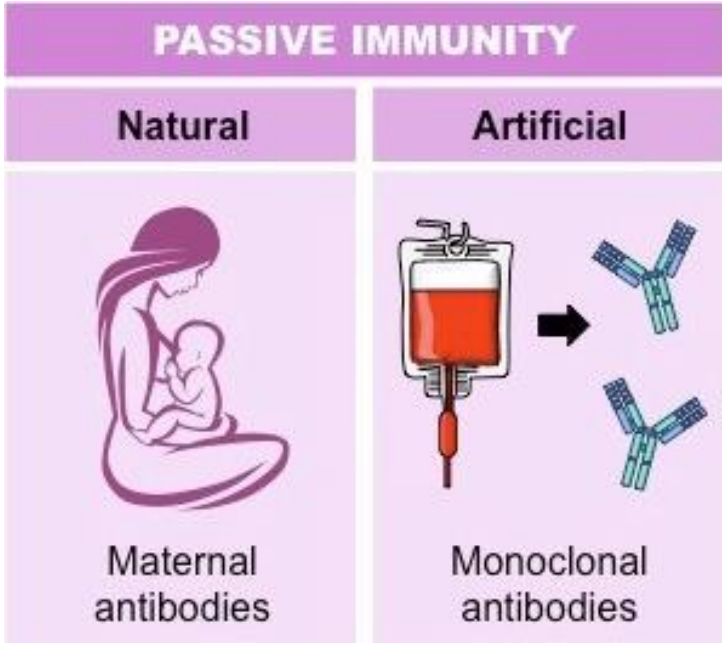
Two major forms of immunity – passive and active

Passive. transfer of antibodies from one person to another

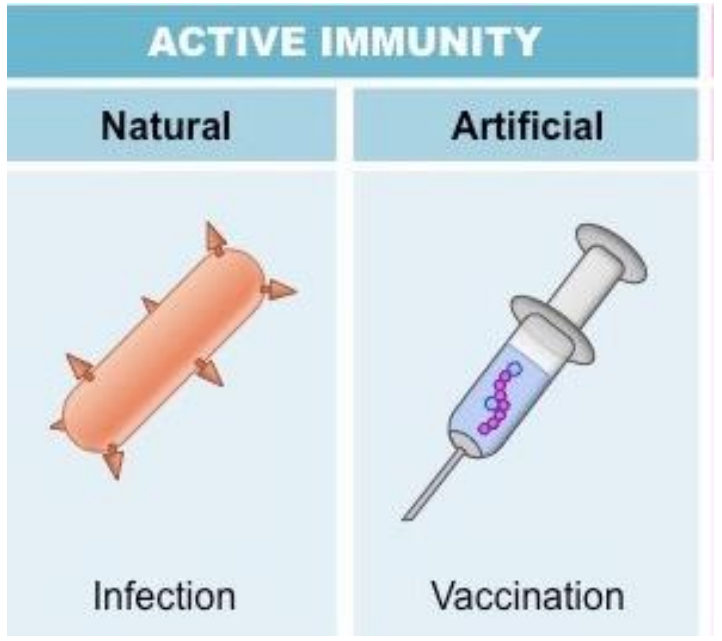
- Examples: maternal or pooled from donated samples

Active. pathogen exposures that generates an effective immune response and leads to memory of the pathogen

- Examples: infection 'out in the wild' (aka natural) or vaccines



https://ib.bioninja.com.au/higher-level/topic-11-animal-physiology/111-antibody-production-and/types-of-immunity.html



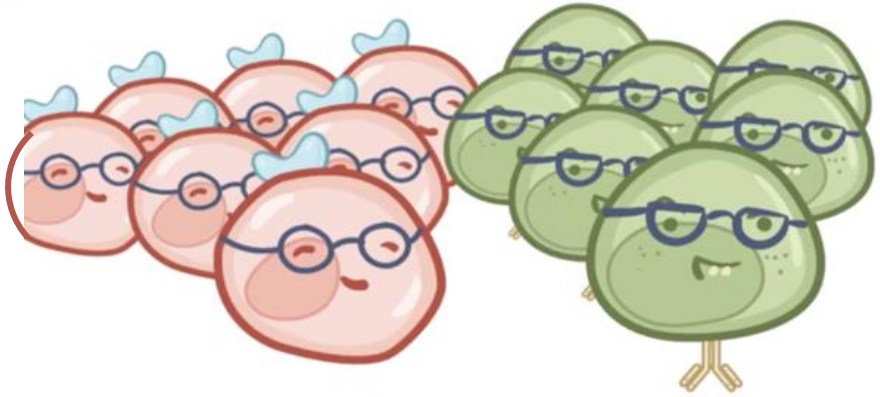
The goal of **passive immunization** is <u>transient</u> protection or alleviation of an existing condition

The goal of **active immunization** is <u>long-lasting</u> **immunologic memory** and protective immunity

Vaccines Train the Immune System

- Vaccines work *with* our immune system to provide long-lasting protection
- **Vaccines are <u>harmless</u> forms of the pathogen** that train the B and T cells of our immune system to recognize and remember (called ‘memory’ cells) the pathogen
- These **memory cells** will be ready to attack when the real, harmful pathogen enters the body

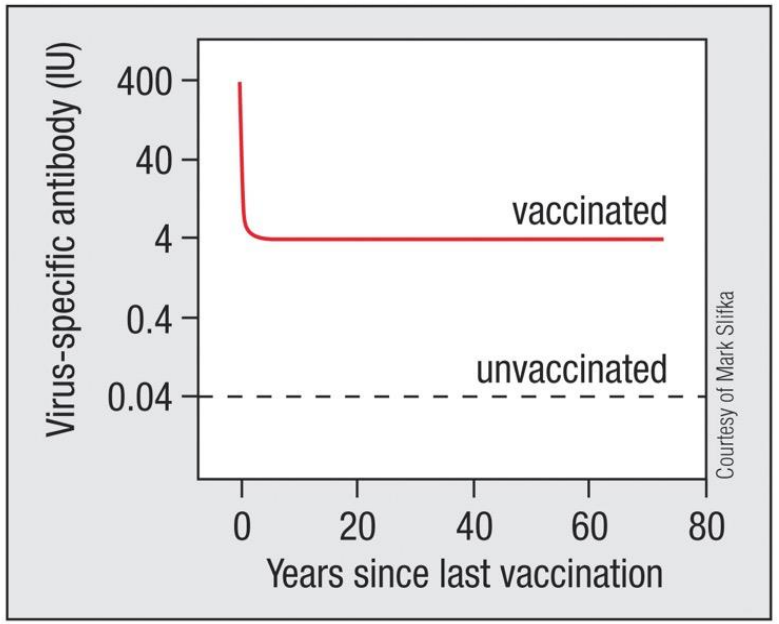
The ultimate goal of a vaccine is to provide **long-lasting protection** through the creation of **memory B and T cells**



Memory T cells **Memory B cells**

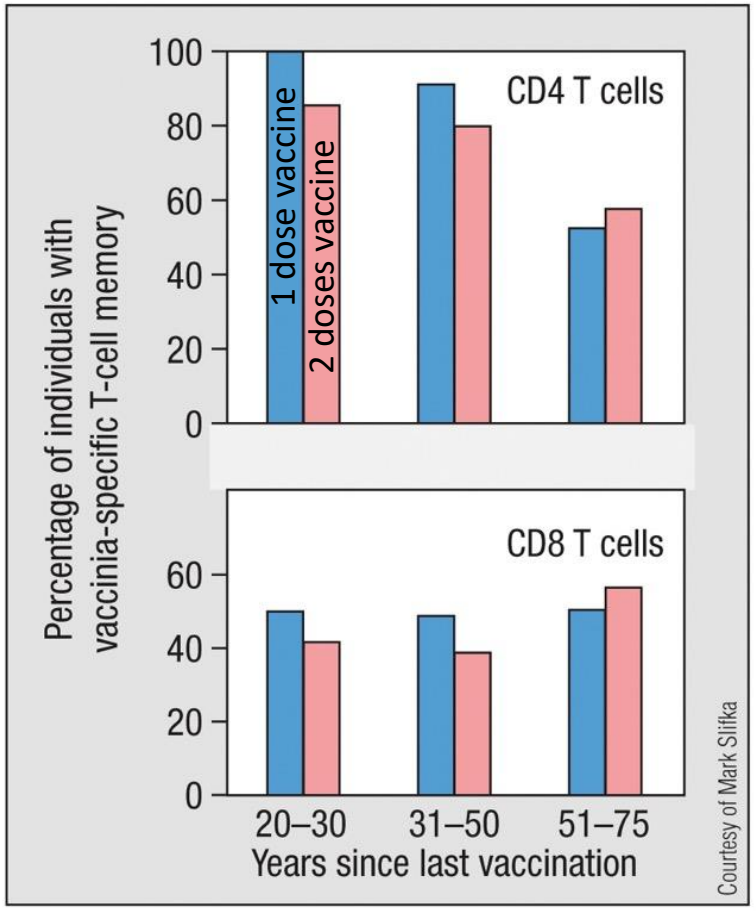
Long-term active protection

Active immunization elicits long-term protection (memory)

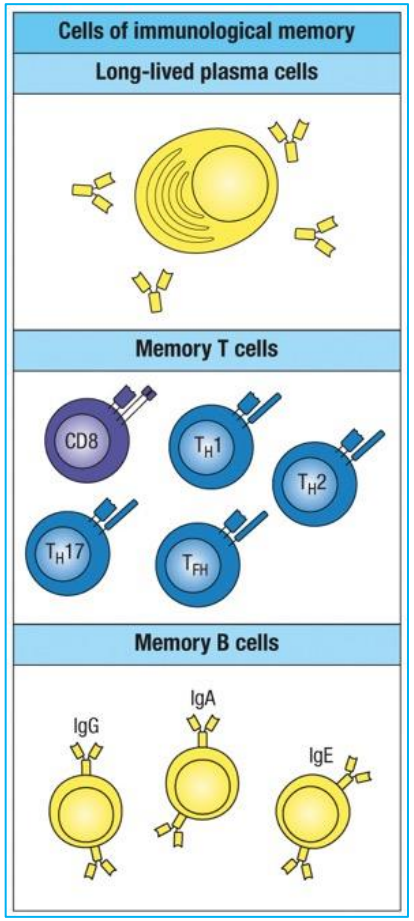


Parham Immunology

anti-vaccinia antibodies (B cells)



anti-vaccinia T cells



FUN FACT.
B cells and T cells can be trained to remember pathogens

- Anti-vaccinia antibodies (B cells) *and* CD4 and CD8 T cells continue to persist for as long as **75 years** after the last exposure to vaccinia virus, the smallpox surrogate that is used for vaccination, due to **long-lived memory B and T cells**

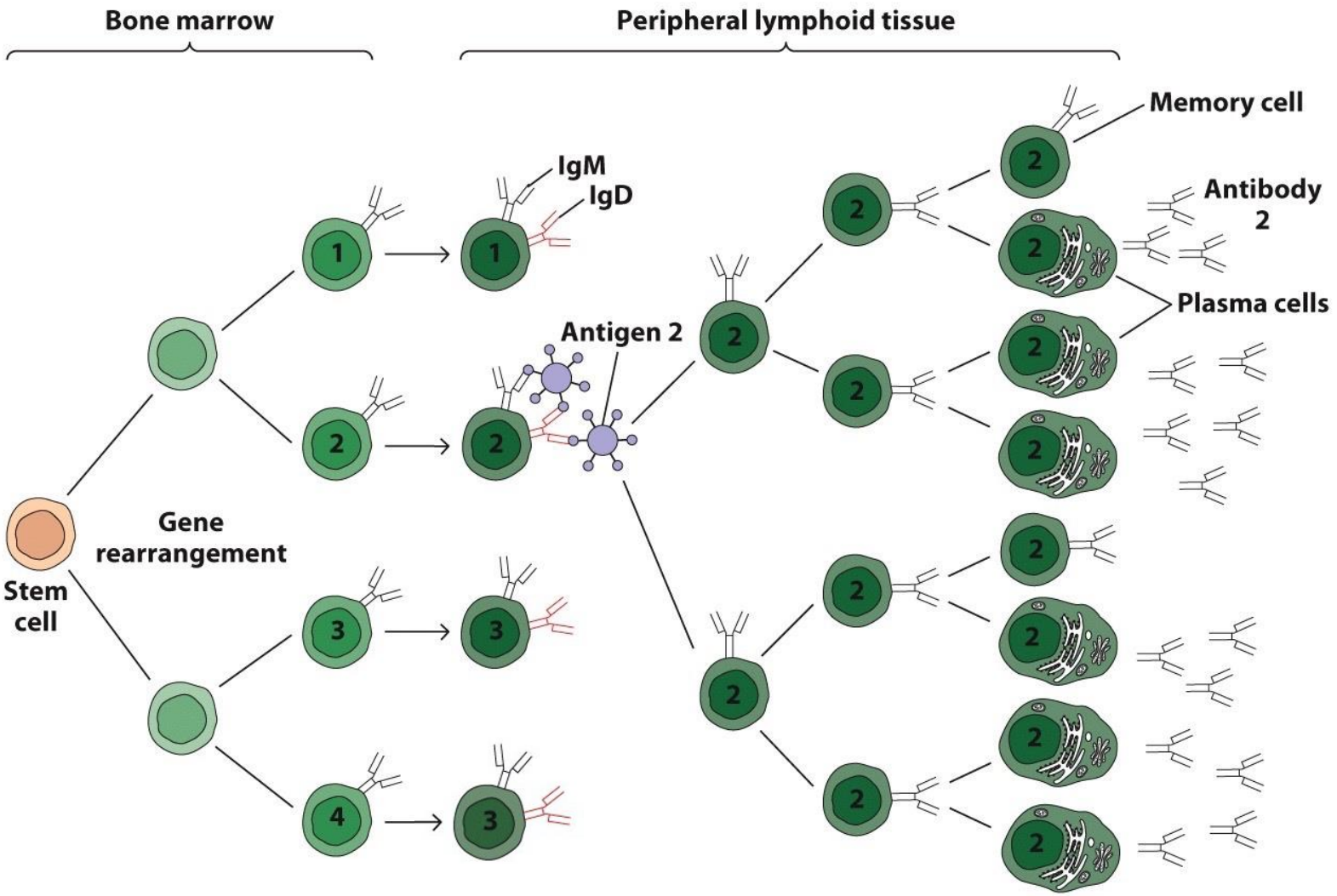
B and T cells are specific for 1 antigen*

Each B cell and each T cell has a unique specificity

Every time we encounter a pathogen (in the wild or in a vaccine) only a few B cells and T cells respond!

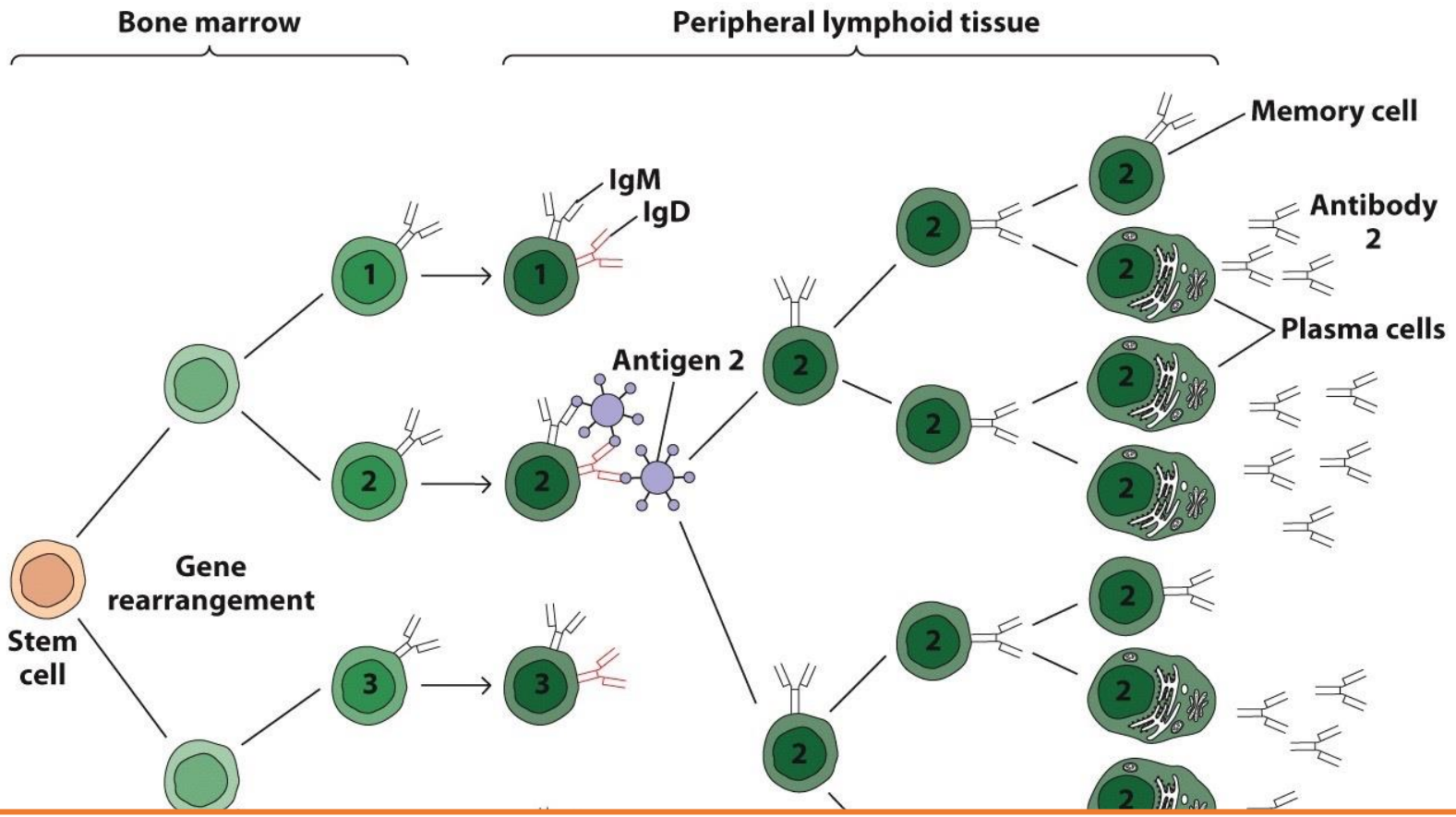
*actually 1 piece of 1 antigen

B and T cells are specific for 1 antigen*



Due to the <u>exquisite specificity</u> of each B cell and its unique and specific BCRs, only a small number of B cells will respond to any given pathogen that enters our body

Specificity is due to ‘clonal selection theory’ of B and T cells



FUN FACT. The specificity of B cells and T cells of the adaptive arm of the immune system means that we can NOT overwhelm the immune system through vaccination. Ever.

- Just like all other antigens detected in the body, the principle of clonal selection is at play in response to vaccine antigens
- Vaccine antigens induce the proliferation of the few cells that have antigen receptors (BCR for B cells, TCR for T cells) specific for the pathogenic components in the vaccine

‘History’ of immunizations and antigens - decreased amounts over time!

1900		1960		1980		2000	
Vaccine	Proteins	Vaccine	Proteins	Vaccine	Proteins	Vaccine	Proteins/ Polysacc
Smallpox	~200	Smallpox	~200	Diphtheria	1	Diphtheria	1
Total	~200	Diphtheria	1	Tetanus	1	Tetanus	1
		Tetanus	1	WC-Pertussis (whole cell)	~3000	AC-Pertussis (acellular)	2–5
		WC-Pertussis	~3000	Polio	15	Polio	15
		Polio	15	Measles	10	Measles	10
		Total	**~3217**	Mumps	9	Mumps	9
				Rubella	5	Rubella	5
				Total	**~3041**	Hib	2
						Varicella	69
						Pneumococcus	8
						Hepatitis B	1
						Total	**123–126**

The number of antigens in all immunizations combined has decreased over time!

Review > Pediatrics. 2002 Jan;109(1):124-9. doi: 10.1542/peds.109.1.124.

Addressing parents' concerns: do multiple vaccines overwhelm or weaken the infant's immune system?

Paul A Offit [1], Jessica Quarles, Michael A Gerber, Charles J Hackett, Edgar K Marcuse, Tobias R Kollman, Bruce G Gellin, Sarah Landry

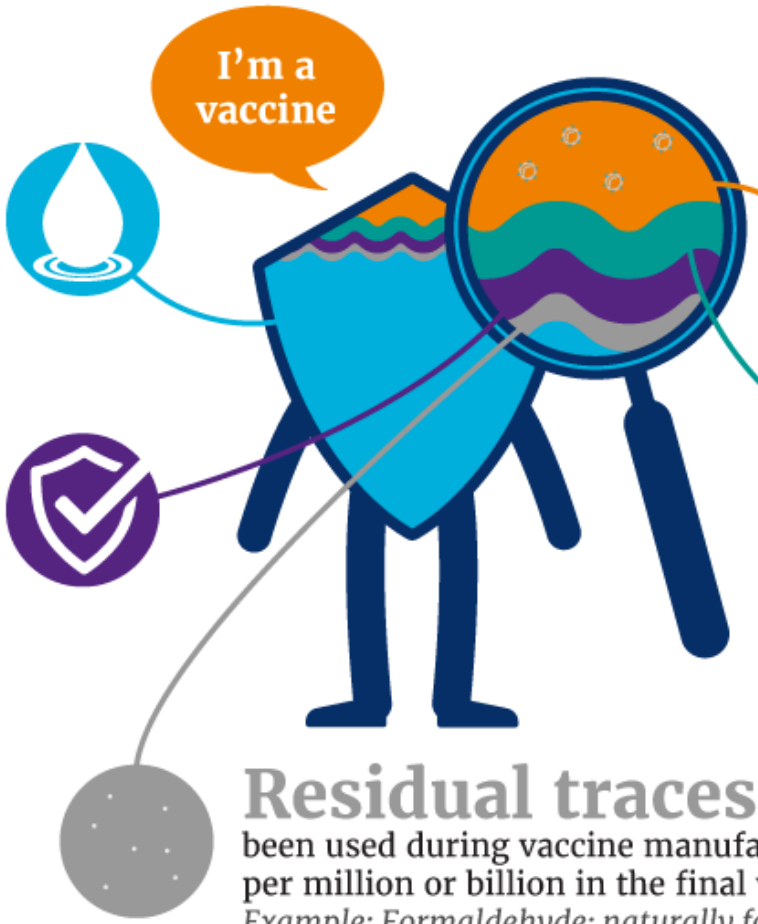
SPOILER ALERT.
No!

Recreated from Offit et al., Pediatrics, January 2002

Celebrate Vaccines
with the British Society for Immunology

What's in a vaccine?

British Society for immunology
www.immunology.org



Water
The main ingredient.

Active ingredient
A very small amount of a harmless form of the bacteria or virus you are immunising against.

Preservatives and stabilisers
Maintain vaccine quality, safe storage and prevent contamination.
Example: Sorbitol; naturally found in fruit in larger amounts.

Adjuvants
Create a stronger immune response to the vaccine. Pose no significant risk to health in the very small quantities used.
Example: Aluminium; naturally found in drinking water at higher levels.

Residual traces
of substances that have been used during vaccine manufacture, measured as parts per million or billion in the final vaccine.
Example: Formaldehyde; naturally found in human body.

Check out my Team Vaccine 'Immunology 101' blog series ☺
Immunology 101 Series: Adjuvants, Aluminum, and Gelatin! Oh My! The Scientific Scoop on Vaccine Ingredients

https://teamvaccine.com/2014/07/11/immunology-101-series-adjuvants-aluminum-and-gelatin-oh-my-the-scientific-scoop-on-vaccine-ingredients/

Adjuvants enhance the immune response!

- Adjuvants are probably the least understood component of a vaccine for the general public
- **Adjuvants enhance the immune response** - they are added into some vaccines to ensure a vigorous and protective response
  - Varies by vaccine formulation; most vaccines that are not live, attenuated don't stimulate the immune system as strongly as desired
- The most common adjuvant is aluminum; it modulates Th2-type response and antibody production through B cell activation
- **Aluminum stimulates the pattern recognition receptors on innate cells and promotes antigen uptake**

Adjuvants used in U.S. vaccines

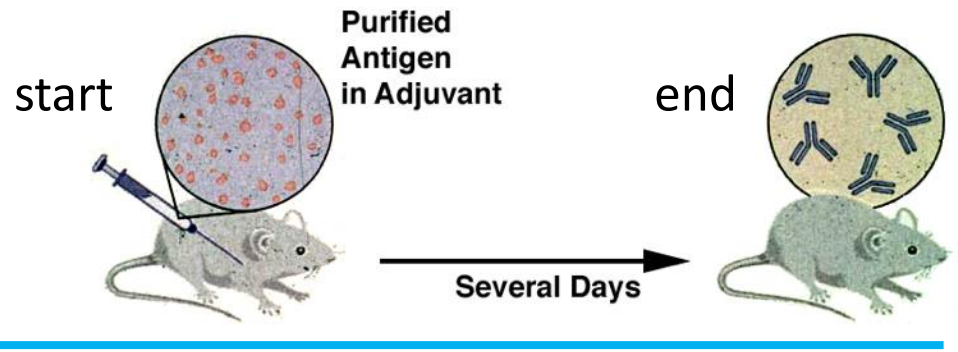
Adjuvant	Composition	Vaccines
Aluminum	One or more of the following: amorphous aluminum hydroxyphosphate sulfate (AAHS), aluminum hydroxide, aluminum phosphate, potassium aluminum sulfate (Alum)	Anthrax, DT, DTaP (Daptacel), DTaP (Infanrix), DTaP-IPV (Kinrix), DTaP-IPV (Quadracel), DTaP-HepB-IPV (Pediarix), DTaP –IPV/Hib (Pentacel), Hep A (Havrix), Hep A (Vaqta), Hep B (Engerix-B), Hep B (Recombivax), HepA/Hep B (Twinrix), HIB (PedvaxHIB), HPV (Gardasil 9), Japanese encephalitis (Ixiaro), MenB (Bexsero, Trumenba), Pneumococcal (Prevnar 13), Td (Tenivac), Td (Mass Biologics), Tdap (Adacel), Tdap (Boostrix)
AS04	Monophosphoryl lipid A (MPL) + aluminum salt	Cervarix
MF59	Oil in water emulsion composed of squalene	Fluad
$AS01_B$	Monophosphoryl lipid A (MPL) and QS-21, a natural compound extracted from the Chilean soapbark tree, combined in a liposomal formulation	Shingrix
CpG 1018	Cytosine phosphoguanine (CpG), a synthetic form of DNA that mimics bacterial and viral genetic material	Heplisav-B
No adjuvant		ActHIB, chickenpox, live zoster (Zostavax), measles, mumps & rubella (MMR), meningococcal (Menactra, Menveo), rotavirus, seasonal influenza (except Fluad), single antigen polio (IPOL), yellow fever

Most with no adjuvant are live, attenuated vaccines b/c the immune response is vigorous

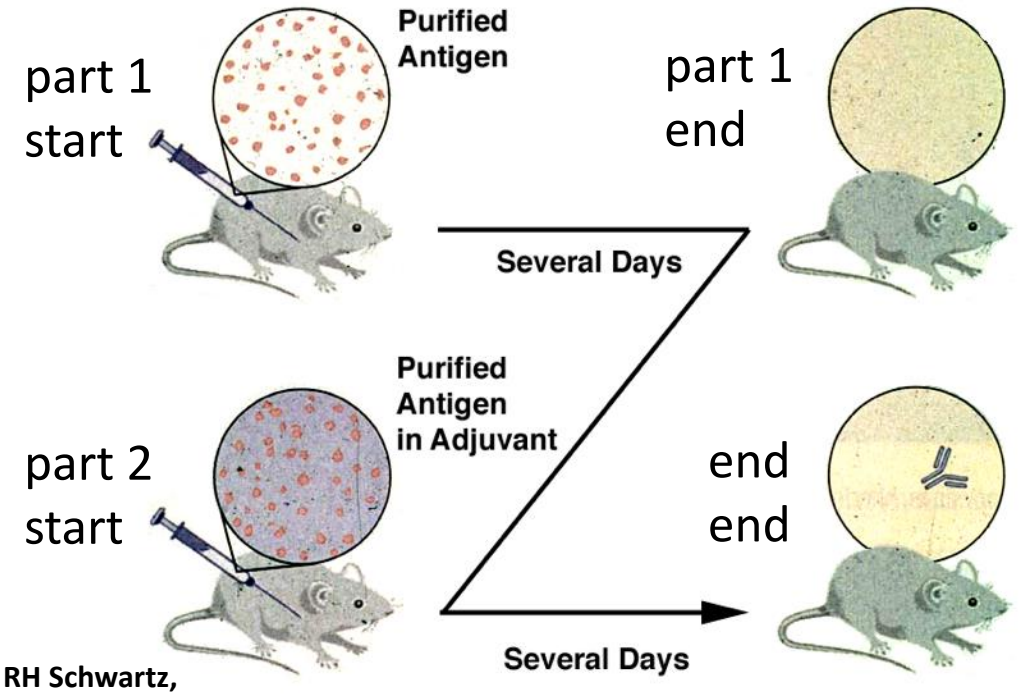
https://www.cdc.gov/vaccinesafety/concerns/adjuvants.html

Adjuvants enhance the immune response!

circa 1970



Immune response!!



No Immune response – purified antigen is not immunogenic, does not stimulate an immune response

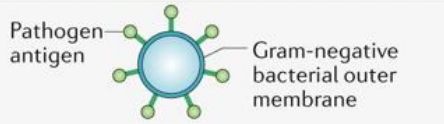
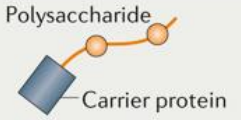
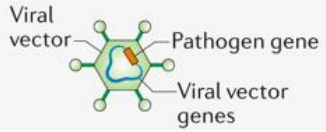
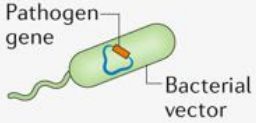
Weak Immune response – immune system has seen the antigen and produces little to no response upon second exposure – is tolerant

RH Schwartz,
Scientific American, 1993

Experiment that demonstrated the usefulness of adjuvants

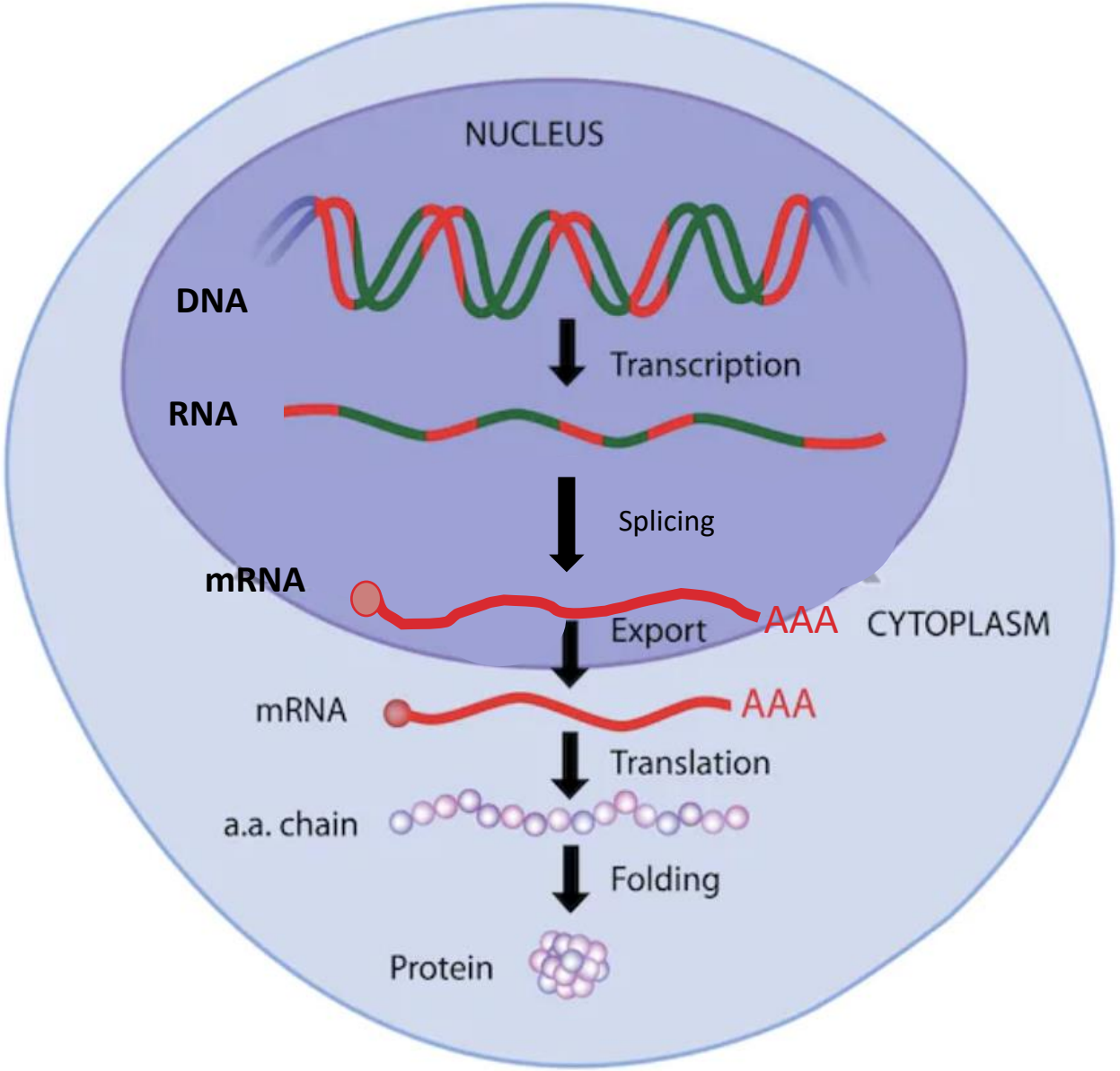
Numerous vaccine formulations for numerous types of pathogens

Type of vaccine		Licensed vaccines using this technology	First introduced
Live attenuated (weakened or inactivated)		Measles, mumps, rubella, yellow fever, influenza, oral polio, typhoid, Japanese encephalitis, rotavirus, BCG, varicella zoster	1798 (smallpox)
Killed whole organism		Whole-cell pertussis, polio, influenza, Japanese encephalitis, hepatitis A, rabies	1896 (typhoid)
Toxoid		Diphtheria, tetanus	1923 (diphtheria)
Subunit (purified protein, recombinant protein, polysaccharide, peptide)		Pertussis, influenza, hepatitis B, meningococcal, pneumococcal, typhoid, hepatitis A	1970 (anthrax)
Virus-like particle		Human papillomavirus	1986 (hepatitis B)

Type of vaccine		Licensed vaccines using this technology	First introduced
Outer membrane vesicle		Group B meningococcal	1987 (group B meningococcal)
Protein–polysaccharide conjugate		*Haemophilus influenzae* type B, pneumococcal, meningococcal, typhoid	1987 (*H. influenzae* type b)
Viral vectored		Ebola	2019 (Ebola)
Nucleic acid vaccine		SARS-CoV-2	2020 (SARS-CoV-2)
Bacterial vectored		Experimental	–

Pollard, A.J., Bijker, E.M. A guide to vaccinology: from basic principles to new developments. *Nat Rev Immunol* **21,** 83–100 (2021). https://doi.org/10.1038/s41577-020-00479-7

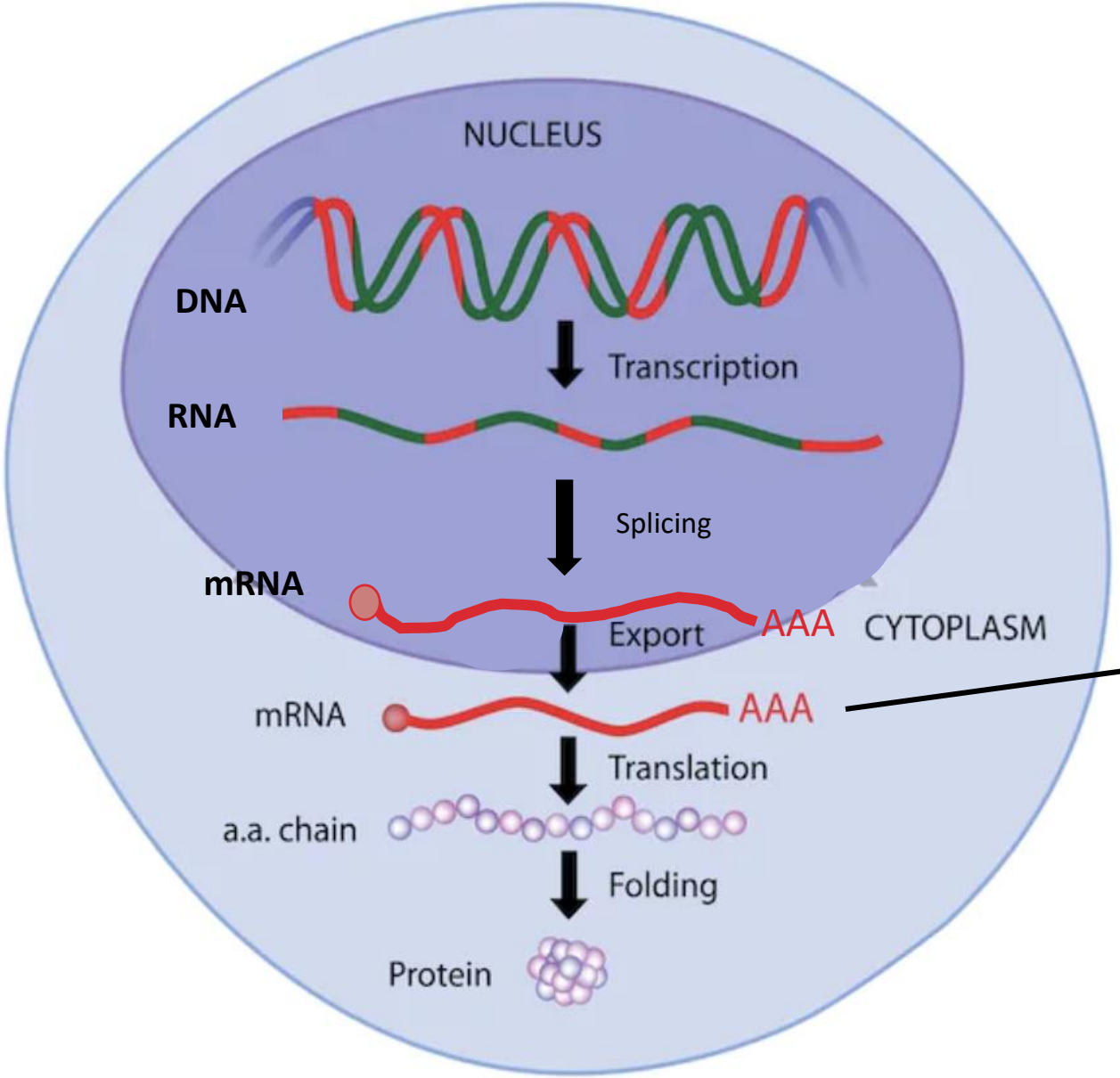
Every cell in our body uses genetic instructions to make protein

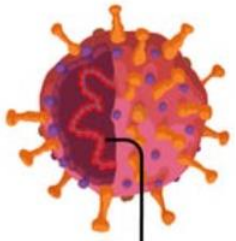


central dogma of molecular biology

DNA → (transcription) RNA (mRNA) → (translation) protein

mRNA vaccines use our cellular machinery to make spike protein





The coronavirus is studied in labs

Scientists sequence the virus' genetic code

mRNA that codes for the spike protein is purified and used in the vaccine

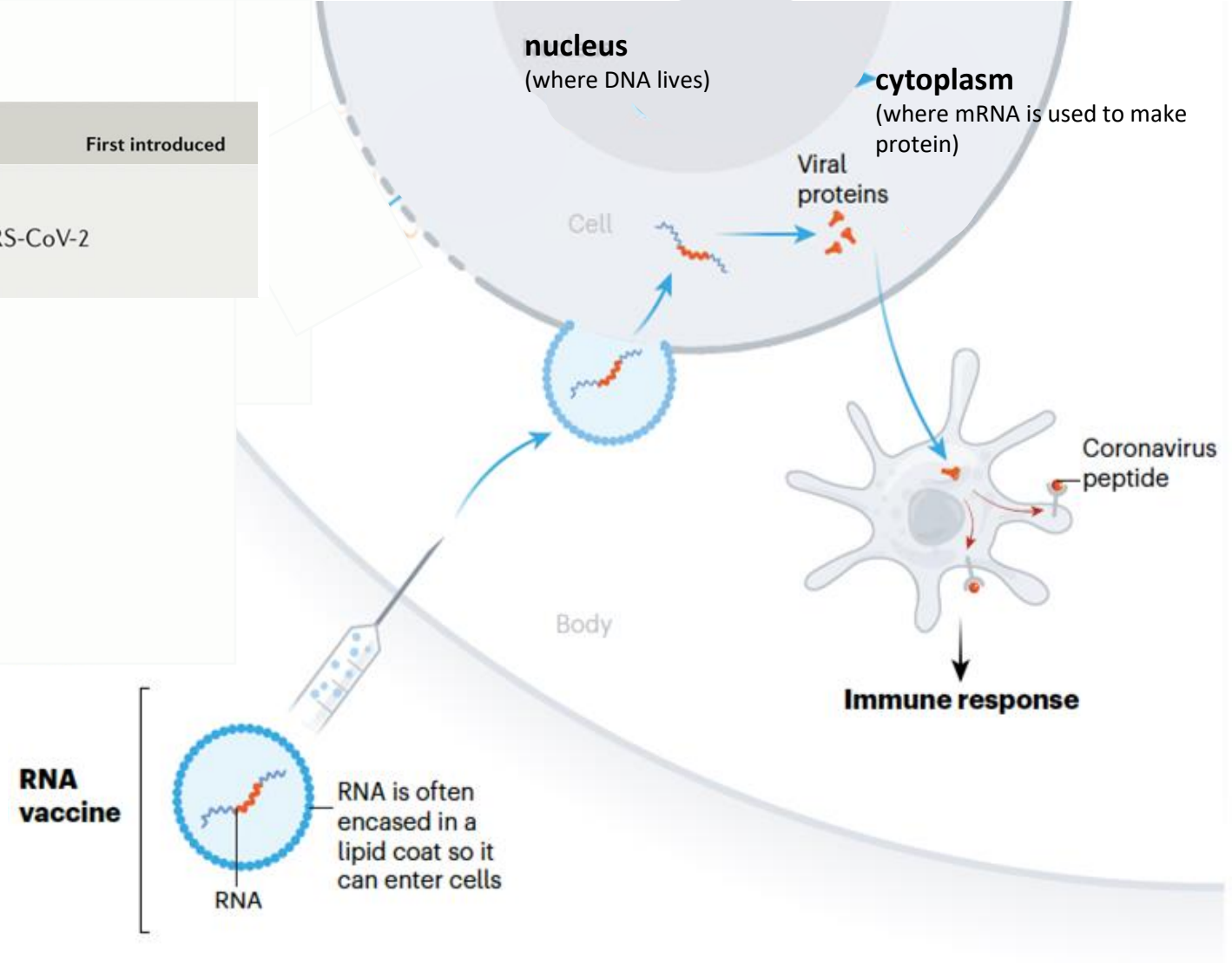
The cells in our body use the mRNA to make coronavirus spike protein

Our immune system responds and makes protective antibody

NIH. Senate Hearing 090920.

mRNA Vaccines

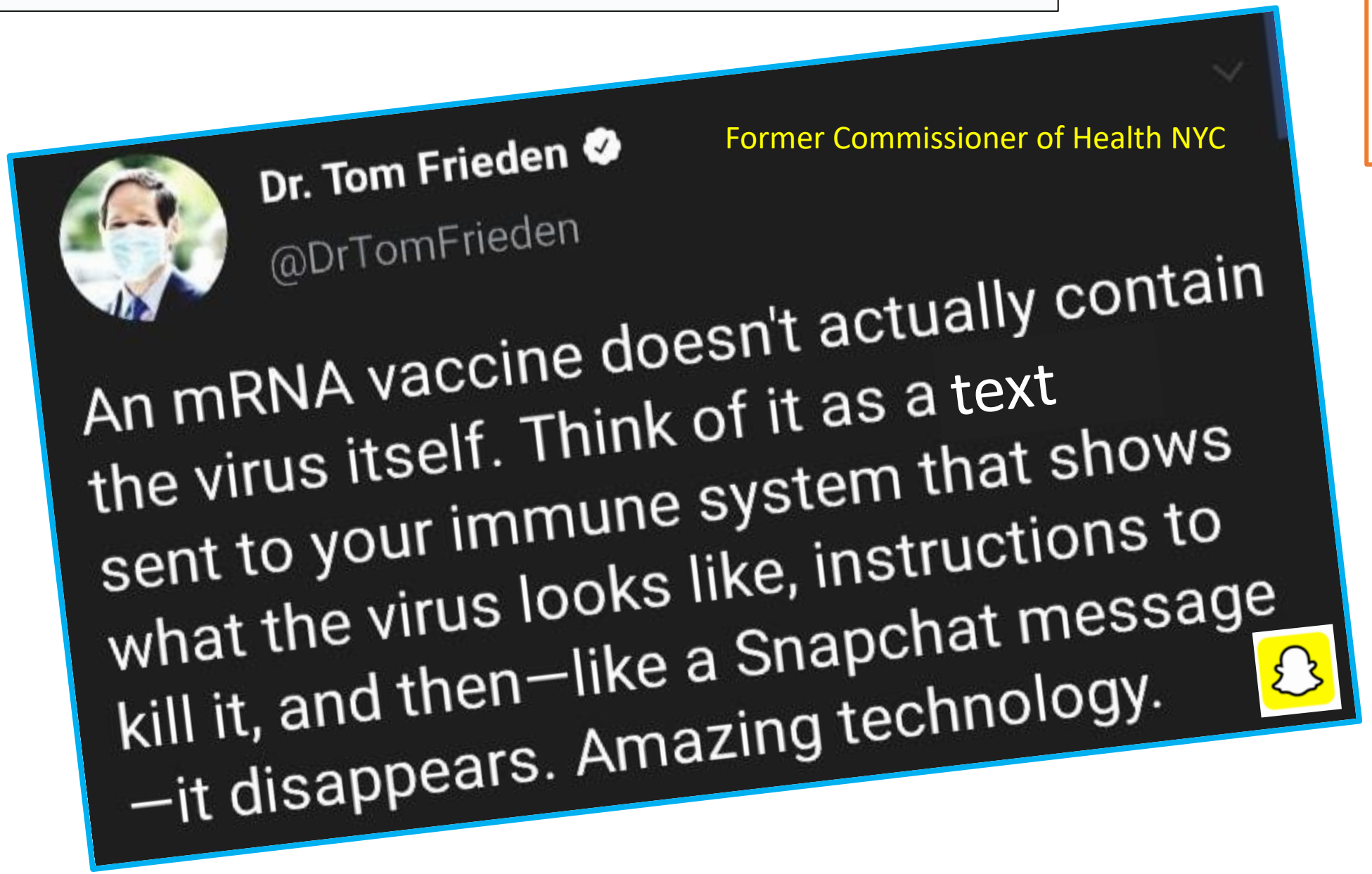
Type of vaccine		Licensed vaccines using this technology	First introduced
Nucleic acid vaccine	DNA	RNA, Lipid coat	SARS-CoV-2



- **mRNA surrounded by a lipid 'bubble'** is injected into muscle cells and used as instructions to make the SARS-CoV-2 viral spike protein
- The immune system recognizes the spike proteins as foreign and uses them to mount an immune response to produce plasma cells (antibody) and memory B and T cells for long-term protection

Callaway et al. Nature. April 2020.

mRNA-based vaccines disappear in 24 hours



FUN FACT. The mRNA is gone within 24 hours of injection

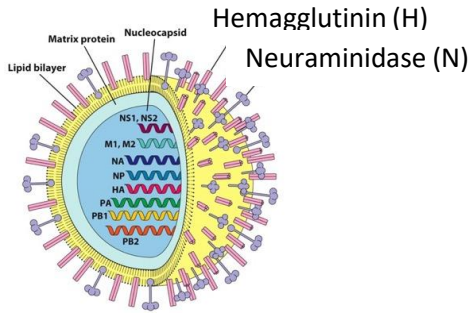
Live attenuated virus vaccines

Type of vaccine		Licensed vaccines using this technology
Live attenuated (weakened or inactivated)		Measles, mumps, rubella, yellow fever, influenza, oral polio, typhoid, Japanese encephalitis, rotavirus, BCG, varicella zoster

- Contains a non-pathogenic (i.e. does not cause disease) version of a virus that has been derived from a wild-type (WT) virulent strain
- Generally produced by growing virus in cells of nonhuman origin or long-term human cultured cells until deemed non-pathogenic
- The antigens for the attenuated version of the virus must be identical or very similar to the WT virus so that the immune response to the vaccine virus provides protection from the WT virus

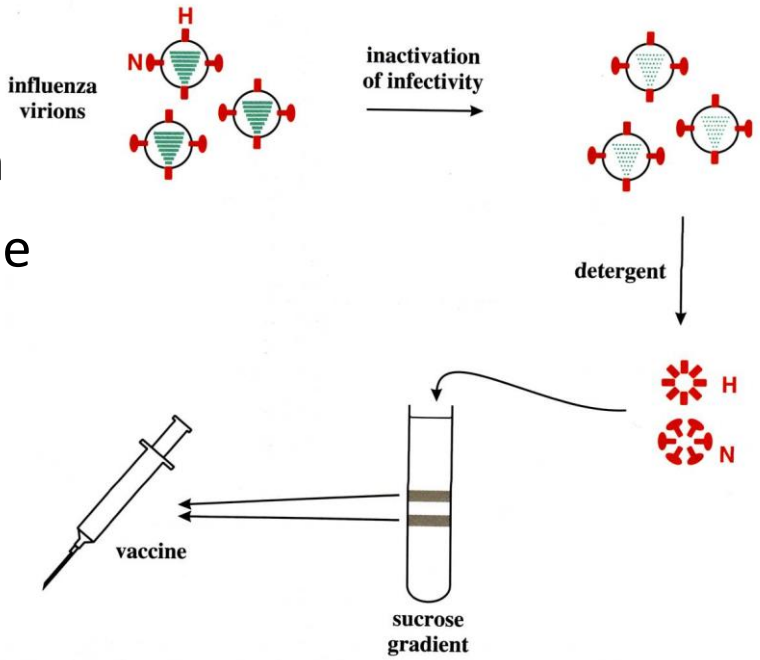
Advantages. The amount of virus antigen in the body increases as the virus replicates and the **immune response is typically wide-ranging** and includes B cells, CD4, and CD8 T cells

Subunit vaccines



Cross-section drawing of influenza virus

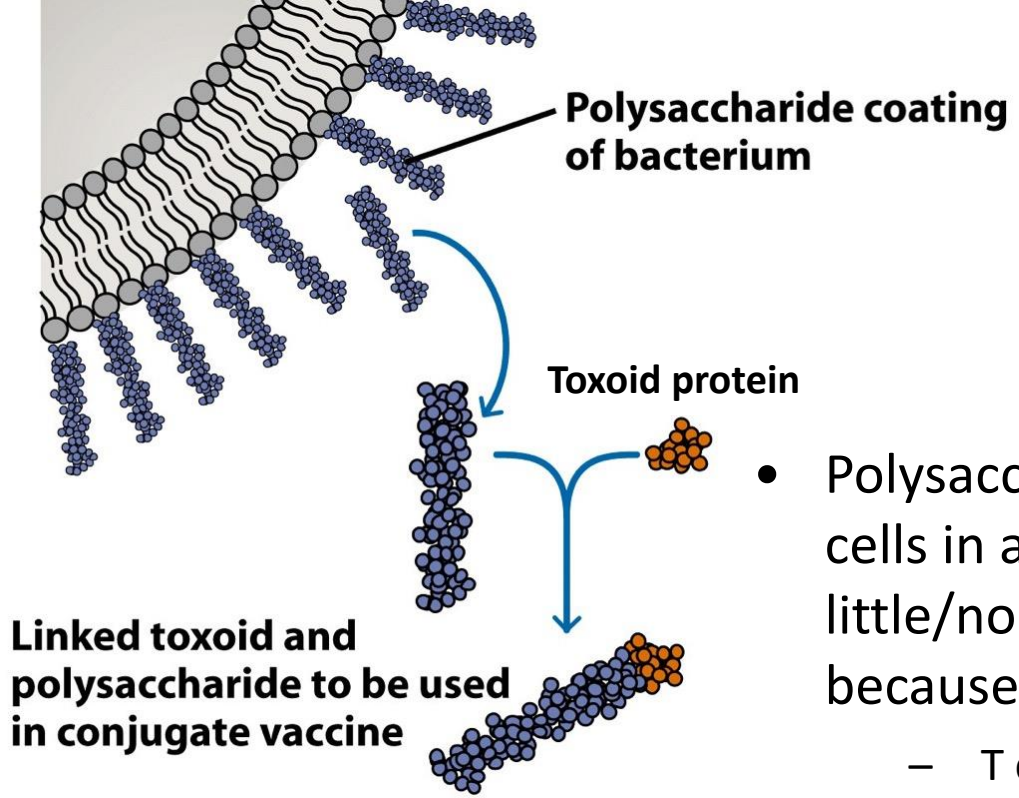
Type of vaccine	Licensed vaccines using this technology	First introduced
Subunit (purified protein, recombinant protein, polysaccharide, peptide)		Pertussis, influenza, hepatitis B, meningococcal, pneumococcal, typhoid, hepatitis A

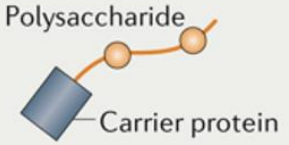


- A subunit vaccine contains purified outer components of the pathogen
- Example, the injection formulation of the influenza vaccine contains the surface antigens hemagglutinin (**H**) and neuraminidase (**N**)
- The H and N subunits are then purified to make the subunit vaccine
- The only bits of the virus that are in the vaccine are the outer surface components – H & N – everything else is missing!

Advantages. You can't get the flu from the flu shot!
The innate antigen-presenting cells pick up bits of the injected vaccine to show off to T cells to alert the adaptive immune system to train and provide long-lasting protection via memory cells as well as antibody production (plasma B cells)

Conjugate Vaccines



Type of vaccine		Licensed vaccines using this technology	First introduced
Protein–polysaccharide conjugate		*Haemophilus influenzae* type B, pneumococcal, meningococcal, typhoid	

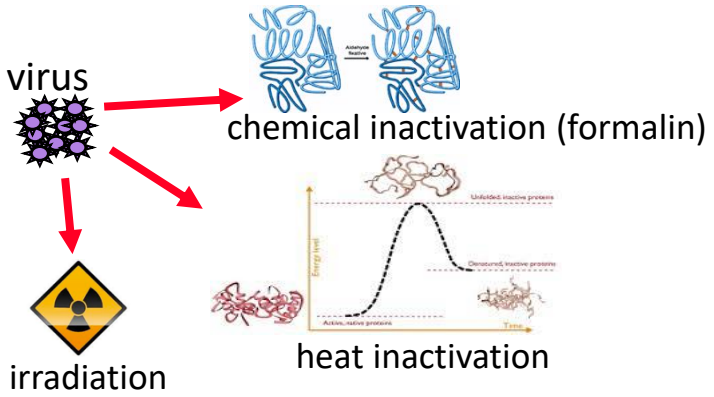
- Polysaccharides on the outer surface of some bacterium will activate B cells in a T cell *independent* manner resulting in IgM production, little/no class switching and little/no development of memory cells because T cells are not called into action
  - T cells only respond to protein, not polysaccharide
- One way to involve CD4+ helper T cells directly is to conjugate the polysaccharide antigen to a protein carrier (example here is an inactive toxin, called a toxoid)

Advantages. The **immune response** includes B cells and CD4+ helper T cells so that memory is produced and the type of immunoglobulin produced is higher affinity - IgG

Inactivated or Killed Vaccines

Type of vaccine		Licensed vaccines using this technology	First introduced
Killed whole organism		Whole-cell pertussis, polio, influenza, Japanese encephalitis, hepatitis A, rabies	

- Inactivated or killed virus vaccines are made by mass producing the virulent virus and then inactivating the infectivity, typically treated with a chemical like formalin or heat treatment
- There is difficulty in determining the correct concentration of chemical and a reaction time that inactivates the virus but leaves the antigens unchanged so that they remain immunogenic



Scientists want to inactivate the virus but do not want to destroy it beyond recognition as it must molecularly resemble (look like) the wild-type virus so that the immune memory cells produced in response to the vaccine are able to recognize the infectious, wild-type virus.

Immune response to inactivated protein antigen

(e.g. injected form of the annual influenza vaccine)

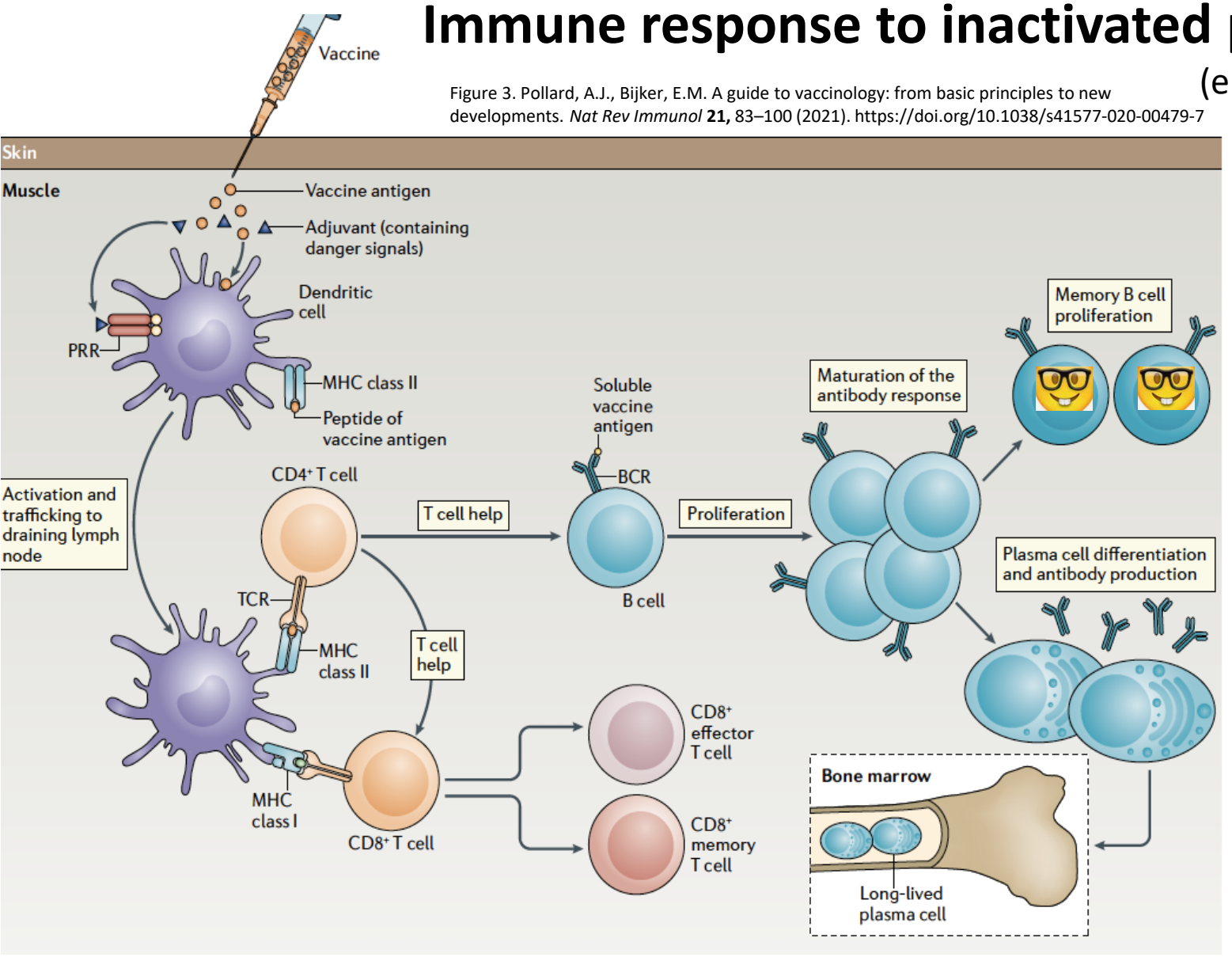


Figure 3. Pollard, A.J., Bijker, E.M. A guide to vaccinology: from basic principles to new developments. *Nat Rev Immunol* **21,** 83–100 (2021). https://doi.org/10.1038/s41577-020-00479-7

- Vaccine (protein antigen) is injected into the muscle and is taken up by dendritic cells, activated by PRRs from the adjuvant, and traffic to the lymph node
- Vaccine peptide antigens are presented on MHC ‘display’ molecules to activate specific T cells through their TCR
- Specific B cells recognize vaccine antigen via BCR and obtain T cell help to activate, proliferate, and drive maturation toward memory and plasma cells (antibody factories), which results in rapid rise in serum antibody levels

- **Memory B cells and T cells provide long-term protection for next encounter with pathogen**

DISEASED

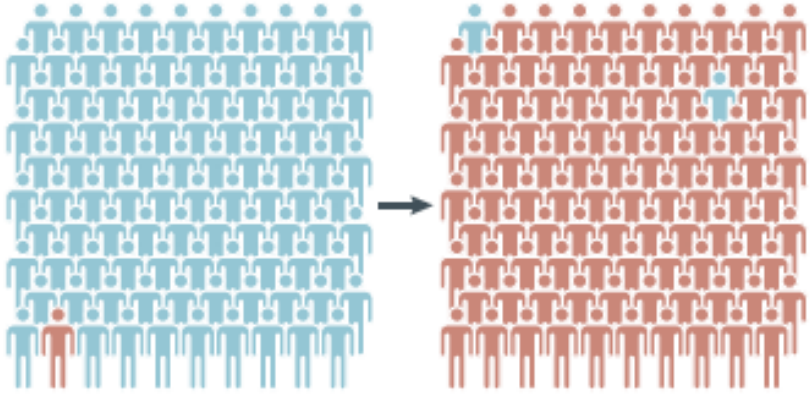
SUSCEPTIBLE

VACCINATED

HERD OR COMMUNITY IMMUNITY

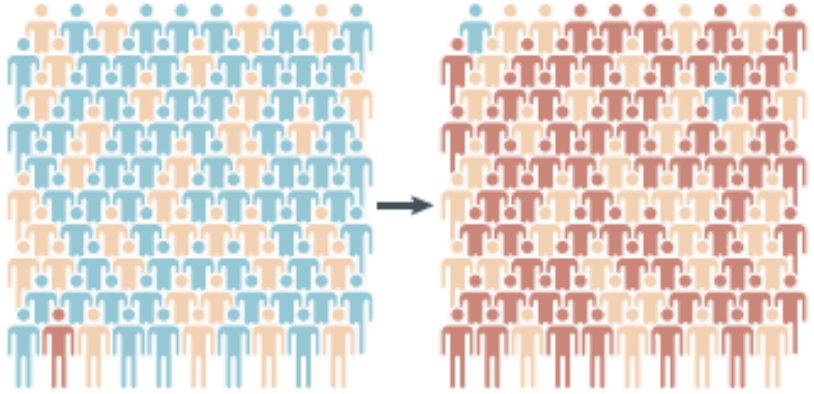
Those who are vaccinated protect those who are not vaccinated by decreasing the spread of disease within their communities

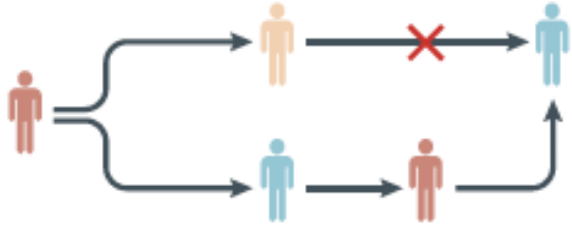
No vaccination



Infection passes from individuals with disease to susceptible individuals and spreads throughout the population

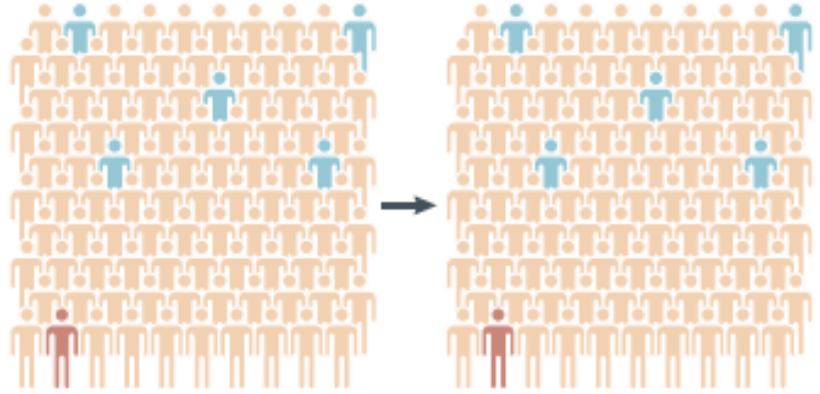
Vaccination below threshold for protection of community

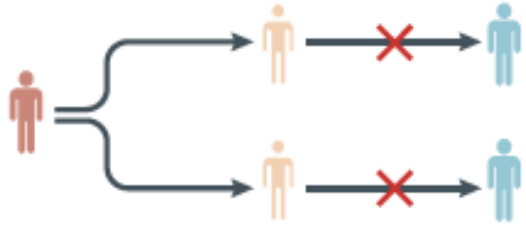




Infection can still pass to susceptible individuals and spread throughout the population, except to those who are vaccinated

Vaccination above threshold for protection of community



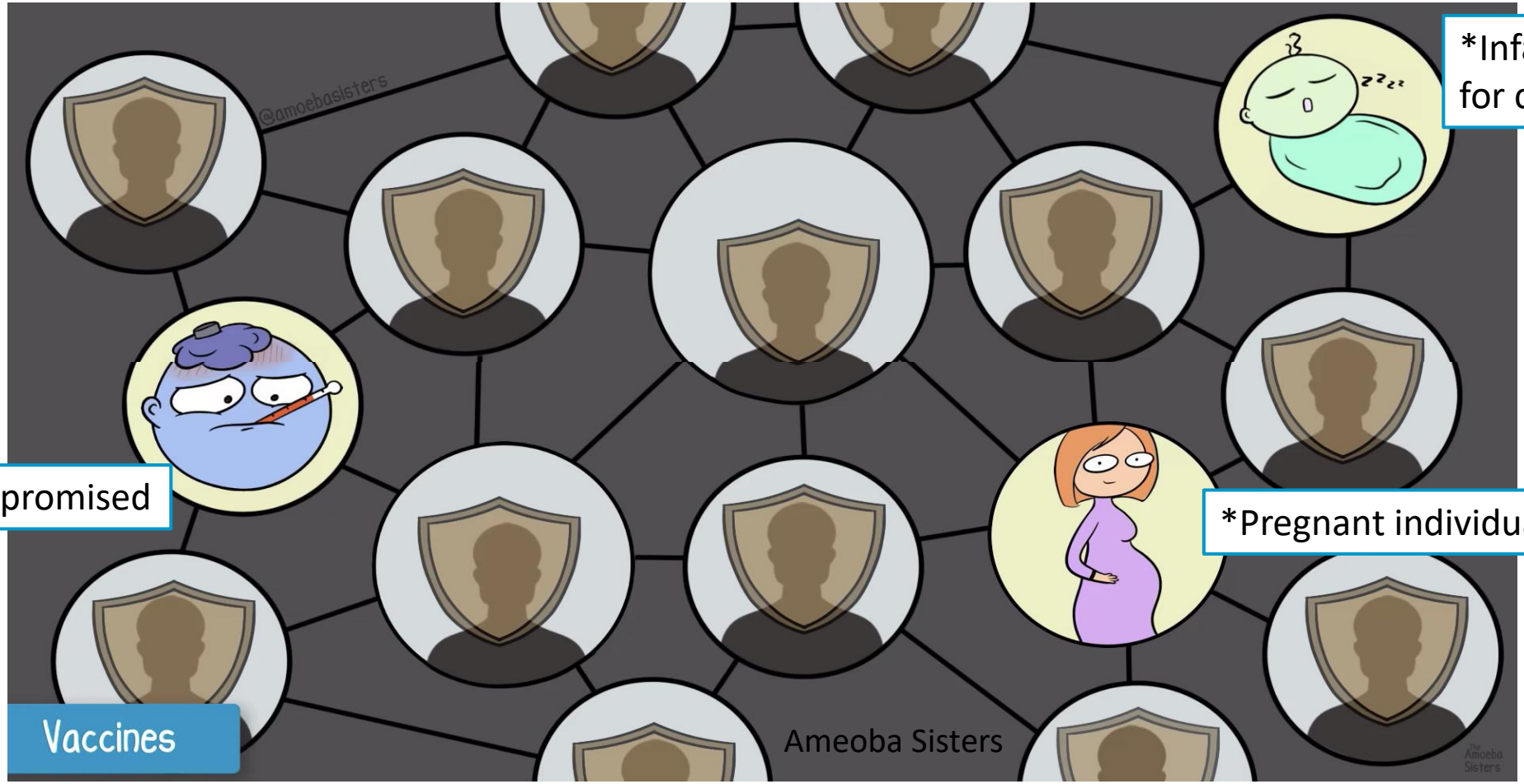


Infection cannot spread in the population and susceptible individuals are shielded by vaccinated individuals

Pollard, A.J., Bijker, E.M. A guide to vaccinology: from basic principles to new developments. *Nat Rev Immunol* **21,** 83–100 (2021).

Herd or Community Immunity

Those who are vaccinated protect or ‘shield’ those who are not vaccinated* by decreasing the spread of disease within their communities



*Infants too young for certain vaccines

*Immunocompromised

*Pregnant individuals

Get vaccinated to protect yourself and others who need to be ‘shielded’

Who needs to be ‘shielded’?
Altered immunocompetence and Vaccines

- **Individuals who have altered immunocompetence need special consideration**
  - not everyone can be safely vaccinated
- ‘Altered immunocompetence’ is a term that encompasses immunosuppression, immunodeficiency, and the state of being immunocompromised – can be classified as primary or secondary
- **Primary immunodeficiencies generally are inherited** and include conditions defined by an inherent absence or quantitative deficiency of cellular, humoral, or both components that provide immunity.
  - Examples include congenital immunodeficiency diseases such as X-linked agammaglobulinemia (XLA), severe combined immunodeficiency (SCID), and chronic granulomatous disease (CGD)
- **Secondary immunodeficiency is acquired** and is defined by loss or qualitative deficiency in cellular or humoral immune components that occurs as a result of a disease process or its therapy.
  - Examples of secondary immunodeficiency include HIV infection, hematopoietic malignancies, treatment with radiation, and treatment with immunosuppressive drugs, pregnancy, etc.

Who decides who gets vaccines and timing?

The Advisory Committee on Immunization Practices (ACIP)

A committee of physicians and scientists dedicated to advising the CDC on vaccines and vaccine practices

Altered Immunocompetence

General Best Practice Guidelines for Immunization: Best Practices Guidance of the Advisory Committee on Immunization Practices (ACIP)

Printer friendly version [27 pages]

Updates

This section incorporates general content from the Infectious Diseases Society of America policy statement, 2013 IDSA Clinical Practice Guideline for Vaccination of the Immunocompromised Host (1), to which CDC provided input in November 2011. The evidence supporting this guidance is based on expert opinion and arrived at by consensus.

https://www.cdc.gov/vaccines/hcp/acip-recs/general-recs/immunocompetence.html

Is there an app for that??
Yes!!

[Download Schedules App](#)

American Academy of Pediatrics (AAP) Red Book

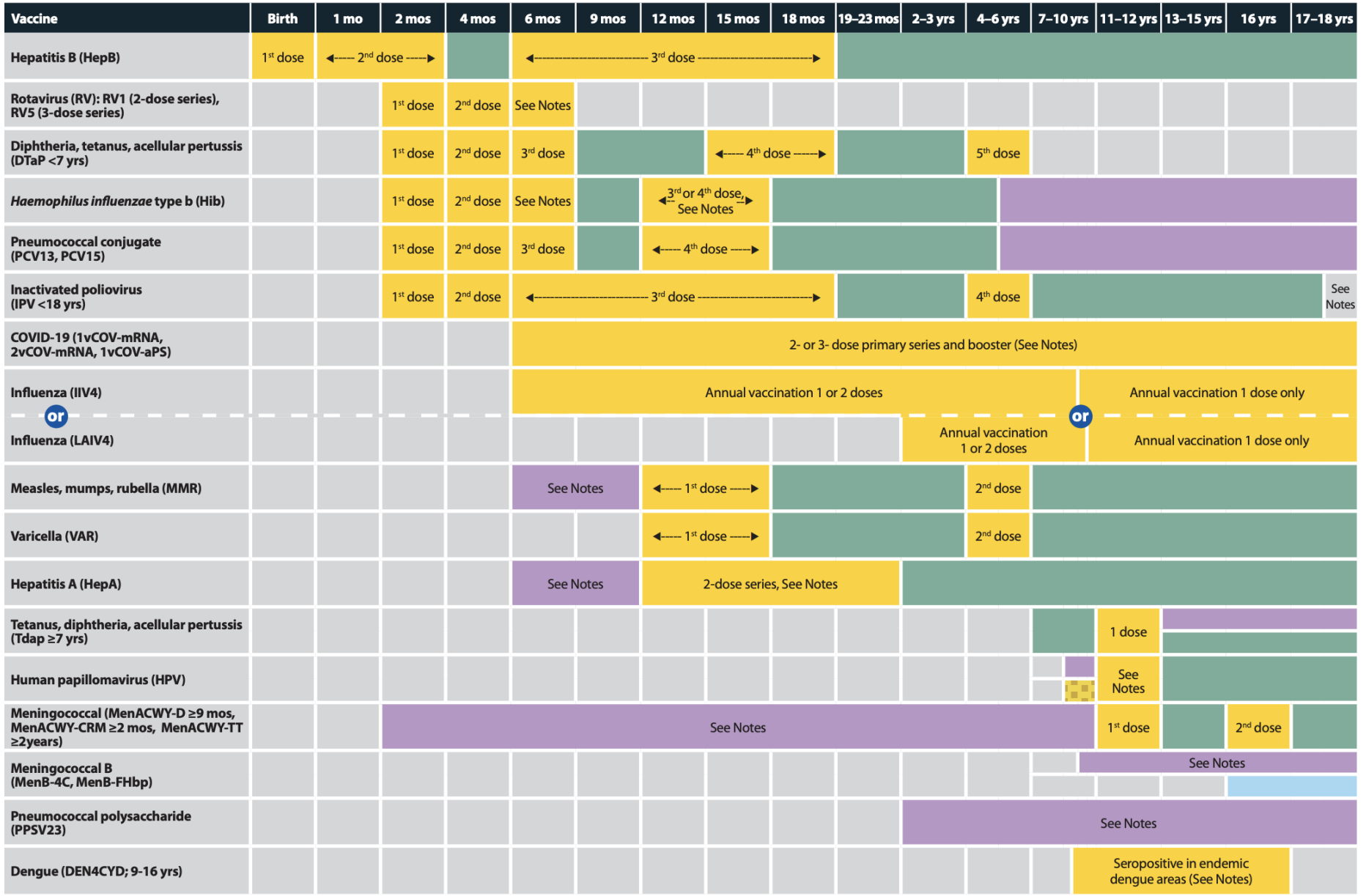
https://redbook.solutions.aap.org/selfserve/ssPage.aspx?SelfServeContentId=Immunization_Schedules

Table 1

COVID-19 vaccination recommendations have changed. Find the latest recommendations at www.cdc.gov/covidschedule

Recommended Child and Adolescent Immunization Schedule for ages 18 years or younger, United States, 2023

These recommendations must be read with the notes that follow. For those who fall behind or start late, provide catch-up vaccination at the earliest opportunity as indicated by the green bars. To determine minimum intervals between doses, see the catch-up schedule (Table 2).



Compare Table 3 to Table 1

American Academy of Pediatrics (AAP) Red Book

https://redbook.solutions.aap.org/selfserve/ssPage.aspx?SelfServeContentId=Immunization_Schedules

Table 3 Recommended Child and Adolescent Immunization Schedule by Medical Indication, United States, 2023

Always use this table in conjunction with Table 1 and the Notes that follow.

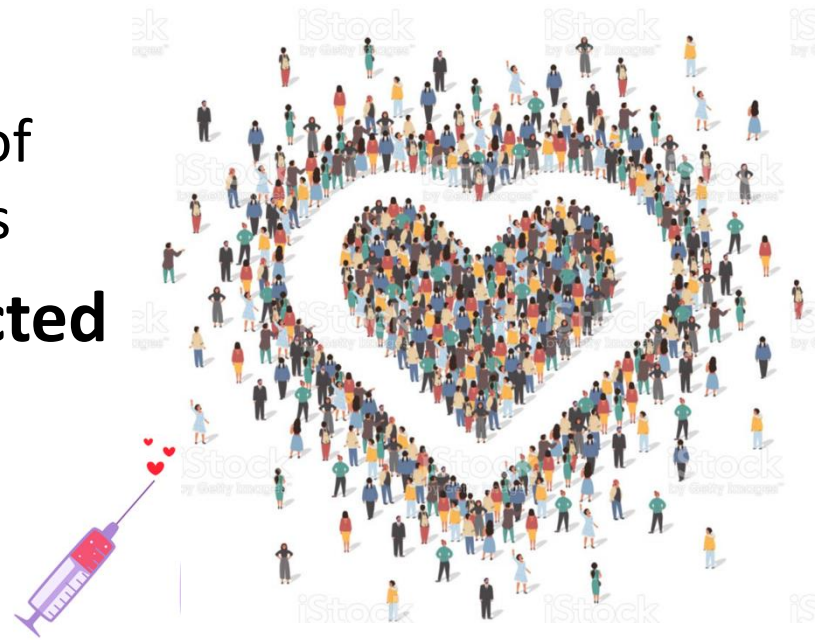
VACCINE	INDICATION										
	Pregnancy	Immunocompromised status (excluding HIV infection)	HIV infection CD4+ counta: <15% or total CD4 cell count of <200/mm³	HIV infection CD4+ counta: ≥15% and total CD4 cell count of ≥200/mm³	Kidney failure, end-stage renal disease, or on hemodialysis	Heart disease or chronic lung disease	CSF leak or cochlear implant	Asplenia or persistent complement component deficiencies	Chronic liver disease	Diabetes
Hepatitis B										
Rotavirus		SCID[b]								
Diphtheria, tetanus, and acellular pertussis (DTaP)										
Haemophilus influenzae type b										
Pneumococcal conjugate										
Inactivated poliovirus										
COVID-19		See Notes	See Notes							
Influenza (IIV4)										
or										
Influenza (LAIV4)						Asthma, wheezing: 2–4yrs[c]				
Measles, mumps, rubella	*									
Varicella	*									
Hepatitis A										
Tetanus, diphtheria, and acellular pertussis (Tdap)										
Human papillomavirus	*									
Meningococcal ACWY										
Meningococcal B										
Pneumococcal polysaccharide										
Dengue										

- Vaccination according to the routine schedule recommended
- Recommended for persons with an additional risk factor for which the vaccine would be indicated
- Vaccination is recommended, and additional doses may be necessary based on medical condition or vaccine. See Notes.
- Precaution–vaccine might be indicated if benefit of protection outweighs risk of adverse reaction
- Contraindicated or not recommended–vaccine should not be administered
- No recommendation/not applicable

*Vaccinate after pregnancy

SUMMARY

- The immune system is a mobile defense system that continually patrols and deploys cells as needed across the body
- Vaccines are harmless forms of pathogen that work *with* the immune system to train our B and T cells (adaptive) to provide long-lasting protection
- The B and T cells of our adaptive immune system are individually highly specific and when combined incredibly diverse
- Due to the exquisite specificity built into our B and T cells, our immune systems can't be overwhelmed by antigen or immunization
- Preventive vaccines have led to the control or elimination of many infectious diseases that once claimed millions of lives
- **We need to view our communities as interconnected humans who take care of each other and provide protection for those who can't be vaccinated**



CONCEPT CHECKS

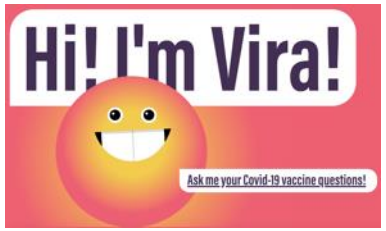
1. **Compare** innate immunity to adaptive immunity
2. **Compare** passive immunization to active immunization
3. **Utilize** the concept of clonal selection to refute the statement, “too many vaccines too soon overwhelms the immune system”
4. **Explain** why dependence on herd immunity is dangerous for the individual and society
5. **Discuss** vaccination in populations with altered immunocompetence

THANK YOU!

QUESTIONS?

Ask now or email later

Aimee.Bernard@cuanschutz.edu



COVID vaccine questions?
Ask Vira the VaxChatBot at http://vaxchat.org/

RESOURCES

Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™
Vaccines & Immunizations
https://www.cdc.gov/vaccines/index.html

voices for vaccines
credible vaccine information for families, from families
https://www.voicesforvaccines.org

IMMUNIZE COLORADO
https://www.immunizecolorado.org/

Immunize.org
https://www.immunize.org/vaccines/

healthychildren.org
Powered by pediatricians. Trusted by parents.
from the American Academy of Pediatrics
https://www.healthychildren.org/

MORE OPTIONS TO LEARN IMMUNOLOGY with AIMEE BERNARD

SOCIAL MEDIA

TikTok @ImmuNinja

@apbSCIENCE

BLOG

Team Vaccine
Immunology 101 Series

IMMUNIZE COLORADO

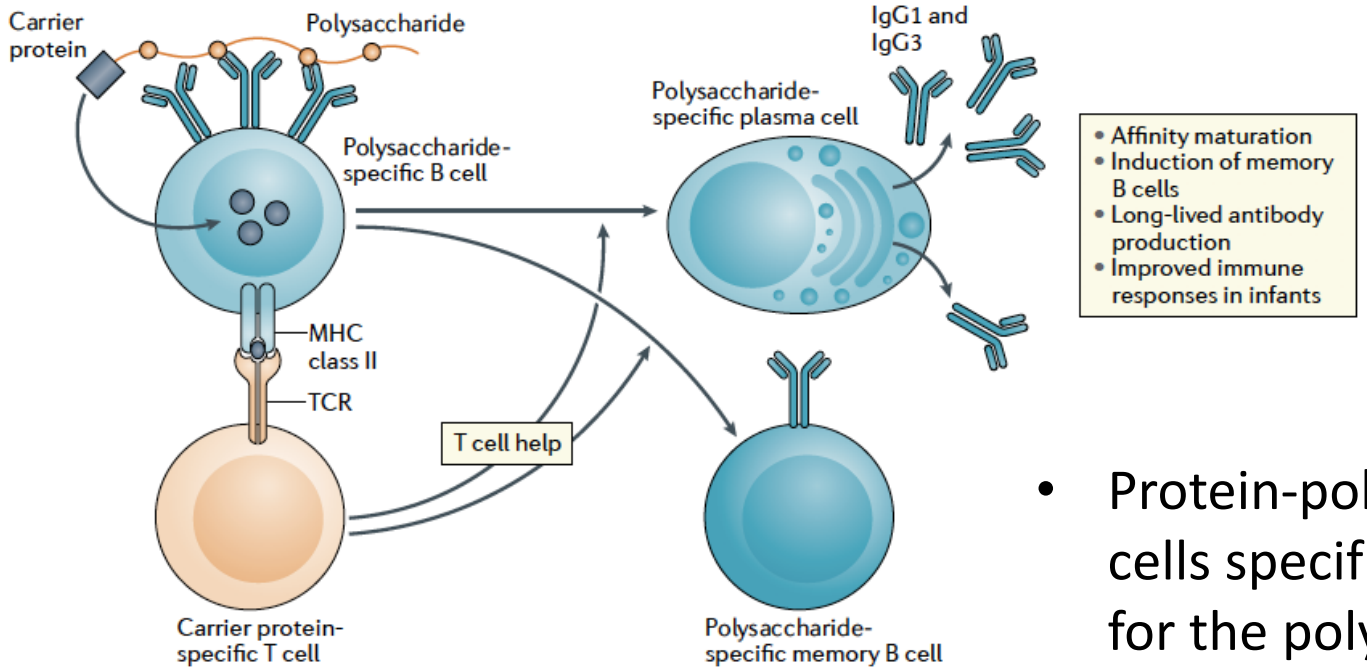
PODCAST

HELP! MAKE IT MAKE SENSE WITH DR. TONI AND DR. AIMEE

Help! Make It Make Sense
with Dr. Toni & Dr. Aimee

Immune response to conjugate vaccines

Figure 6. Pollard, A.J., Bijker, E.M. A guide to vaccinology: from basic principles to new developments. *Nat Rev Immunol* **21,** 83–100 (2021). https://doi.org/10.1038/s41577-020-00479-7



- Protein-polysaccharide conjugate vaccines engage T cells specific for the carrier protein while B cells specific for the polysaccharide recognize and bind antigen
- **T cells provide help to B cells** ☺ leading to affinity maturation and isotype switching of the immunoglobulin
- Plasma cells (terminally differentiated B cells that are antibody factories) and memory B are created to provide long-term protection for next encounter with pathogen

Vaccine-Preventable Diseases and the Vaccines that Prevent Them

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

Disease	Vaccine	Disease spread by	Disease symptoms	Disease complications
Chickenpox	Varicella vaccine protects against chickenpox.	Air, direct contact	Rash, tiredness, headache, fever	Infected blisters, bleeding disorders, encephalitis (brain swelling), pneumonia (infection in the lungs)
Diphtheria	DTaP* vaccine protects against diphtheria.	Air, direct contact	Sore throat, mild fever, weakness, swollen glands in neck	Swelling of the heart muscle, heart failure, coma, paralysis, death
Hib	Hib vaccine protects against *Haemophilus influenzae* type b.	Air, direct contact	May be no symptoms unless bacteria enter the blood	Meningitis (infection of the covering around the brain and spinal cord), intellectual disability, epiglottitis (life-threatening infection that can block the windpipe and lead to serious breathing problems), pneumonia (infection in the lungs), death
Hepatitis A	HepA vaccine protects against hepatitis A.	Direct contact, contaminated food or water	May be no symptoms, fever, stomach pain, loss of appetite, fatigue, vomiting, jaundice (yellowing of skin and eyes), dark urine	Liver failure, arthralgia (joint pain), kidney, pancreatic and blood disorders
Hepatitis B	HepB vaccine protects against hepatitis B.	Contact with blood or body fluids	May be no symptoms, fever, headache, weakness, vomiting, jaundice (yellowing of skin and eyes), joint pain	Chronic liver infection, liver failure, liver cancer
Influenza (Flu)	Flu vaccine protects against influenza.	Air, direct contact	Fever, muscle pain, sore throat, cough, extreme fatigue	Pneumonia (infection in the lungs)
Measles	MMR** vaccine protects against measles.	Air, direct contact	Rash, fever, cough, runny nose, pink eye	Encephalitis (brain swelling), pneumonia (infection in the lungs), death
Mumps	MMR**vaccine protects against mumps.	Air, direct contact	Swollen salivary glands (under the jaw), fever, headache, tiredness, muscle pain	Meningitis (infection of the covering around the brain and spinal cord) , encephalitis (brain swelling), inflammation of testicles or ovaries, deafness
Pertussis	DTaP* vaccine protects against pertussis (whooping cough).	Air, direct contact	Severe cough, runny nose, apnea (a pause in breathing in infants)	Pneumonia (infection in the lungs), death
Polio	IPV vaccine protects against polio.	Air, direct contact, through the mouth	May be no symptoms, sore throat, fever, nausea, headache	Paralysis, death
Pneumococcal	PCV13 vaccine protects against pneumococcus.	Air, direct contact	May be no symptoms, pneumonia (infection in the lungs)	Bacteremia (blood infection), meningitis (infection of the covering around the brain and spinal cord), death
Rotavirus	RV vaccine protects against rotavirus.	Through the mouth	Diarrhea, fever, vomiting	Severe diarrhea, dehydration
Rubella	MMR** vaccine protects against rubella.	Air, direct contact	Sometimes rash, fever, swollen lymph nodes	Very serious in pregnant women—can lead to miscarriage, stillbirth, premature delivery, birth defects
Tetanus	DTaP* vaccine protects against tetanus.	Exposure through cuts in skin	Stiffness in neck and abdominal muscles, difficulty swallowing, muscle spasms, fever	Broken bones, breathing difficulty, death

* DTaP combines protection against diphtheria, tetanus, and pertussis.
** MMR combines protection against measles, mumps, and rubella.

Last updated January 2020 • CS314226-B