Week 3 – Infectious Diseases and Vaccines

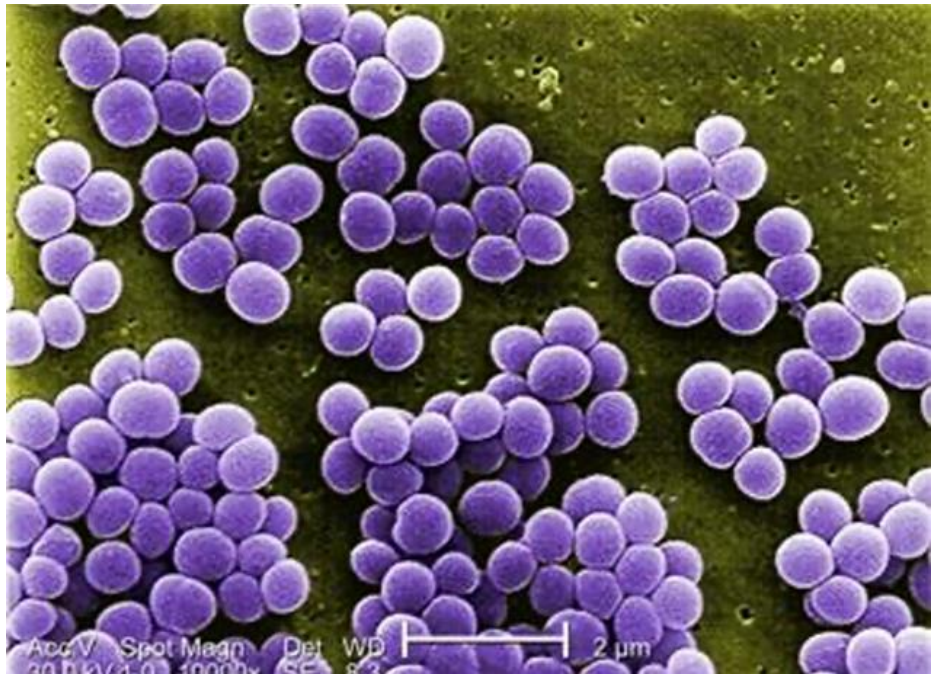
Spring 2022

Causes of Infectious Diseases

- Infectious diseases are caused by pathogenic microbes
  - Bacteria, viruses, parasites, fungi
- These microbes can make virulence factors, which allow…
  - Host invasion
  - Evasion of the immune system
  - Tissue damage
- These diseases spread person to person, either directly or indirectly
- Note the difference between infectious diseases and non-infectious diseases
  - You cannot "catch" non-infectious diseases (like diabetes)

Bacterial Pathogens

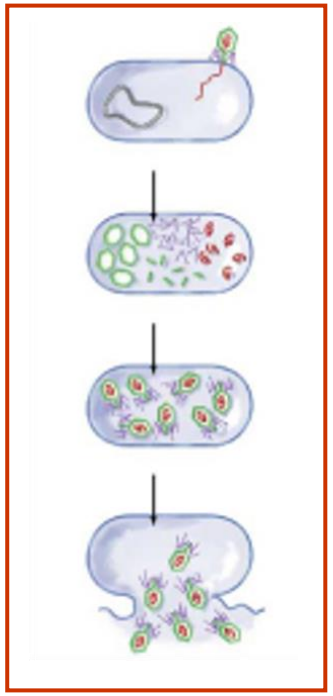
- Single-celled microbes
- Prokaryotic (lack a cell nucleus)
- Can reproduce without a host (unlike viruses)
- Examples
  - *E. coli*: "diarrhea from contaminated water or food"
  - *Streptococcus*: "strep throat"
  - *Staphylococcus* (staph infection): "septic shock"
- Treated with antibiotics (like penicillin)



Electron microscope image of Staphylococcus aureus

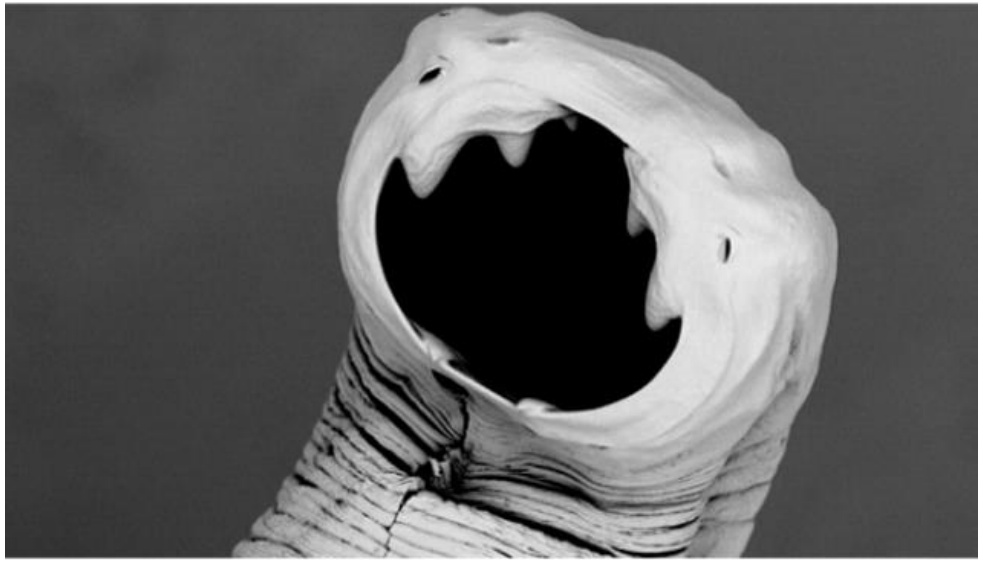
Viral Pathogens

- Genetic material with a protein coat
- Cannot reproduce independently
  - Side note: because viruses cannot reproduce independently, they are not considered "living"
- Hijack host cells and take over function of cell
- Examples
  - Influenza: "seasonal flu"
  - Rhinovirus: "common cold"
  - HIV: causes AIDS
  - COVID-19
- Not treated with antibiotics



Parasitic Pathogens

- Range in size from single-celled protozoa to worms that can be seen with the naked eye
  - Protozoa are unicellular eukaryotes (contain a cell nucleus, unlike bacteria)
- Use the host for food and a place to live
- Examples
  - Plasmodium: “malaria”
  - Necator: “hookworm”
  - Cestoda: “tapeworm”



A hookworm taking a selfie (look at those teeth!)

Fungal Pathogens

- (Mostly) multicellular organisms
- More common when:
  - Immune system is weak
  - On antibiotics for another infection
- Examples
  - Trichophyton: “athlete’s foot,” “ringworm”
    - Note ringworm is not actually a worm but a fungus
  - Candida: “yeast infection,” “oral thrush”
- Treated with antifungals

Oral thrush

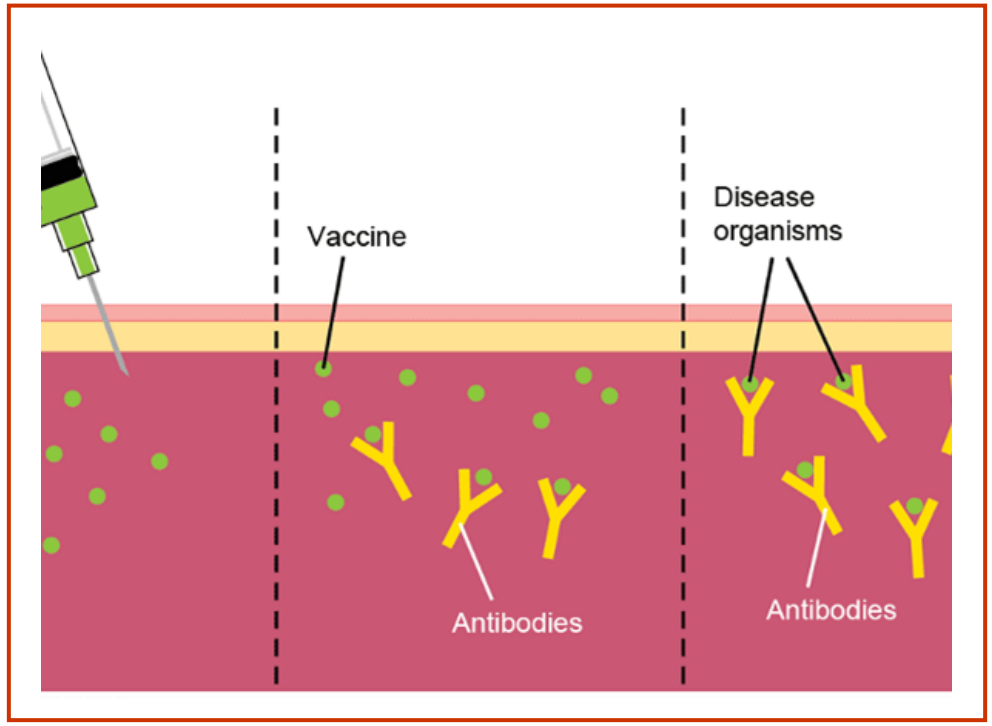
On to Vaccines!

Can you name any diseases that we have vaccines for?

What are Vaccines?

- Vaccines produce immunity against diseases by stimulating the immune system to produce antibodies
- Vaccines come in a variety of types
  - Live-attenuated: a weakened version of the germ that causes a disease
  - Inactivated: a killed version of the germ that causes a disease
  - Subunit: a specific piece of the germ that causes a disease
  - Toxoid: creates immunity to the germ's toxin (harmful substance produced by a microbe)
- Vaccines are powerful because they prevent diseases rather than needing to treat them

How Do Vaccines Work?

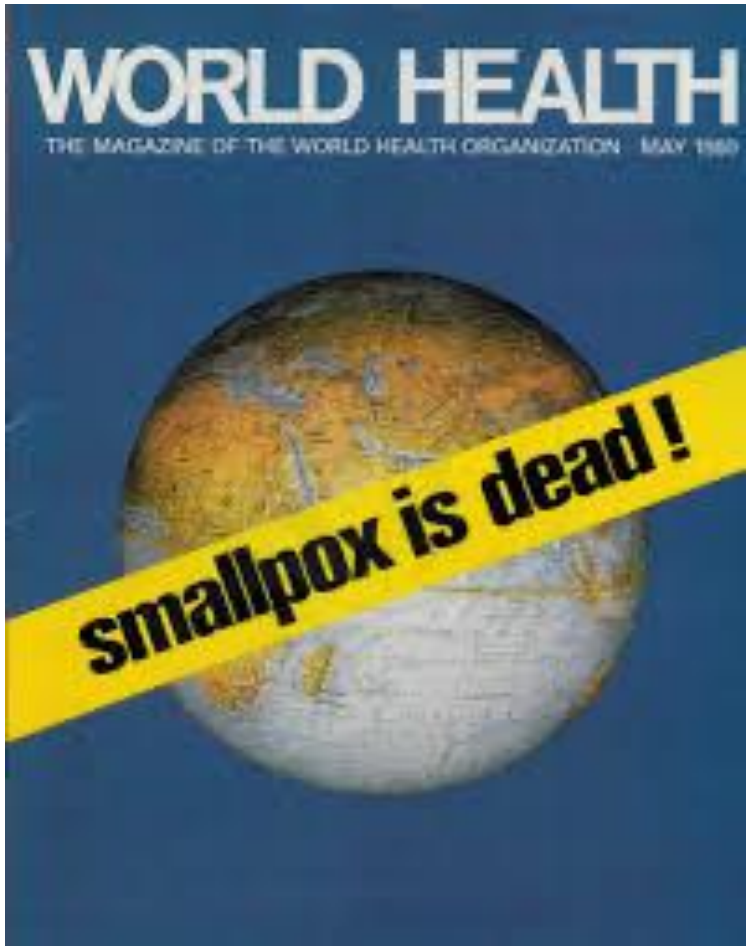


- Immune cells detect Microbial Proteins in the vaccine
- White blood cells (B cells) make antibodies against the pathogen-specific proteins
  - Antibodies are proteins that detect and fight infections
- Some B cells persist as Memory Cells that remember how to detect and fight the pathogen
- Future exposure to the pathogen leads to a stronger/quicker immune response that prevents disease, now that the body has Memory Cells for the disease

A Brief History of Vaccines

- 430 B.C.: Thucydides, the Greek historian, noted that those who had recovered from The Plague of Athens could treat those sick with it
  - He did not know it, but this was because those who already had the disease had antibodies to it
- Variolation: first method of inoculation against smallpox. Rub the scabs/excretions of recovered smallpox patients onto the skin of someone else. Produced a mild but protective disease; used in ancient Asia and brought to Europe in 1721
- 1796: Edward Jenner noticed people who had a disease called "cow pox" were immune to the more deadly disease "smallpox." He injected people with cow pox to protect them from smallpox;
  - The term "vaccination" derives from this ("vacca" is Latin for "cow").

Smallpox: A Vaccine Success Story

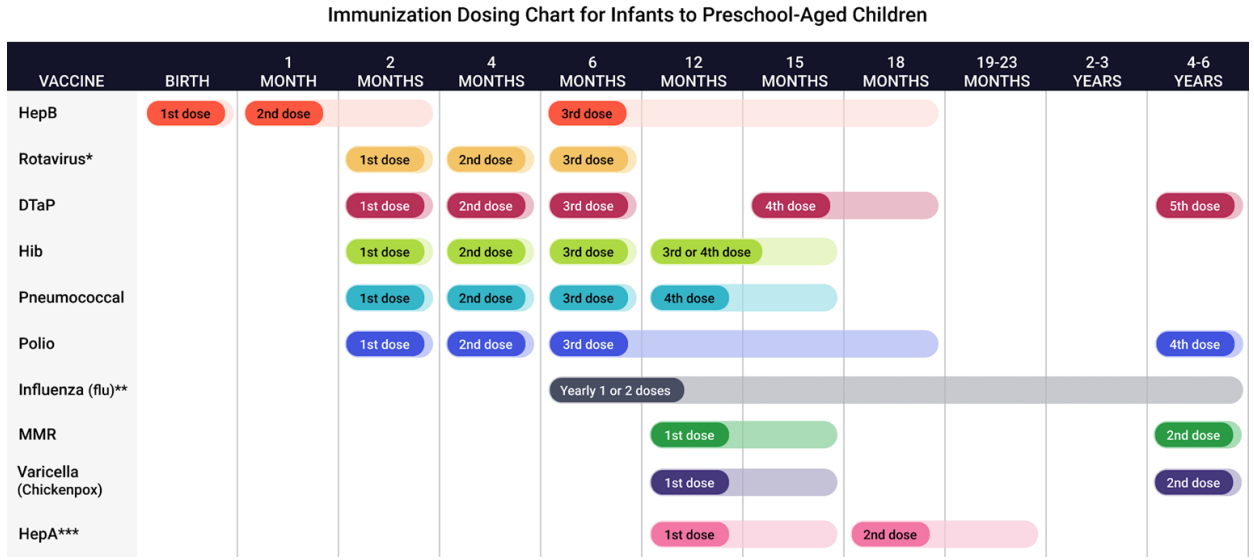


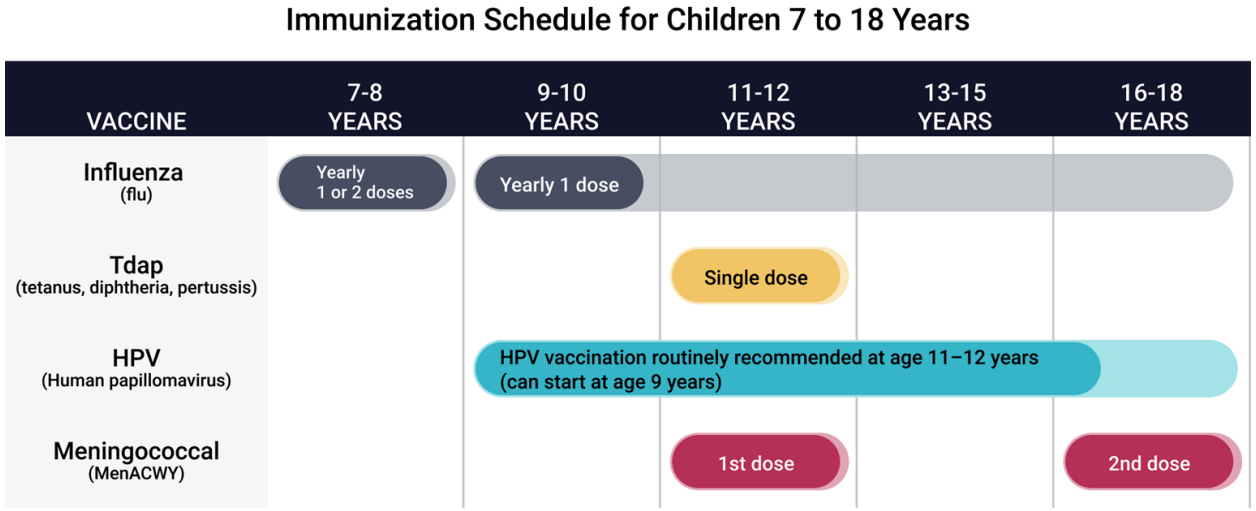
- Smallpox is a disfiguring and potentially deadly disease caused by the Variola virus.
- Prior to the 20th century, smallpox killed, maimed, or disfigured 1 in 4 people.1
- With the development of a vaccine, a global effort was made by the WHO to eliminate smallpox.
- Smallpox was officially eradicated in 1980, which is widely regarded as the greatest public health achievement in human history.
- Despite all of the destruction it caused throughout history, we are actually no longer vaccinated against smallpox, because it is no longer here

Polio: A Vaccine Success Story

- 1952: 58,000 Americans contracted polio, frequently leading to paralysis and even death
- Salk (1952): inactivated polio vaccine
- Sabin (1957): live attenuated vaccine
- 1994: Western world "free" of polio
- Success lead to modification of recommendations: now use inactivated polio vaccine to avoid rare reversions to virulent form
- As of 2020, wild polio virus is only found in Pakistan and Afghanistan

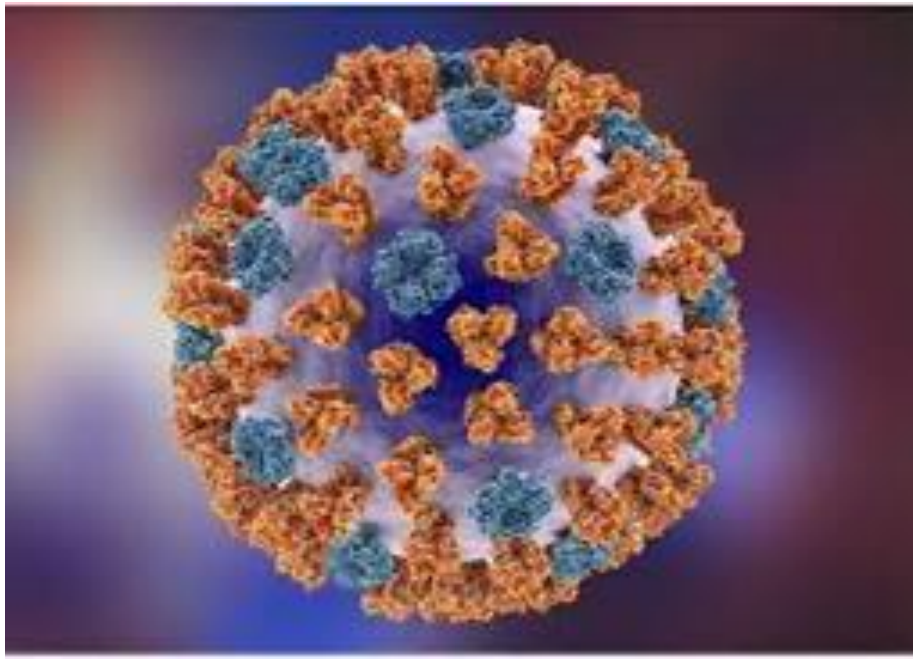
Modern Vaccines – Childhood Vaccination Schedule





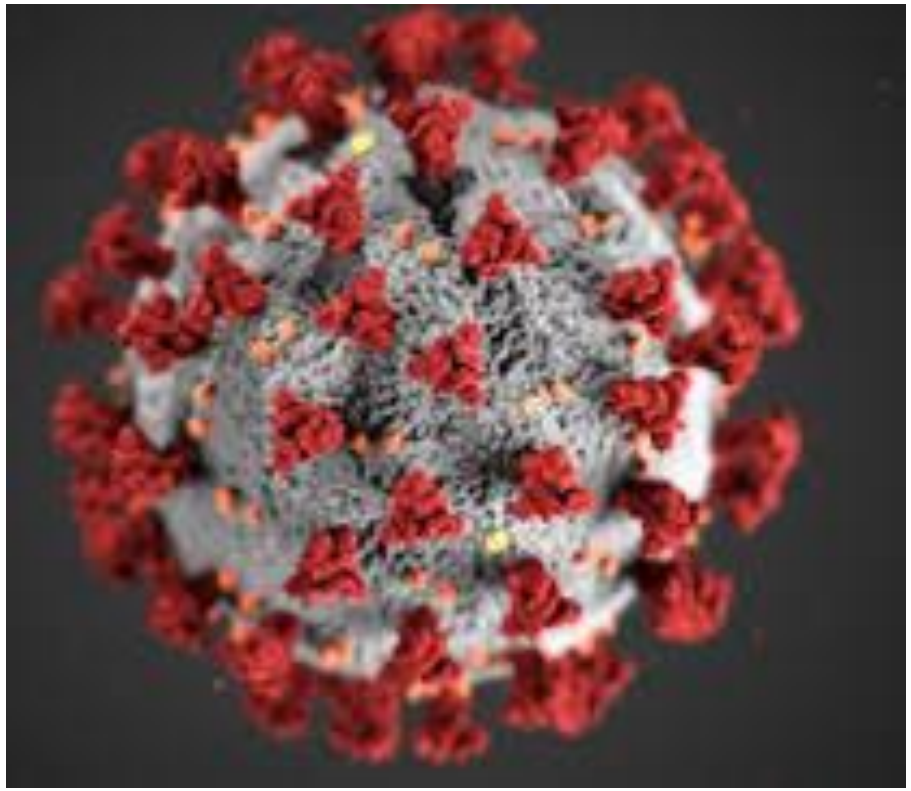
- The CDC recommends these schedules for all immune-competent children in the US.
- Children do not receive any known benefits from following schedules that spread out or delay vaccines.
- There is no credible evidence that vaccinations cause autism!

Modern Vaccines - Influenza



- Influenza, commonly known as “the flu”, is caused by a virus that infects the respiratory tracts of many animals, including humans
- The flu is a potentially serious disease that can lead to hospitalization and even death
- An annual seasonal flu vaccine is the best way to protect against the flu
- A new vaccine is necessary each year because there are many different and frequently mutating strains of the flu

Modern Vaccines – COVID-19



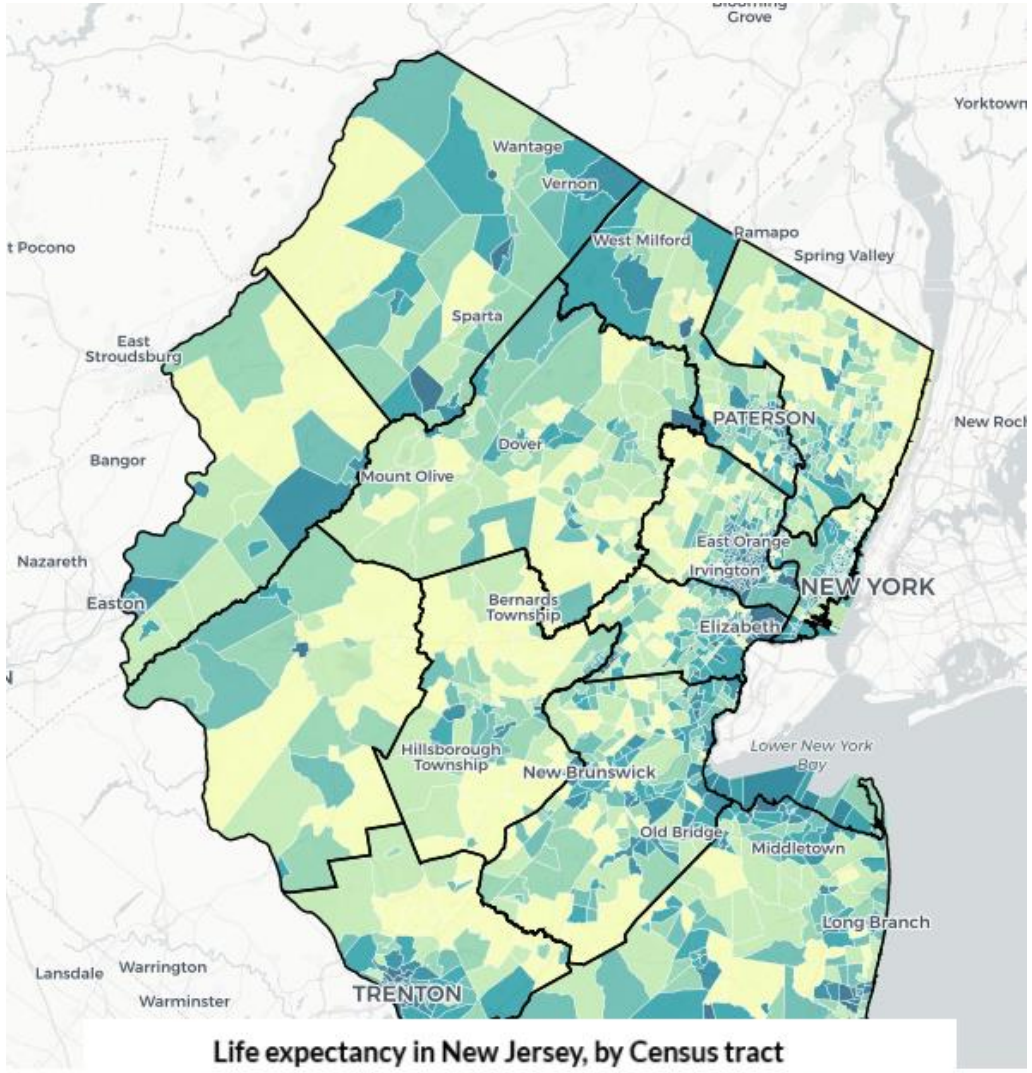
- COVID-19 is a disease caused by a coronavirus and spread through respiratory droplets
- This coronavirus variant is particularly dangerous as it can cause a cytokine storm that precipitates septic shock and even death
- Prevention of the disease is achieved through social distancing, mask wearing in public, frequent hand-washing, and now by vaccination

COVID Vaccine Mechanisms

- The Pfizer and Moderna vaccines are mRNA vaccines; they teach cells to produce a viral protein in order to stimulate the immune response. They do not inject the virus itself.
- Both of these vaccines are >94% effective at preventing symptomatic disease
- The Johnson & Johnson vaccine is a viral-vector vaccine. It inserts COVID-19 genetic material into a different type of virus (adenovirus), and then allows this adenovirus to infect human cells.
- The adenovirus is used as a "vector" for getting the COVID genetic material into the body.
- The inserted COVID-19 genetic material in the adenovirus expresses certain COVID viral proteins, which the body can then make antibodies to.
- Note that the disease-causing portions of the adenovirus DNA are removed in this vaccine; this way the adenovirus vector does not make you sick.

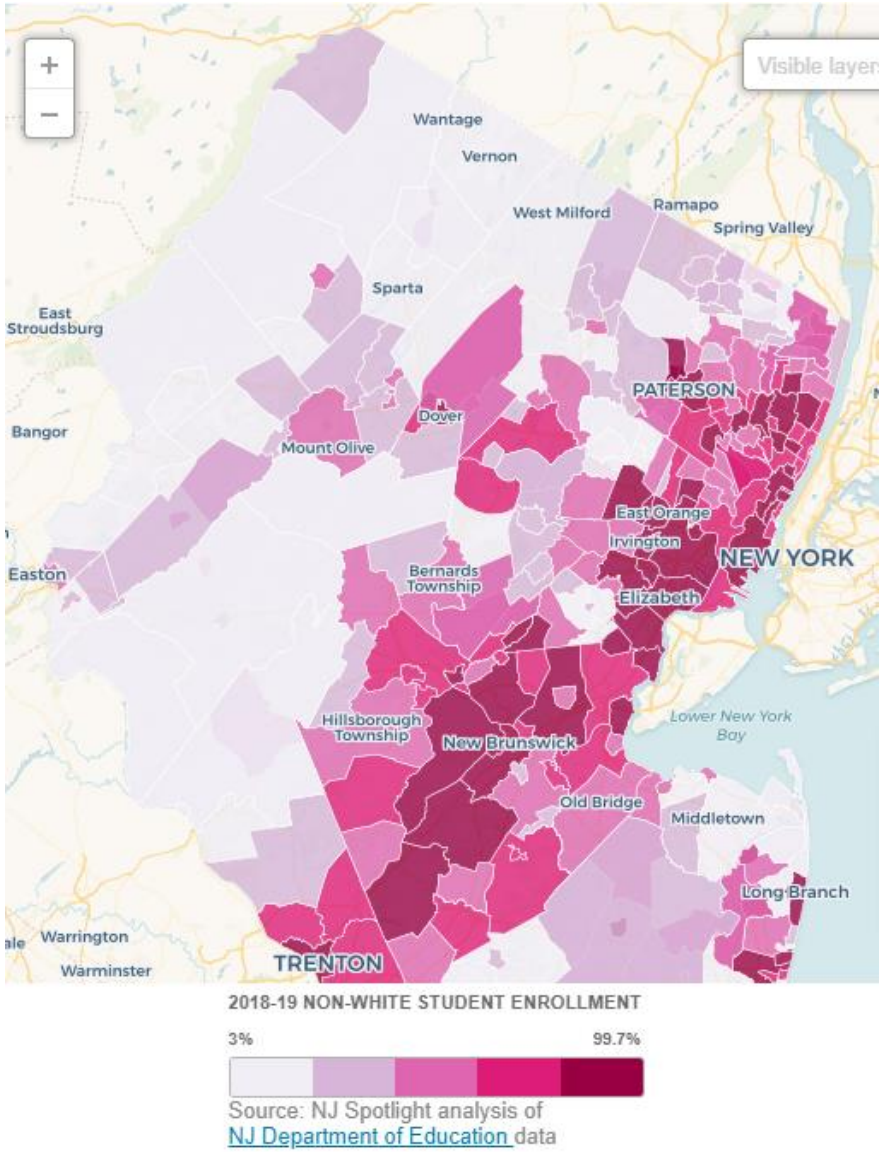
Medical Ethics Case Study – Context

- This map shows the life expectancy in each census area in the northern part of New Jersey
  - The *darker* the area, the *lower* the life expectancy
- *What's the range of life expectancies among NJ residents?*
- *What do you notice about the areas that tend to have lower life expectancies? What about the areas with higher life expectancies?*
- *What are some possible explanations for these differences?*



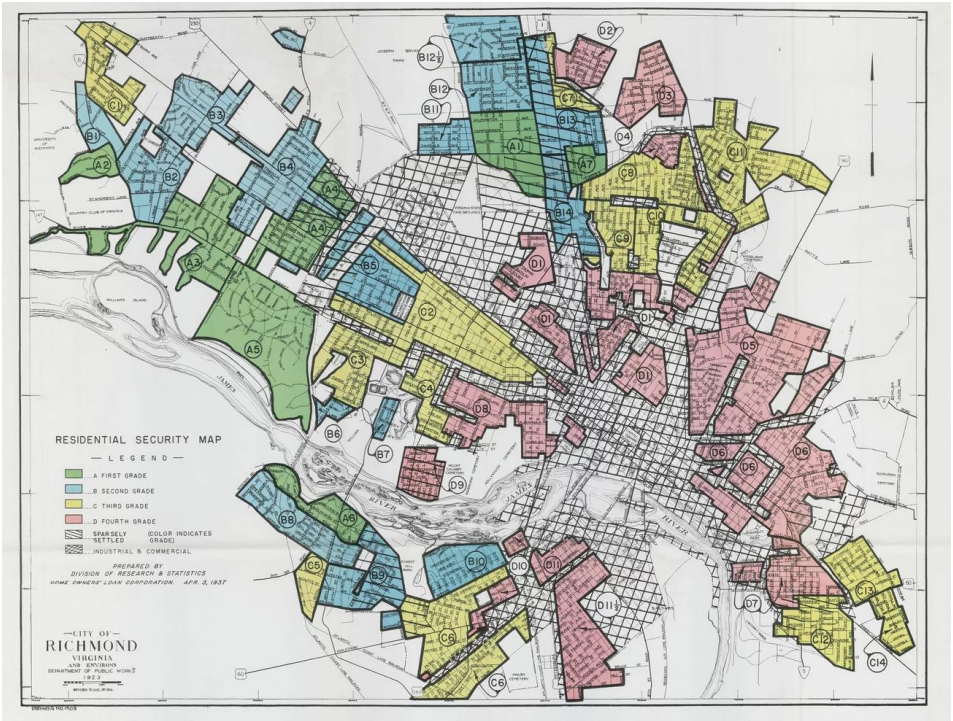
Medical Ethics Case Study – Context

- *This* map shows the percent of high school students who are non-white in the same regions as the previous map
  - The *darker* the area, the *lower* the lower the percentage of white students
- *How does this map compare to the previous one?*
- *What might this suggest about healthcare in areas that are mostly white vs areas that are mostly non-white?*



Medical Ethics Case Study – Context

- In the 1930s, the Home Owners' Loan Corporation (HOLC) was tasked by the U.S. Government to refinance home mortgages
- The HOLC drew maps that divided major cities into zones and labelled them based on how 'safe' it would be to give home loans in that area
- The areas designated as the highest risk were marked in red; the vast majority of these were neighborhoods with large populations of racial minorities



HOLC map of Richmond, VA

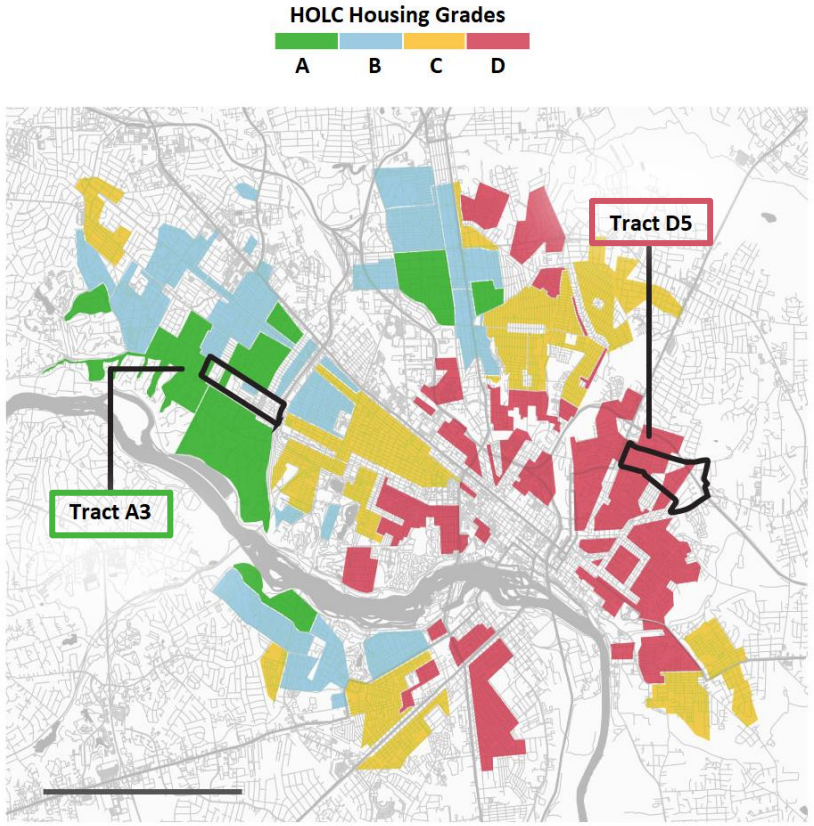
- As a result, it was much harder for many minorities to get loans and buy homes than white people
- This practice became known as '**redlining**' and its effects are still felt today

Medical Ethics Case Study – Context

PRESENT DAY HEALTH AND SOCIOECONOMIC DATA	TRACT A3	TRACT D5
Social Vulnerability Index	0.015	0.84
Life expectancy	89.3 years	68.1 years
Poverty rate	3.6%	59.6%
Percent minority	1.1%	98.9%
Diabetes rate	6%	22.1%
Obesity rate	22.4%	50.5%
High blood pressure rate	22.3%	48%
Pulmonary disease rate	3.8%	13.3%

Source: HOLC map courtesy of Digital Scholarship Lab and NCRC, "Not Even Past: Social Vulnerability and the Legacy of Redlining." Street outlines © OpenStreetMap contributors.

Credit: Connie Hanzhang Jin/NPR



HOLC zoning of Richmond, VA

- Even 90 years later, we can see *significant* health disparities along these man-made boundaries, even within the same city
- Living just 10 miles to the west increases your life expectancy by **20 years!**

Medical Ethics Case Study – Patient Presentation

- Ms. M., a 60-year-old, unemployed, uninsured black woman, presented to the emergency department at a Chicago community hospital with a breast lump.
- The emergency medicine physician suspected an infection and, without diagnostic testing or planned follow-up, discharged her with a prescription for antibiotics.
- *What type of infectious pathogen would antibiotics be effective in treating?*
- *What are some other possible causes of a lump in the breast?*
- *If you were the emergency medicine physician, is there anything else you would want to do before you sent this patient home?*

Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

Medical Ethics Case Study – Patient Follow-Up

- When the lump persisted, Ms. M. obtained a mammogram, which revealed potential breast cancer.
- She was referred to a general surgeon on staff at the community hospital, who excised the cancer and recommended a mastectomy (surgical removal of the breast) with axillary node dissection. Ms. M. was neither informed of her cancer's stage nor referred to an oncologist.
- *Why might a mastectomy be needed with some forms of breast cancer, even after a tumor is cut out?*
- *If you were the general surgeon, what information would you want to have before deciding whether or not to recommend a serious surgery like a mastectomy?*

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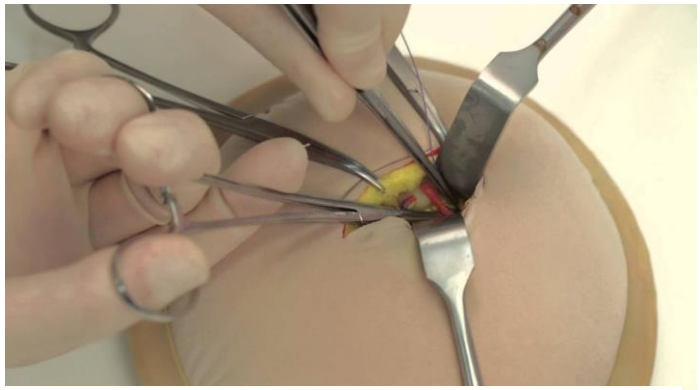
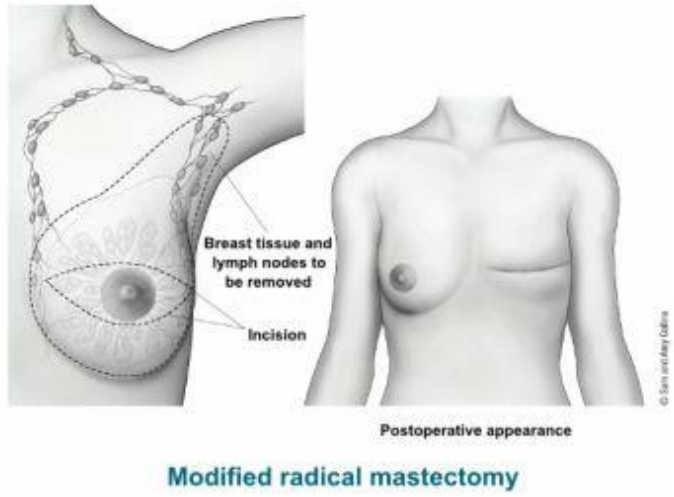
Medical Ethics Case Study – Patient Follow-Up

- Before undergoing a mastectomy, Ms. M was contacted by a navigator who'd been assigned to the hospital by the nonprofit Metropolitan Chicago Breast Cancer Task Force to review abnormal mammograms and guide women into evidence-based treatment.
- The navigator referred Ms. M. to a breast surgical oncologist at an academic medical center who informed her that she had stage III infiltrating ductal carcinoma and had only needed a needle biopsy — not an excisional biopsy — and that a mastectomy was unnecessary.

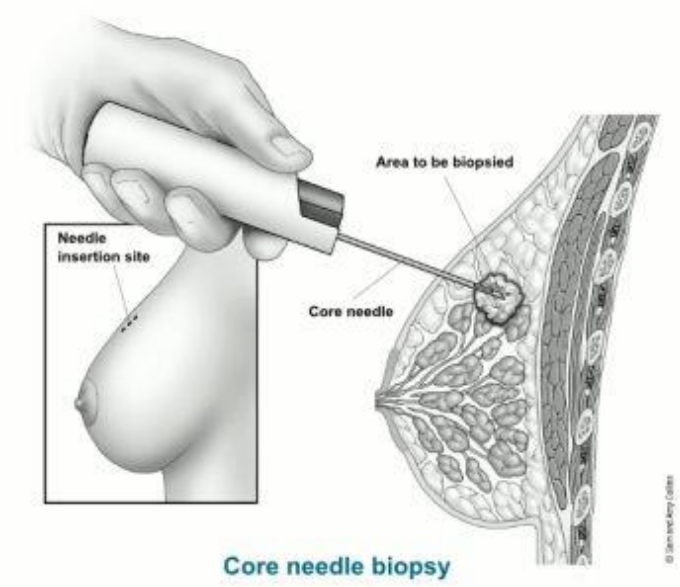
Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

Medical Ethics Case Study – Surgical Procedures





- On the upper left is a simulated excisional biopsy, in which a potential tumor is surgically removed; this is the procedure that Ms. M underwent.



- At the lower left is a mastectomy with axillary node dissection. This is the procedure the general surgeon suggested Ms. M undergo.
- At the upper right is a needle biopsy; this is the procedure that the specialist told Ms. M should have been done in the first place, even before the excisional biopsy.

Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

Medical Ethics Case Study – Continued

- *What are some reasons the general surgeon may have suggested a procedure (a mastectomy) that was drastically different from the procedure suggested by the breast cancer specialist (a needle biopsy)?*
- *How might things have turned out differently for Ms. M if she had not been contacted by the patient navigator from the nonprofit organization?*

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Medical Ethics Case Study – Influencing Factors

- Many hospitals in Chicago's largely black neighborhoods lack an American College of Surgeons (ACS) Commission on Cancer Center designation, which provides a quality framework to guide cancer care.
- Of the 12 Chicago hospitals with this designation, only 2 are located on the city's predominantly black South Side. In addition, hospitals that serve Chicago's minority neighborhoods often face financial constraints that limit the breadth of their cancer care services.
- This serves as an example of "structural racism", in which *historical* and *contemporary* racial inequities in outcomes are perpetuated by social, economic, and political systems; in this case, in outcomes for breast cancer.

Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

Medical Ethics Case Study – Influencing Factors

- *What are some ways you can think of to help identify these disparities in health care?*
- *What are some ways you can think of to help ensure that everyone has equal access to healthcare?*

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Medical Ethics Case Study – Findings

- The authors of this study suggested three changes that could address this issue:
  1. "Make the invisible visible": Clinicians can examine the data on their patients' outcomes and compare them to standard quality measures to make sure different patient populations are achieving the same outcomes
  2. "Change the narrative": The same organization that helped Ms. M find appropriate care not only helped to raise awareness about these healthcare disparities, but also to change the accepted explanation; they showed that this disparity was largely influenced by social factors and was not a result of any genetic predisposition to breast cancer among black women.
  3. "Make systemic changes": This healthcare organization launched a number of initiatives to link at-risk patients with appropriate care (as was the case with Ms. M) as well to ensure that surgeons and radiologists involved in breast cancer treatment received proper training at all Chicago hospitals.

Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

Medical Ethics Case Study – Case Follow-Up

- At an academic medical center, Ms. M. received appropriate treatment for stage III infiltrating ductal carcinoma, including:
  - Induction chemotherapy
  - Wider excision of the lumpectomy site
  - Radiation treatment.
- Six months after her diagnosis, she remained cancer-free.

Adapted from: Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).

That's all for today!

- Enjoy your faculty lecture with Dr. Brandi (filling in for Dr. Dalla Piazza) and we'll see you next week!

References

- https://www.npr.org/sections/health-shots/2020/11/19/911909187/in-u-s-cities-the-health-effects-of-past-housing-discrimination-are-plain-to-see
- https://www.njspotlightnews.org/2020/01/interactive-map-enrollment-data-shows-segregation-persists-in-nj-school-system/
- https://www.nj.com/data/2019/02/see-how-long-people-live-in-every-nj-neighborhood-mapped.html
- Connolly, N. D. B.; Winling, LaDale; Nelson, Robert K.; Marciano, Richard (2018-01-19), "Mapping inequality", The Routledge Companion to Spatial History, Routledge, pp. 502–524
- Pallok, K., De Maio, F. & Ansell, D. A. Structural Racism — A 60-Year-Old Black Woman with Breast Cancer. N Engl J Med 380, 1489–1493 (2019).