Vaccines: Past, Present and Future

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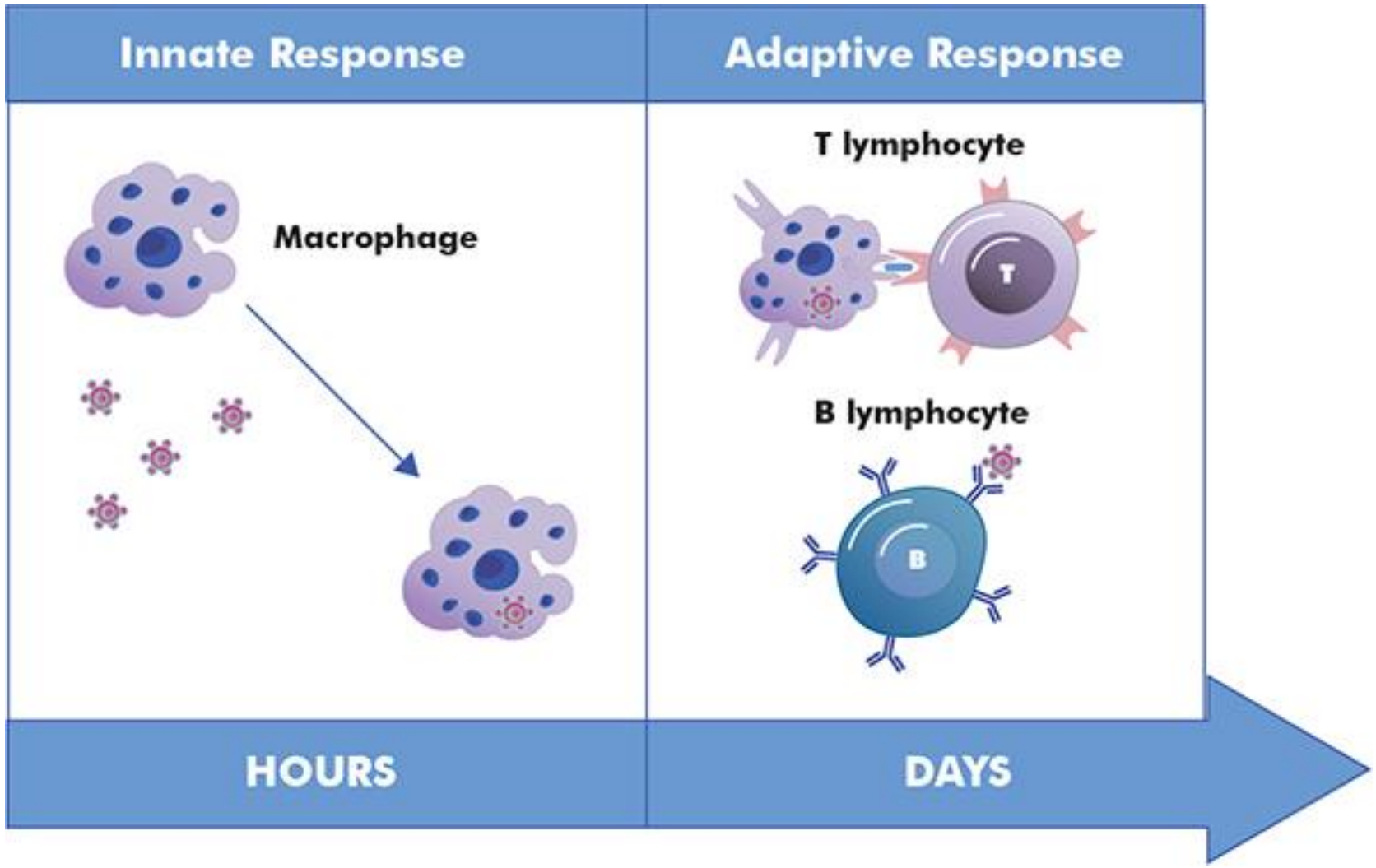
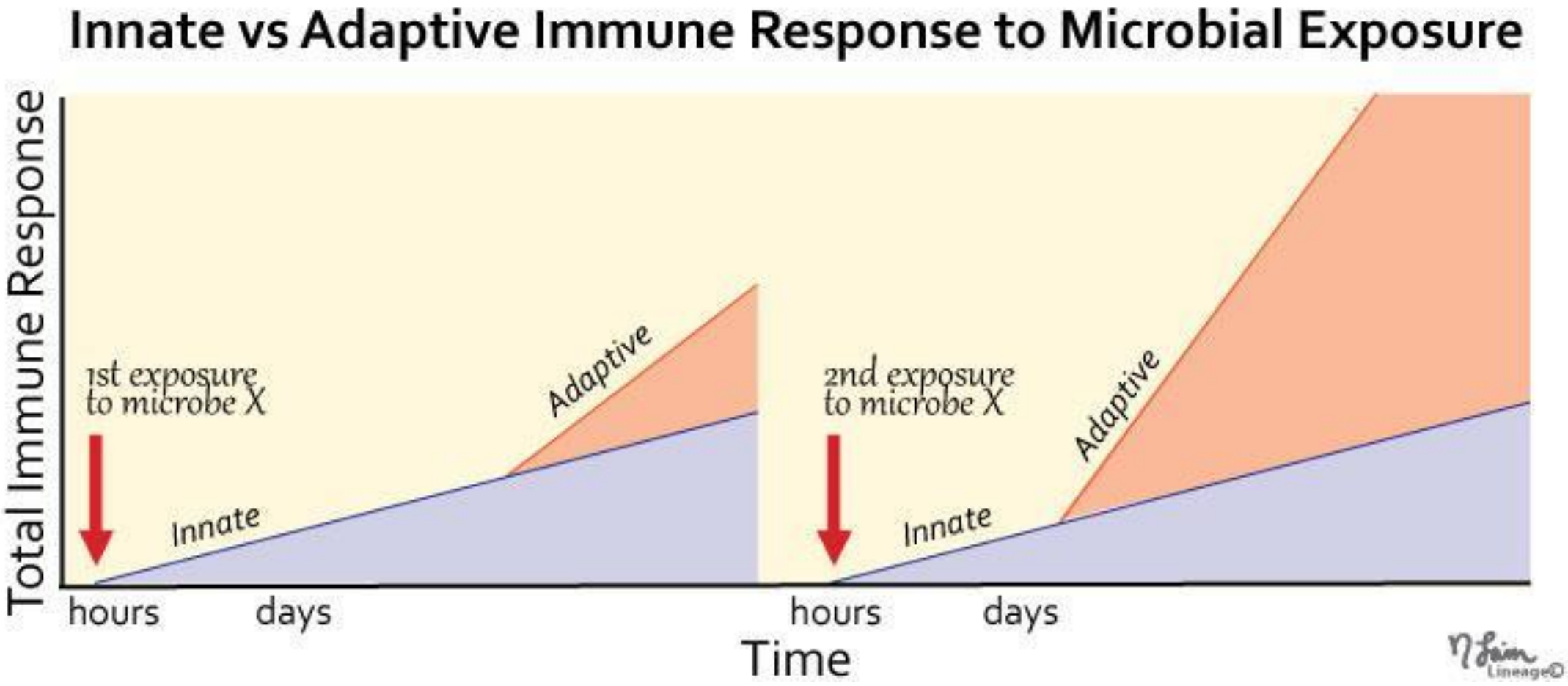
Why Vaccinate?

Immune Response



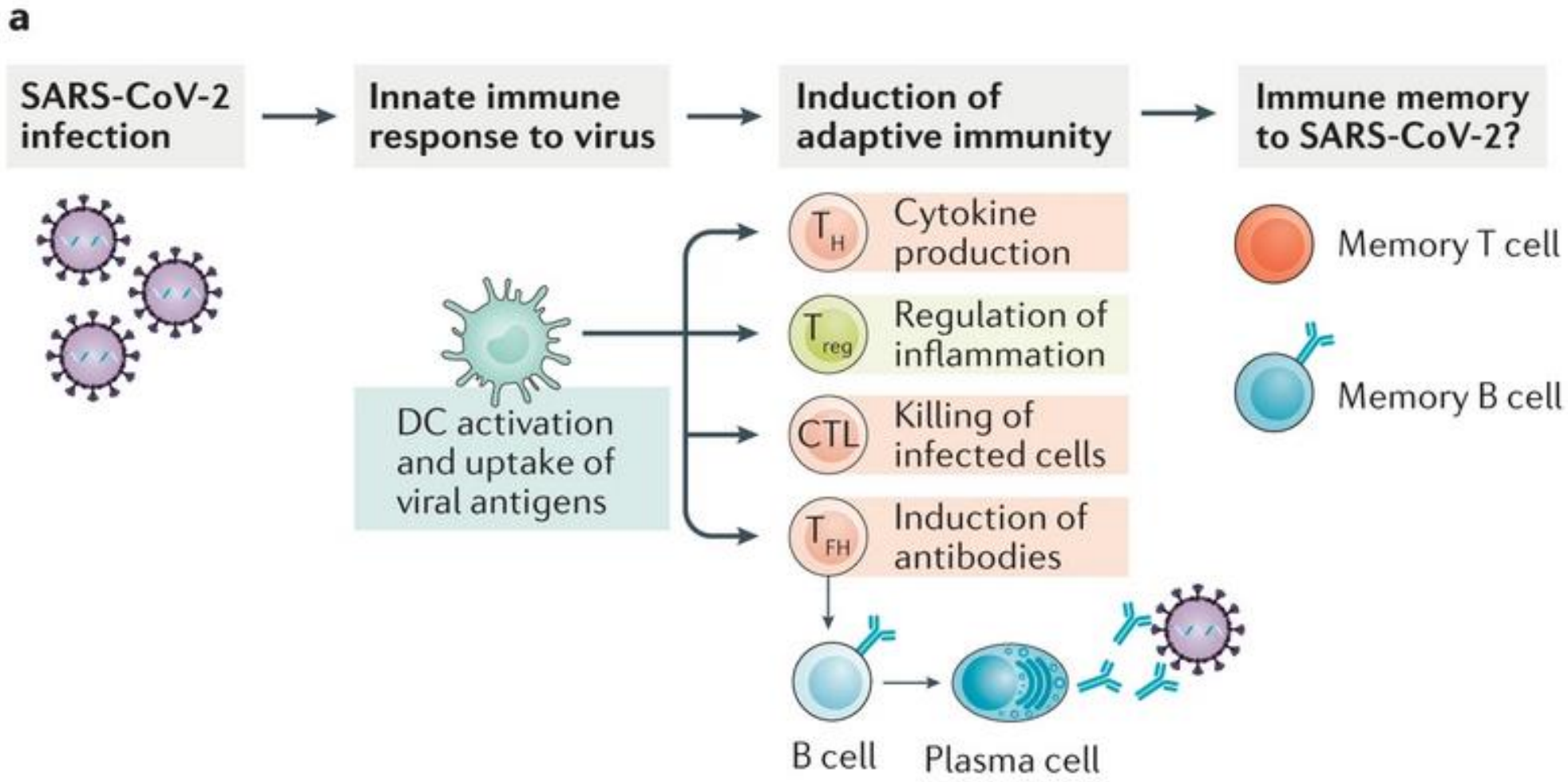
https://www.novusbio.com/research-areas/immunology

Primary vs. Secondary Exposure

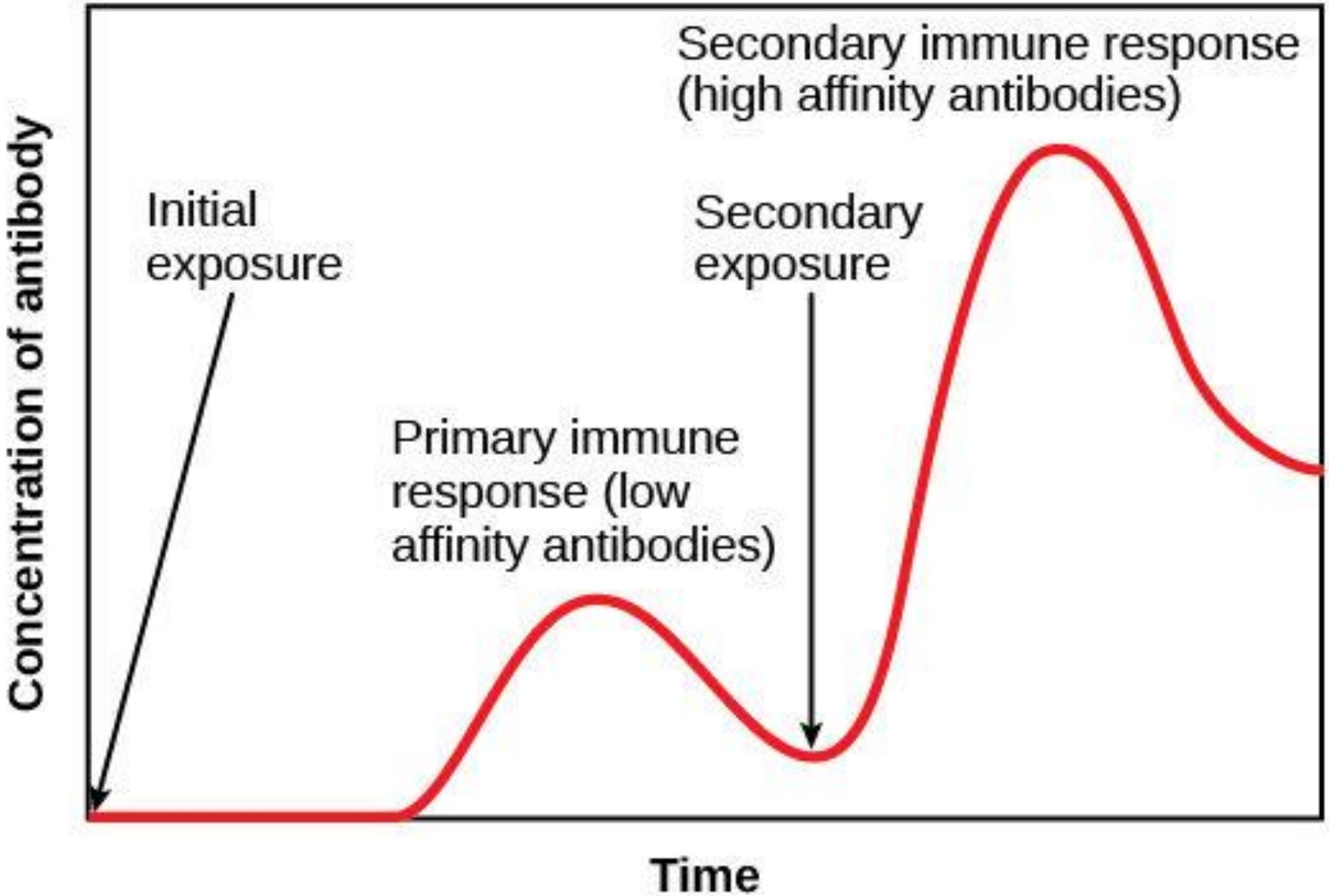


https://step1.medbullets.com/immunology/105041/innate-vs-adaptive-immunity

Immune Memory



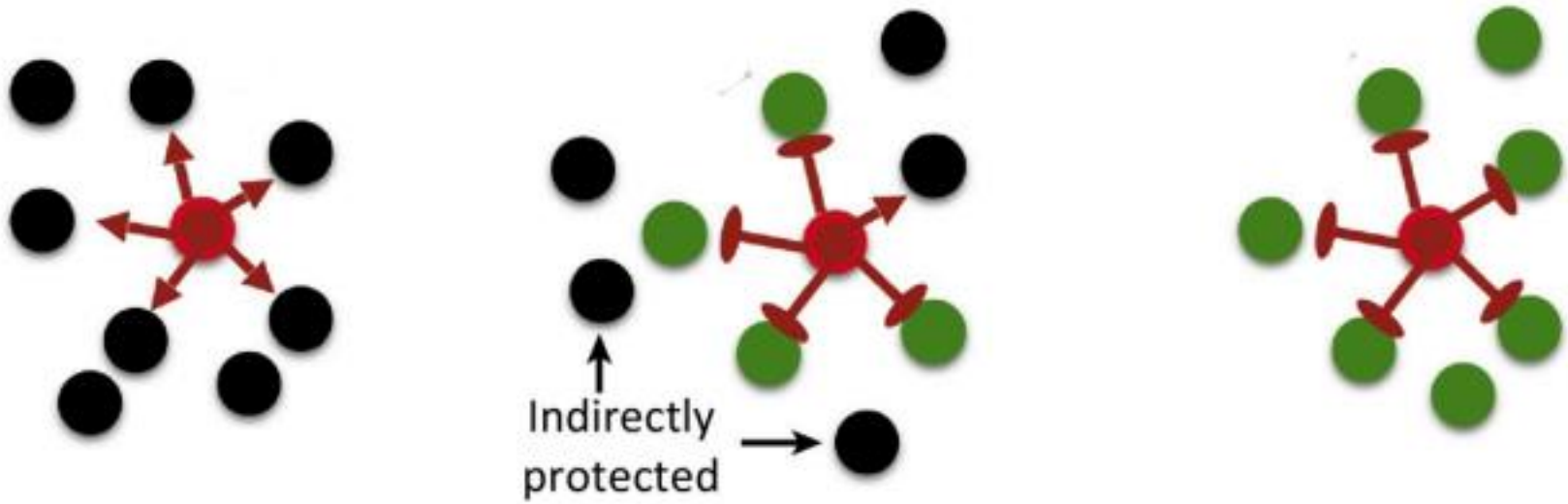
https://www.nature.com/articles/s41577-020-00436-4

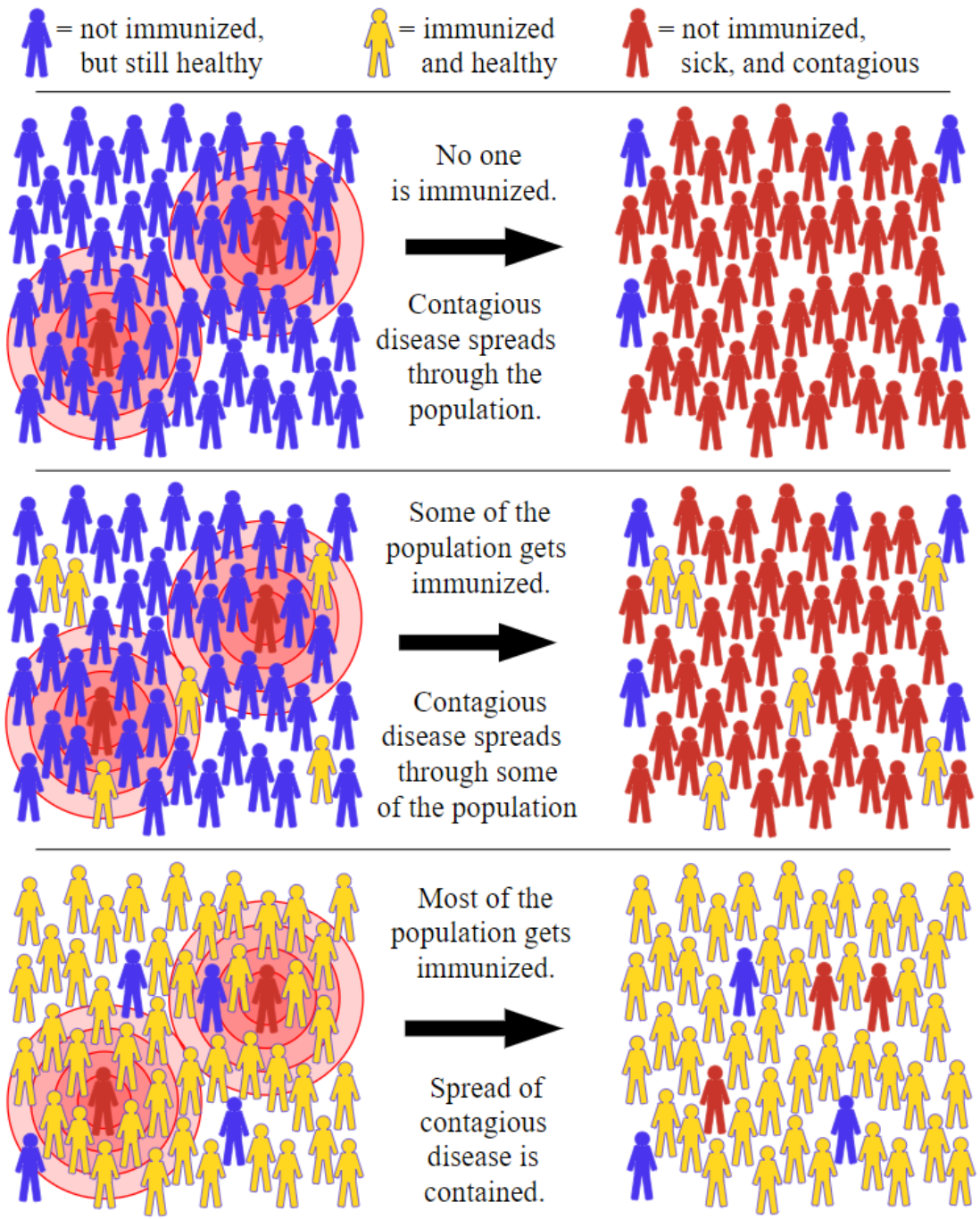


https://courses.lumenlearning.com/wm-biology2/chapter/immunological-memory/

A key concept about how vaccines work: Herd Immunity

- Maintenance of a critical level of immunity
- Herd immunity = population scale immunity

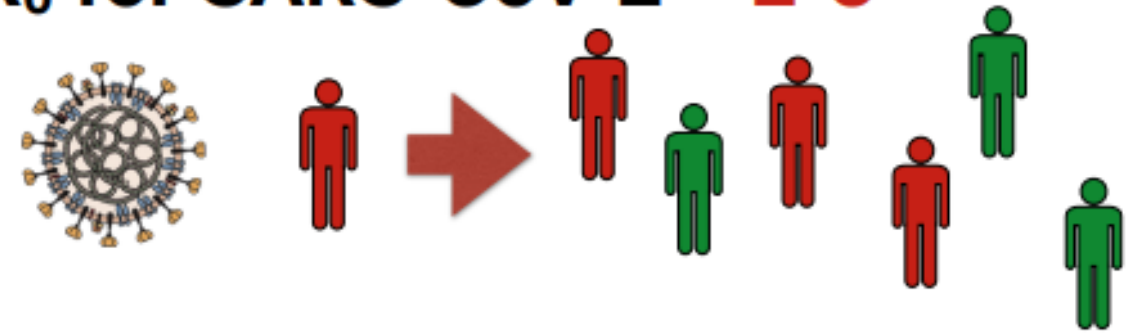




Herd Immunity

- Virus spread stops when the probability of infection drops below a critical threshold
- The threshold is virus (e.g. R_0) and population specific
- Smallpox: 80 - 85%
- Measles: 93 - 95%
- No vaccine is 100% effective
- When 80% of population is immunized with measles, 76% of population is immune

R_0 for SARS-CoV-2 = 2-3

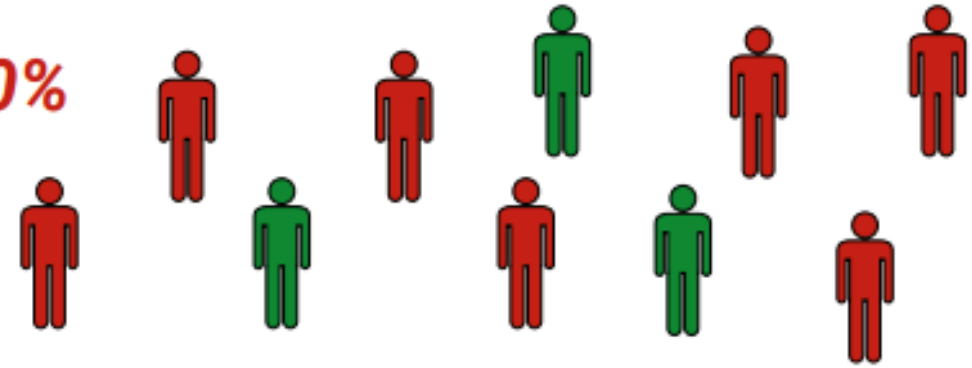


Number of people who must be vaccinated to prevent virus spread:

$$1 - 1/R_0$$

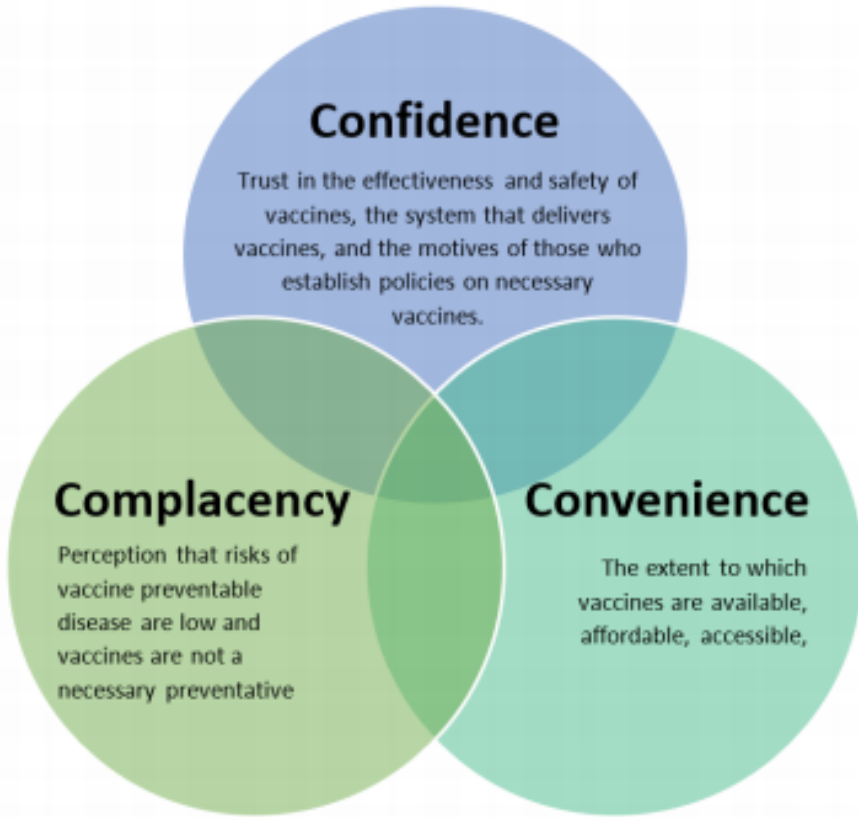
Fraction of people who must be immune to prevent virus spread:

50-70%



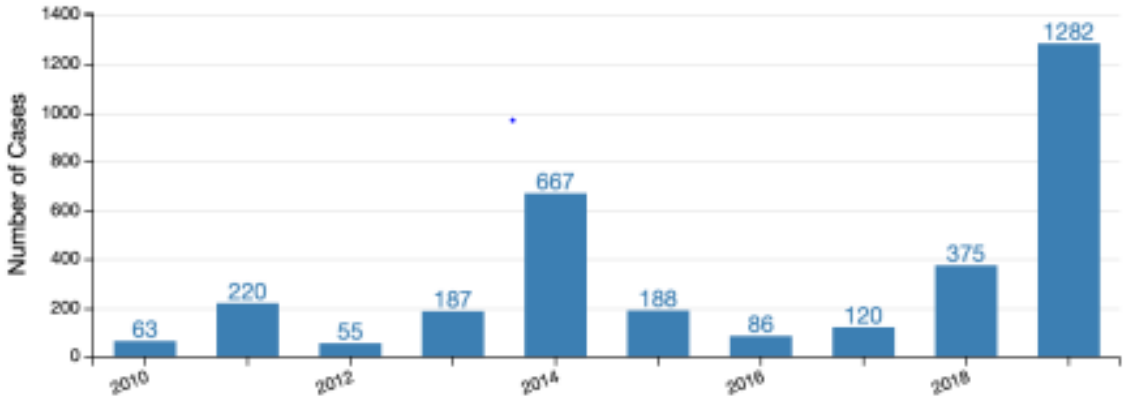
Vaccine hesitancy is dangerous to any vaccine program

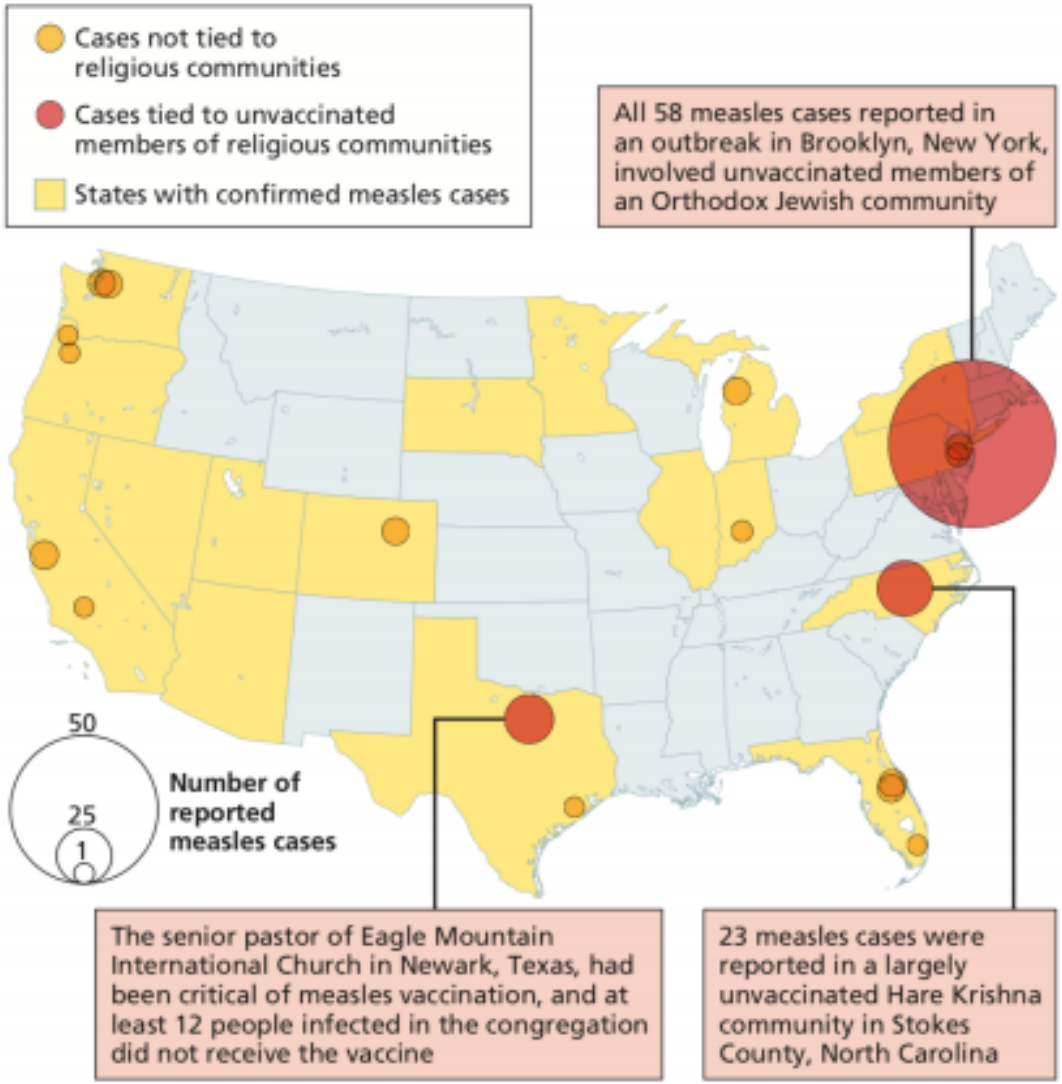
- "Viral diseases are a thing of the past"
- "Herd immunity has not been proven to work"
- "Polio is long gone"
- "I never get the flu"
- "Measles is just a trivial kid's disease"
- "Chicken pox only affects kids"
- "Kids should get infected naturally"
- "I'm not injecting anything into *my* body"
- "Vaccines make you sick, they cause autism, they cause multiple sclerosis, etc etc"
- "I know a guy who got the flu shot and then got the flu"
- "I can't afford to immunize my kids"
- "I don't have time this year"



When these attitudes prevail, society has serious problems with large-scale vaccination programs

Vaccine programs depend on public acceptance of their value





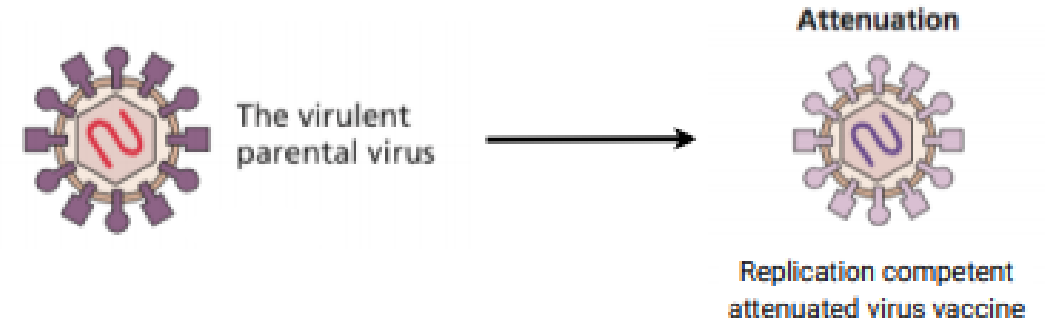
Principles of Virology, ASM Press

What are Vaccines?

Pre-exposure to Pathogen

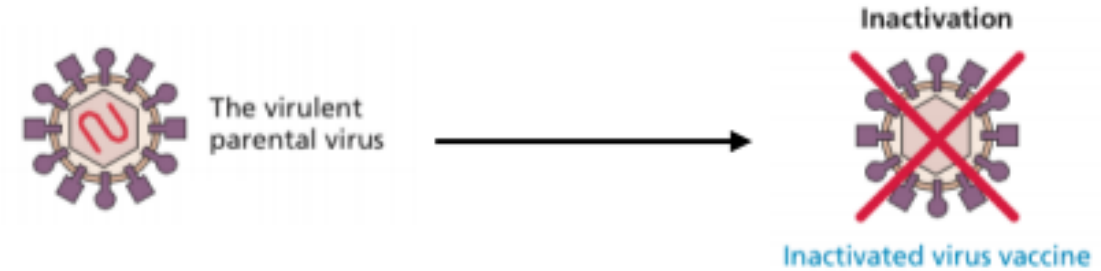
- Typically “live” or “killed”
- Live is weakened or attenuated
- Killed is inactivated
- Newer vaccines may just be a piece of a pathogen
  - “subunit vaccine”
- Or piece of genetic information
  - “DNA” or “RNA vaccine”

Replication competent, attenuated vaccines



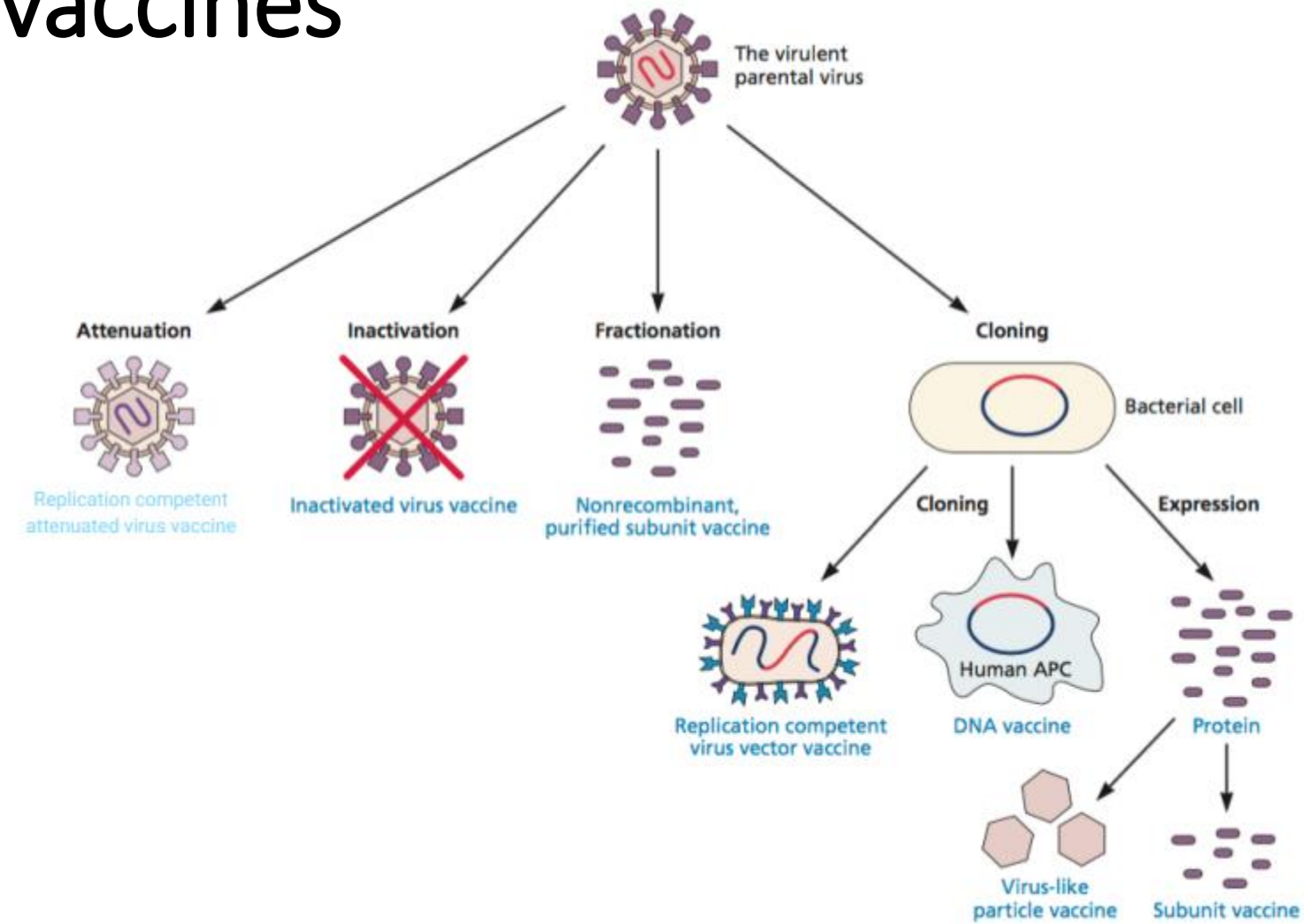
- Viral replication occurs, stimulates immune response
- Infection induces mild or inapparent disease

Inactivated vaccines



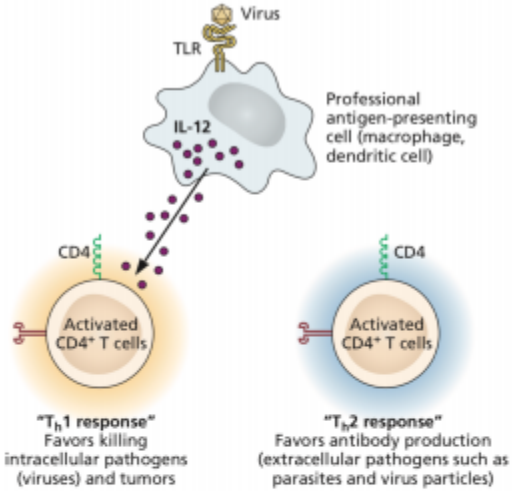
- Chemical procedures (e.g. formalin, β-propriolactone, nonionic detergents)
- Infectivity is eliminated, antigenicity not compromised

Newer vaccines



Principles of Virology, ASM Press

Requirements of an Effective Vaccine

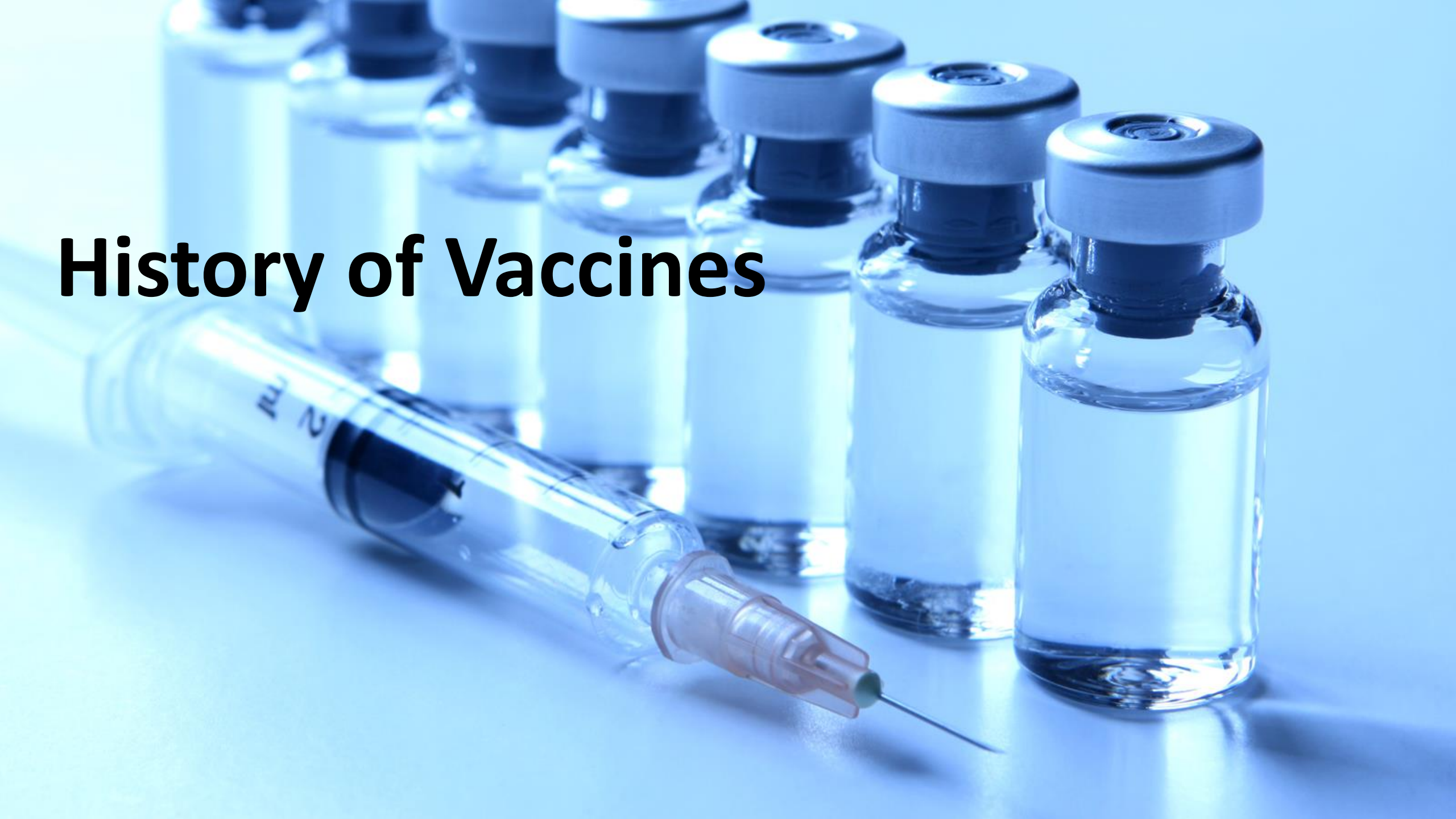


- Induction of an *appropriate immune response*
  - *Th1 vs Th2 response*
- Vaccinated individual must be *protected against disease* caused by a virulent form of the specific pathogen
  - *Just getting 'a response' is not enough (e.g. producing antibodies)*

Requirements of an Effective Vaccine

- Safety: no disease, minimal side effects
- Induce protective immunity in the population
- Protection must be long-lasting
- Low cost (<$1, WHO); genetic stability; storage considerations; delivery (oral vs. needle)

History of Vaccines



Earliest Evidence

- May have started as early as 200 BC with Chinese “variolation” against Smallpox
- Approximately 1022 AD

http://plaza.ufl.edu/sesd/PREVENTION.htm

Earliest Evidence

Approximately 1500 AD

https://amhistory.si.edu/polio/virusvaccine/history.htm

Lady Mary Wortley Montagu

- Wife of Ambassador to Ottoman Empire
- 7 year old son was “engrafted” with smallpox in 1717 in Turkey
- 3 year old daughter was engrafted in 1721 in England during epidemic

https://royalsocietypublishing.org/doi/10.1098/rstb.2014.0378#d3e575

Edward Jenner and Cowpox

- Jenner developed alternate vaccine using cowpox in 1796
- “Variolated” 8 year old James Phipps with cowpox
- Later challenged with variolation (smallpox = Variola)
- Cowpox virus named Vaccinia
- Effective smallpox vaccine

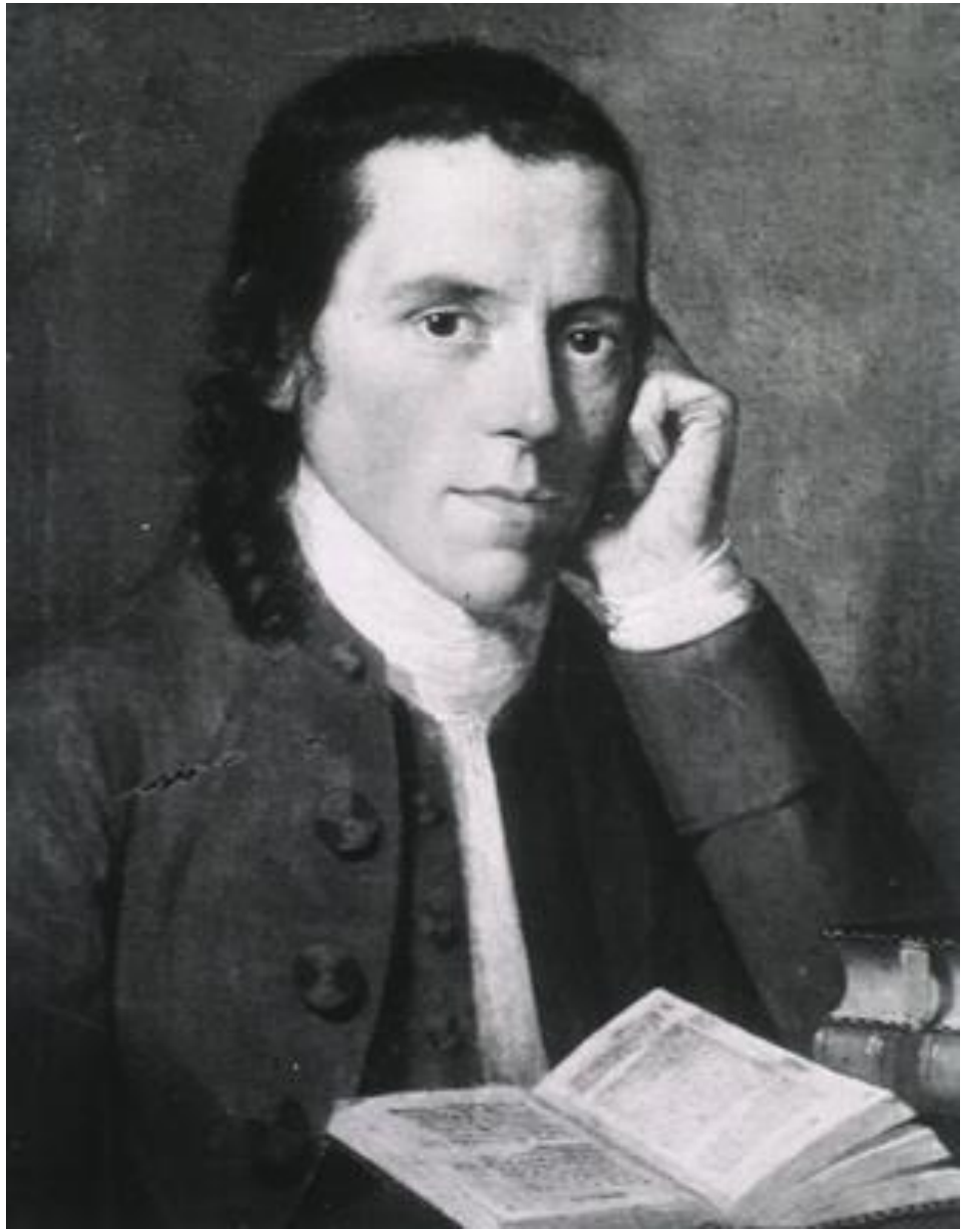
https://www.sciencemuseum.org.uk/objects-and-stories/medicine/smallpox-and-story-vaccination

Rise of Antivaxxers (early 1800's)

https://www.economist.com/1843/2019/08/30/the-original-anti-vaxxers

Benjamin Waterhouse

- Brought vaccination to the US in 1800
- Endorsed by VP Thomas Jefferson
- State of Massachusetts was first to encourage vaccination in 1802
- National Vaccine Agency established in 1813



https://www.historyofvaccines.org/timeline#EVT_60

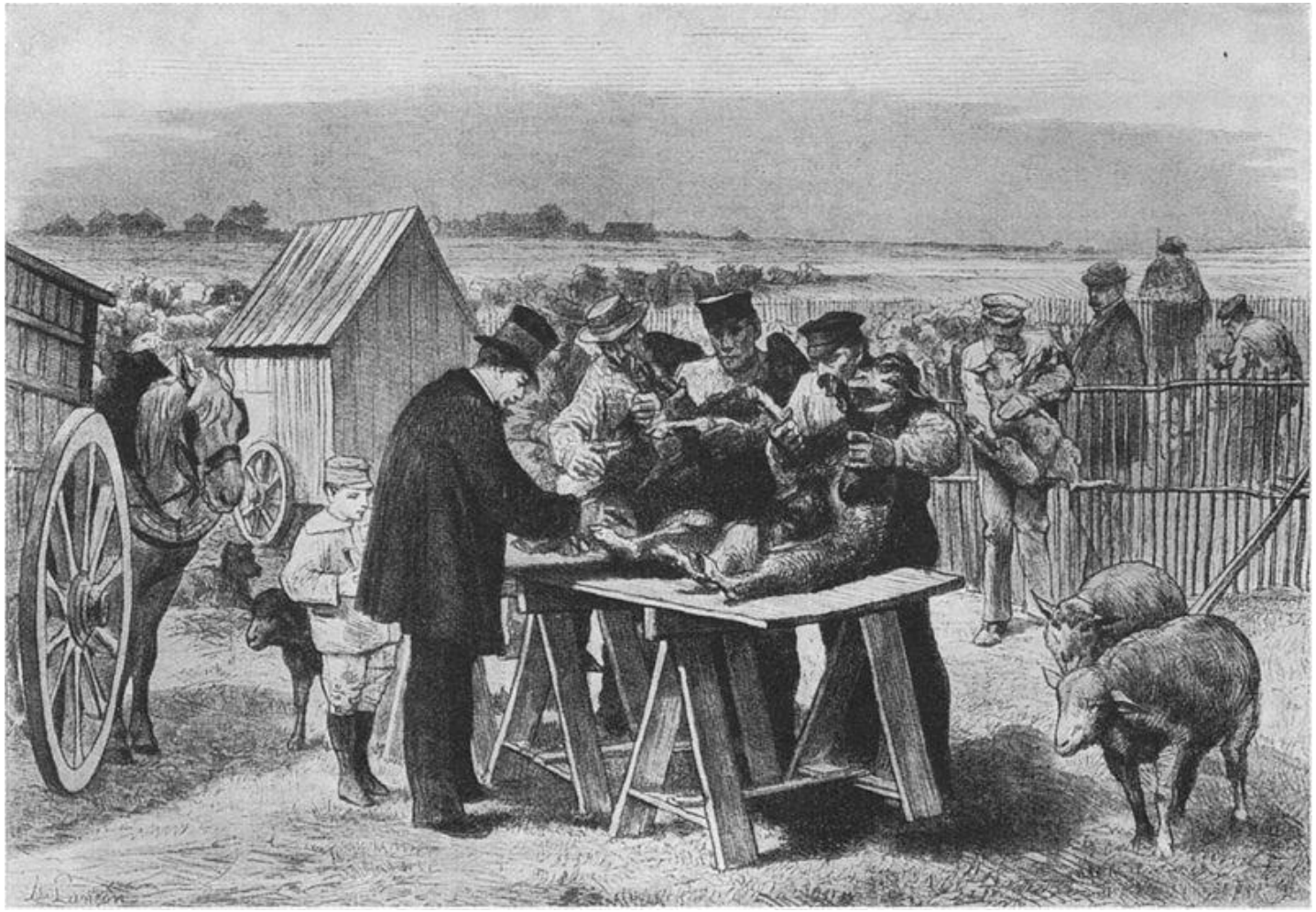
Louis Pasteur and Chicken Cholera

- Fatal disease of chickens
- Determined causative bacterium in 1878
- Developed vaccine accidentally in 1879
- First attenuated vaccine

https://www.vbivaccines.com/wire/louis-pasteur-attenuated-vaccine/

Louis Pasteur and Anthrax

- Causative agent of anthrax determined by Robert Koch
- Pasteur attenuated *B. anthracis*
- Vaccine trial with 50 sheep and 10 cows in 1881



https://commons.wikimedia.org/wiki/File:Louis_Pasteur_in_Pouilly-le-Fort_(Illustration_-_1881).jpg

Louis Pasteur and Rabies

- Attenuated rabies virus by growing in rabbits
- Demonstrated effectiveness in dogs
- Vaccinated 9 year old Joseph Meister in 1885

https://www.awesomestories.com/asset/view/LOUIS-PASTEUR-MEETS-JOSEPH-MEISTER-Louis-Pasteur-and-the-Rabies-Virus

Early Influenza Vaccines

- Early 1940's – Thomas Francis, Jr., MD and Jonas Salk, MD developed flu vaccine with US Army support
- Virus grown in chicken eggs and inactivated

https://www.museumofhealthcare.ca/explore/exhibits/vaccinations/other-vaccines.html

Combination Vaccines

- First combination vaccine included diphtheria toxoid and pertussis in 1943
- Next version also included tetanus toxoid in 1947 (DTP)
- Polio was included for a short while

https://www.museumofhealthcare.ca/explore/exhibits/vaccinations/other-vaccines.html

1952 Polio Epidemic United States

- 52,628 Polio cases reported
- Over 21,000 paralytic
- Over 3,000 deaths

https://www.historyofvaccines.org/timeline#EVT_100321

https://www.npr.org/sections/npr-history-dept/2015/04/10/398515228/defeating-the-disease-that-paralyzed-america

Jonas Salk and Polio

- By 1952, Salk developed an inactivated polio vaccine
- Vaccinated his family in 1953
- Large scale clinical trial in 1954
- Vaccination paused in 1955 due to “Cutter incident”
- IPV phased out in 1968, back in in 1997

https://www.historyofvaccines.org/timeline#EVT_100323

https://www.ksat.com/features/2020/06/23/as-the-world-waits-on-a-covid-19-vaccine-heres-a-peek-at-what-things-looked-like-as-polio-vaccines-surfaced/

Albert Sabin and Polio

- Sabin developed “live” polio vaccine in late 1950’s but had to test overseas
- Most of the rest of the world adopted the attenuated oral vaccine
- Vaccine became available in US in 1960

https://www.kake.com/story/41997712/the-other-time-america-desperately-sought-a-miracle-cure-for-a-devastating-disease


Intermission

Maurice Hilleman and Polio

- Hilleman worked for Merck
- Discovered contaminant virus in the monkey cells (SV40)
- Moved away from monkey tissue culture to grow polio virus

https://www.historyofvaccines.org/timeline#EVT_100810

Maurice Hilleman and Measles

- Hilleman developed attenuated measles vaccine in 1962
- Passaged 80 times through multiple different cells
- Given with a dose of antibodies (gamma globulin)
- In 1968, he passaged 40 extra times, so no IgG needed

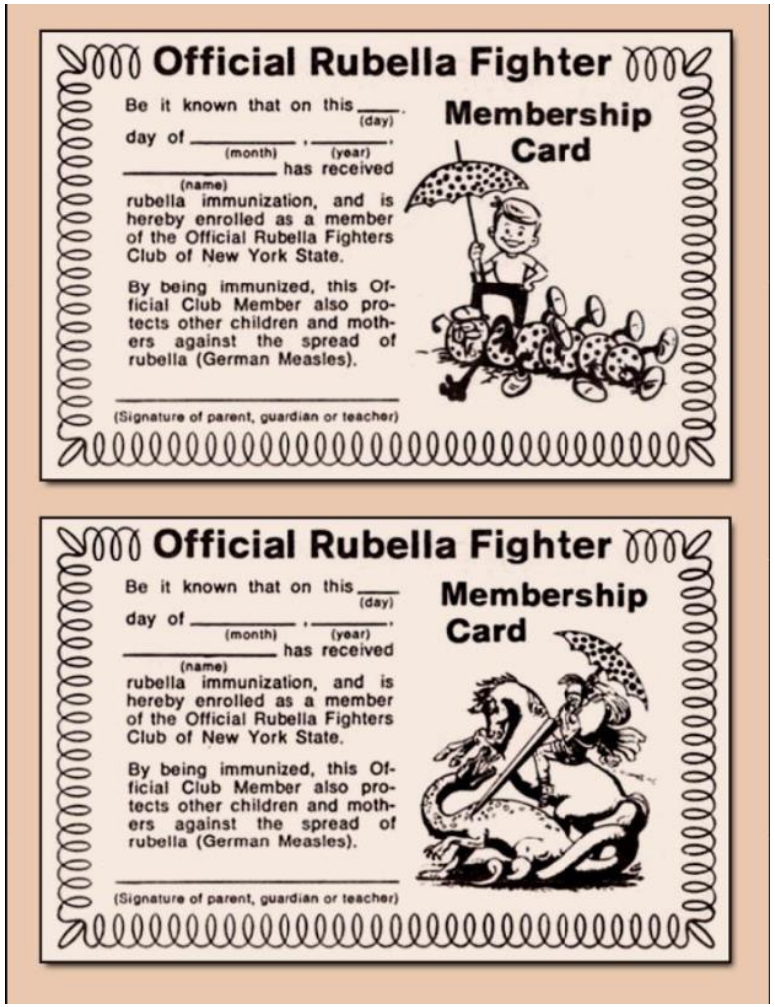
https://www.historyofvaccines.org/timeline#EVT_100812

Maurice Hilleman and Mumps

- In 1963, Hilleman's 6 year old daughter contracted mumps
- Hilleman isolated the virus from her
- Attenuated it for a vaccine
- Given to his other daughter in 1966

https://www.historyofvaccines.org/timeline#EVT_100814

Maurice Hilleman and German Measles



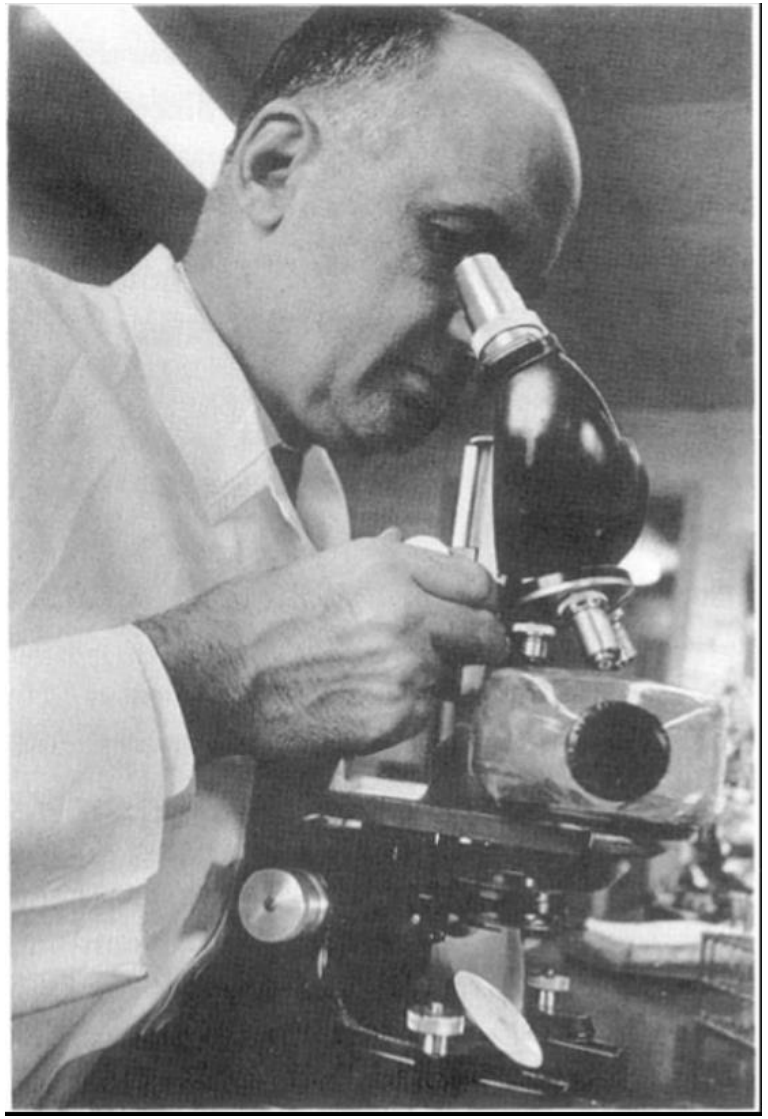
- Rubella caused a major US outbreak in 1967, infecting millions
- Generally mild in children, but caused thousands of miscarriages and 20,000 cases of CRS
- Hilleman developed an attenuated vaccine in 1969

https://www.historyofvaccines.org/timeline#EVT_100727

Maurice Hilleman and Other Vaccines

- Japanese Encephalitis Virus in 1944 (for the Army)
- Marek's disease (in chickens) in 1968
- Hong Kong influenza in 1968
- MMR Vaccine in 1971

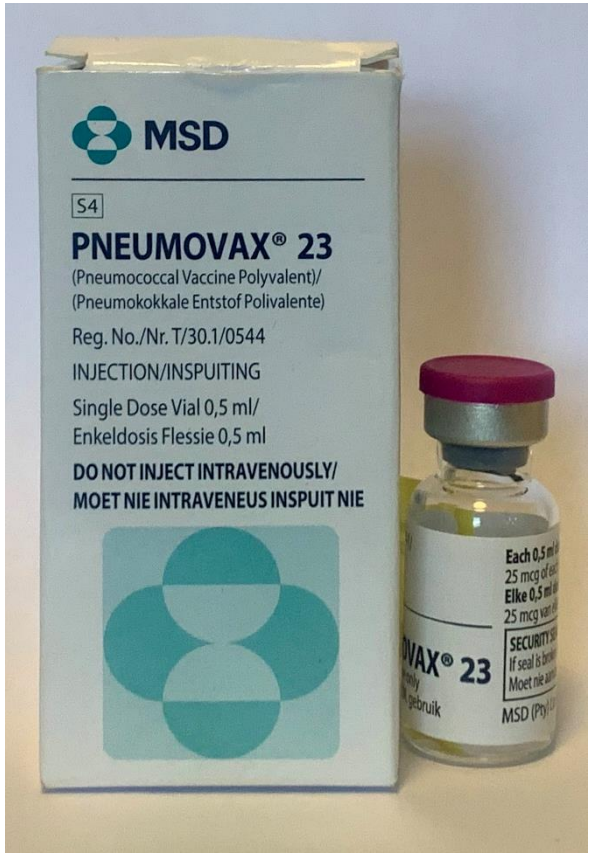
- Hilleman died in 2005



https://www.historyofvaccines.org/timeline#EVT_100822

1970’s – 80’s

- 1975 & 77 – Last wild cases of smallpox (major and minor)
- 1976 – Swine Flu vaccine (Guillain-Barré syndrome)
- 1977 – Pneumococcal vaccine licensed
- 1978 – Measles targeted for Elimination
- 1978 – Accidental smallpox infection in a lab
- 1980 – Smallpox declared eradicated
- 1985 – Polio targeted for Elimination in Americas
- 1985 – Vaccine against *Haemophilus influenzae* B



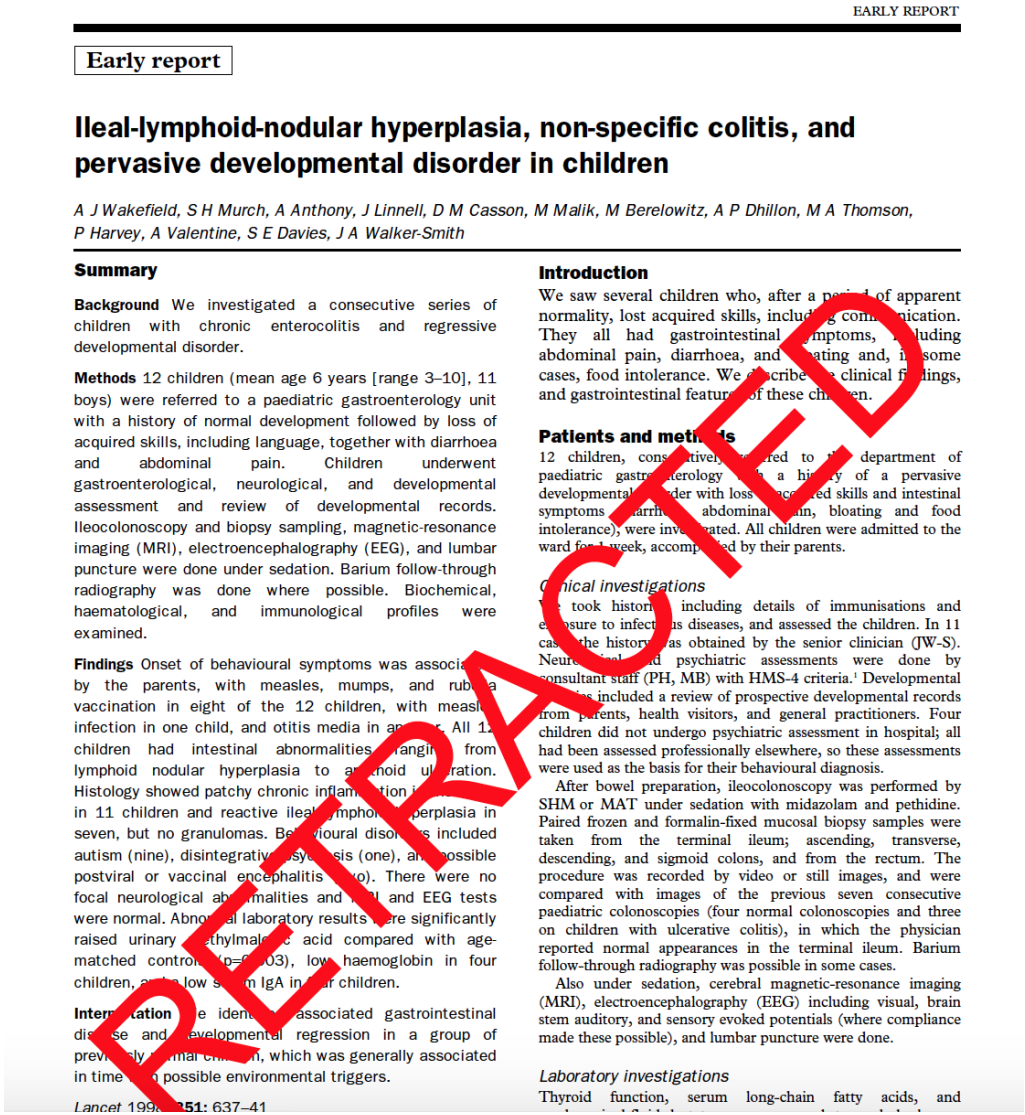
https://www.historyofvaccines.org/timeline#EVT_100335

1980's – 90's

- 1986 – Hepatitis B recombinant vaccine licensed
- 1988 – Polio targeted for Eradication globally
- 1989-91 – Low measles vaccine rate led to 55,622 infections with 123 deaths, 90% in unvaccinated
- 1989 – Oral typhoid vaccine licensed in US
- 1990 – US military ceased routine smallpox vaccination
- 1994 – Polio declared Eliminated in Americas
- 1995 – Hepatitis A vaccine licensed
- 1995 – Chickenpox vaccine licensed in US

https://www.historyofvaccines.org/timeline#EVT_100335

1998 - Andrew Wakefield and MMR



EARLY REPORT

Early report

Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children

A J Wakefield, S H Murch, A Anthony, J Linnell, D M Casson, M Malik, M Berelowitz, A P Dhillon, M A Thomson, P Harvey, A Valentine, S E Davies, J A Walker-Smith

Summary

Background We investigated a consecutive series of children with chronic enterocolitis and regressive developmental disorder.

Methods 12 children (mean age 6 years [range 3–10], 11 boys) were referred to a paediatric gastroenterology unit with a history of normal development followed by loss of acquired skills, including language, together with diarrhoea and abdominal pain. Children underwent gastroenterological, neurological, and developmental assessment and review of developmental records. Ileocolonoscopy and biopsy sampling, magnetic-resonance imaging (MRI), electroencephalography (EEG), and lumbar puncture were done under sedation. Barium follow-through radiography was done where possible. Biochemical, haematological, and immunological profiles were examined.

Findings Onset of behavioural symptoms was associa... by the parents, with measles, mumps, and rub... vaccination in eight of the 12 children, with measl... infection in one child, and otitis media in an... All 12 children had intestinal abnormalities ...rangi... from lymphoid nodular hyperplasia to a... thoid ul...ration. Histology showed patchy chronic inflam...tion i... in 11 children and reactive ileal lympho...perplasia in seven, but no granulomas. Be...viour...l disor...s included autism (nine), disintegrative ...sychosis (one), a... possible postviral or vaccinal encephalitis (...o). There were no focal neurological ab...malities and ...l and EEG tests were normal. Abno...al laboratory results ...ere significantly raised urinary ...ethylmal...c acid compared with age-matched contro... (p=...03), low haemoglobin in four children, a... low s...m IgA in ...r children.

Interp...tation ...e ident... associated gastrointestinal dis...se and ...evelopmental regression in a group of previ...ly ...rmal chi...n, which was generally associated in time ...h possible environmental triggers.

Lancet 199... **351:** 637–41

Introduction

We saw several children who, after a pe...d of apparent normality, lost acquired skills, includ...g com...nication. They all had gastrointestinal ...mptoms, ...luding abdominal pain, diarrhoea, and ...ating and, i... some cases, food intolerance. We d...scribe... clinical f...dings, and gastrointestinal featur... of these chi...en.

Patients and meth...ds

12 children, cons...tively ...rred to t... department of paediatric gastr...terology ...h a hi...y of a pervasive developmental ...der with loss ...ed skills and intestinal symptoms ...arrh... abdominal ...n, bloating and food intolerance), were inve...gated. All children were admitted to the ward for 1 week, accomp...ied by their parents.

Clinical investigations

We took histor... including details of immunisations and e...posure to infect...s diseases, and assessed the children. In 11 cas... the histor... as obtained by the senior clinician (JW-S). Neur...logical and psychiatric assessments were done by consultant staff (PH, MB) with HMS-4 criteria.[1] Developmental ...s included a review of prospective developmental records from ...arents, health visitors, and general practitioners. Four children did not undergo psychiatric assessment in hospital; all had been assessed professionally elsewhere, so these assessments were used as the basis for their behavioural diagnosis.

After bowel preparation, ileocolonoscopy was performed by SHM or MAT under sedation with midazolam and pethidine. Paired frozen and formalin-fixed mucosal biopsy samples were taken from the terminal ileum; ascending, transverse, descending, and sigmoid colons, and from the rectum. The procedure was recorded by video or still images, and were compared with images of the previous seven consecutive paediatric colonoscopies (four normal colonoscopies and three on children with ulcerative colitis), in which the physician reported normal appearances in the terminal ileum. Barium follow-through radiography was possible in some cases.

Also under sedation, cerebral magnetic-resonance imaging (MRI), electroencephalography (EEG) including visual, brain stem auditory, and sensory evoked potentials (where compliance made these possible), and lumbar puncture were done.

Laboratory investigations

Thyroid function, serum long-chain fatty acids, and

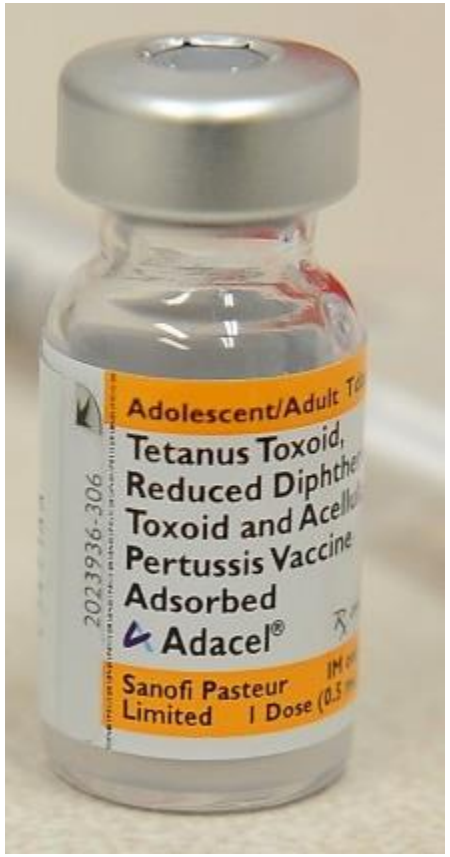
RETRACTED

- Andrew Wakefield questioned safety of MMR vaccine, suggesting it caused autism
- His theory has been debunked numerous times, his original research paper was retracted and his medical license was revoked in 2010
- Public perception persists

https://www.historyofvaccines.org/timeline#EVT_100335

2000's – 2010

- 1999 – DTaP replaces DTP
- 2000 – Endemic measles Eliminated from US
- 2000 – Salk's IPV added back to US schedule
- 2000 – 99% reduction in polio cases worldwide
- 2006 – HPV vaccine licensed in US
- 2006 – HepA vaccine recommended for all children
- 2006 – Rotavirus vaccine recommended
- 2008 – Measles cases increase in US
- 2009 – No diphtheria in US for 5 years

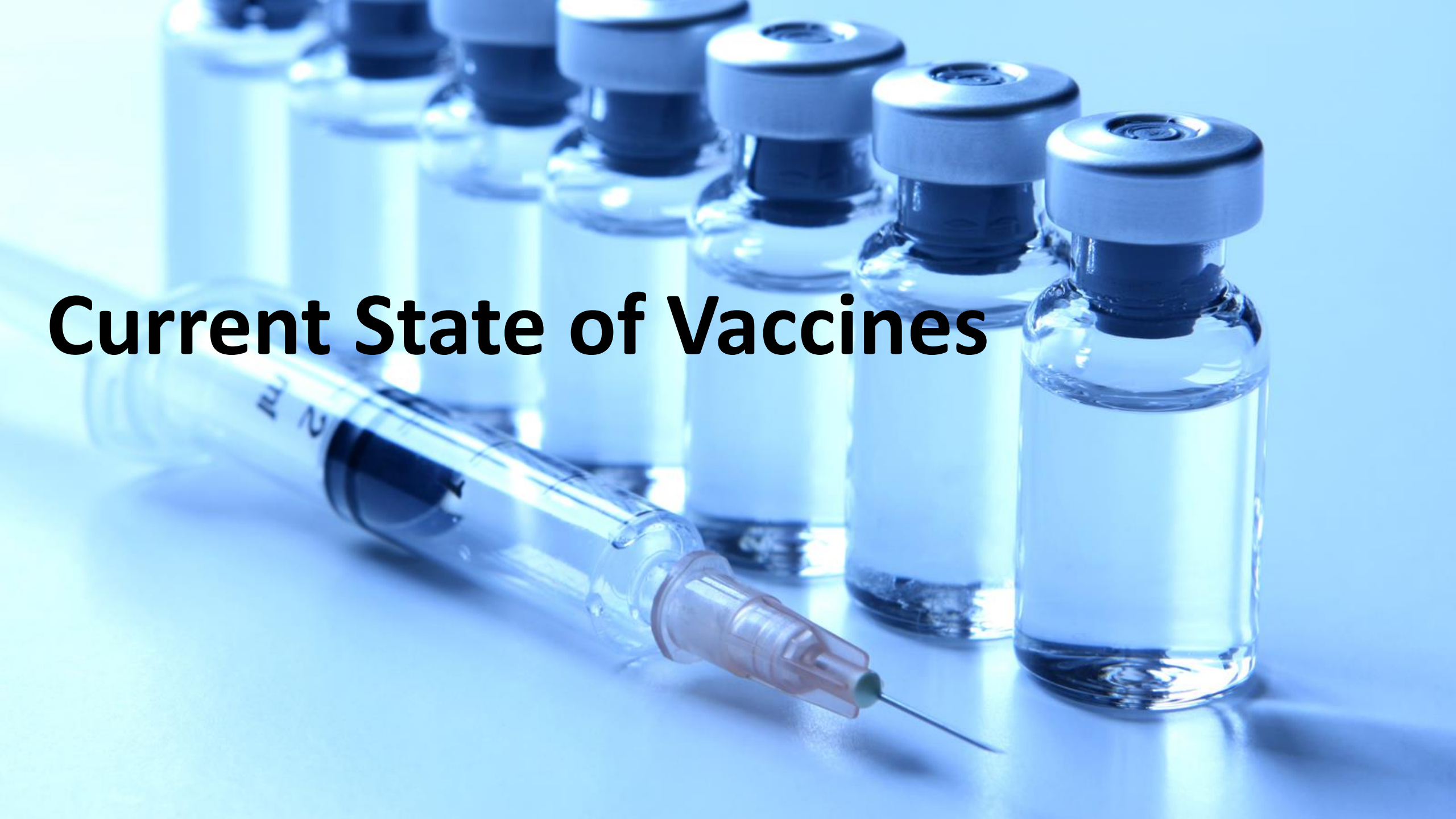


https://www.historyofvaccines.org/timeline#EVT_100335

2010 – now

- 2010 – California pertussis cases increase 418% over 2009
- 2011 – Measles outbreak in US and France
- 2014 – 2 meningiococcal B outbreaks at universities in US
- 2014 – Measles cases increase – outbreak at Disneyland (12/15-20)
- 2015 – Total of 111 cases from Disney outbreak
- 2016 – Zika outbreak
- 2016 – Measles Eliminated from Americas (2 of 3 wild strains)
- 2018 – Only 3 countries with endemic polio, 17 still at risk

https://www.historyofvaccines.org/timeline#EVT_100335



Current State of Vaccines

List of Vaccines Used in United States

26 Diseases

Links to Clinical info about the vaccine

- Adenovirus
- Anthrax
  - AVA (BioThrax)
- Cholera
  - Vaxchora
- Diphtheria
  - DTaP (Daptacel, Infanrix)
  - Td (Tenivac, generic)
  - DT (-generic-)
  - Tdap (Adacel, Boostrix)
  - DTaP-IPV (Kinrix, Quadracel)
  - DTaP-HepB-IPV (Pediarix)
  - DTaP-IPV/Hib (Pentacel)
- Hepatitis A
  - HepA (Havrix, Vaqta)
  - HepA-HepB (Twinrix)
- Hepatitis B
  - HepB (Engerix-B, Recombivax HB, Heplisav-B)
  - DTaP-HepB-IPV (Pediarix)
  - HepA-HepB (Twinrix)
- *Haemophilus influenzae* type b (Hib)
  - Hib (ActHIB, PedvaxHIB, Hiberix)
  - DTaP-IPV/Hib (Pentacel)
- Human Papillomavirus (HPV)
  - HPV9 (Gardasil 9) (For scientific papers, the preferred abbreviation is 9vHPV)
- Seasonal Influenza (Flu) only
  - IIV* (Afluria, Fluad, Flublok, Flucelvax, FluLaval, Fluarix, Fluvirin, Fluzone, Fluzone High-Dose, Fluzone Intradermal)

    *There are various acronyms for inactivated flu vaccines – IIV3, IIV4, RIV3, RIV4 and ccIIV4.
  - LAIV (FluMist)
- Japanese Encephalitis
  - JE (Ixiaro)
- Measles
  - MMR (M-M-R II)
  - MMRV (ProQuad)
- Meningococcal
  - MenACWY (Menactra, Menveo)
  - MenB (Bexsero, Trumenba)
- Mumps
  - MMR (M-M-R II)
  - MMRV (ProQuad)
- Pertussis
  - DTaP (Daptacel, Infanrix)
  - Tdap (Adacel, Boostrix)
  - DTaP-IPV (Kinrix, Quadracel)
  - DTaP-HepB-IPV (Pediarix)
  - DTaP-IPV/Hib (Pentacel)
- Pneumococcal
  - PCV13 (Prevnar13)
  - PPSV23 (Pneumovax 23)
- Polio
  - Polio (Ipol)
  - DTaP-IPV (Kinrix, Quadracel)
  - DTaP-HepB-IPV (Pediarix)
  - DTaP-IPV/Hib (Pentacel)
- Rabies
  - Rabies (Imovax Rabies, RabAvert)
- Rotavirus
  - RV1 (Rotarix)
  - RV5 (RotaTeq)
- Rubella
  - MMR (M-M-R II)
  - MMRV (ProQuad)
- Shingles
  - ZVL (Zostavax)
  - RZV (Shingrix)
- Smallpox
  - Vaccinia (ACAM2000):
- Tetanus
  - DTaP (Daptacel, Infanrix)
  - Td (Tenivac, generic)
  - DT (-generic-)
  - Tdap (Adacel, Boostrix)
  - DTaP-IPV (Kinrix, Quadracel)
  - DTaP-HepB-IPV (Pediarix)
  - DTaP-IPV/Hib (Pentacel)
- Tuberculosis
- Typhoid Fever
  - Typhoid Oral (Vivotif)
  - Typhoid Polysaccharide (Typhim Vi)
- Varicella
  - VAR (Varivax)
  - MMRV (ProQuad):
- Yellow Fever
  - YF (YF-Vax)

Table 1. Recommended Adult Immunization Schedule for ages 19 years or older, United States, 2020

Legend

Recommended vaccination for adults who meet age requirement, lack documentation of vaccination, or lack evidence of past infection	Recommended vaccination for adults with an additional risk factor or another indication	Recommended vaccination based on shared clinical decision-making

No recommendation/Not applicable

Vaccine	19-26 years	27-49 years	50-64 years	≥65 years
Influenza inactivated (IIV) or Influenza recombinant (RIV) Flu Blok	1 dose annually			
or Influenza live attenuated (LAIV) Flu Mist		or 1 dose annually		
Tetanus, diphtheria, pertussis (Tdap or Td)	1 dose Tdap, then Td or Tdap booster every 10 yrs			
Measles, mumps, rubella (MMR)	1 or 2 doses depending on indication (if born in 1957 or later)			
Varicella (VAR)	2 doses (if born in 1980 or later)		2 doses	

Zoster recombinant (RZV) (preferred) Shingrix			2 doses	
or Zoster live (ZVL)				or 1 dose
Human papillomavirus (HPV)	2 or 3 doses depending on age at initial vaccination or condition	27 through 45 years		
Pneumococcal conjugate (PCV13)	1 dose			65 years and older
Pneumococcal polysaccharide (PPSV23)	1 or 2 doses depending on indication			1 dose
Hepatitis A (HepA)	2 or 3 doses depending on vaccine			
Hepatitis B (HepB)	2 or 3 doses depending on vaccine			
Meningococcal A, C, W, Y (MenACWY)	1 or 2 doses depending on indication, see notes for booster recommendations			
Meningococcal B (MenB)	2 or 3 doses depending on vaccine and indication, see notes for booster recommendations			
	19 through 23 years			
Haemophilus influenzae type b (Hib)	1 or 3 doses depending on indication			

Travelers Health

Destinations (245)

Chad
Traveler View

Healthy Travel Packing List

Chad
Clinician View

Find a Clinic

Travel Notices

Travel Advice and Resources

Disease Directory

Yellow Book

Frequently Asked Questions

Chad
Traveler View

Clinician View

Travel Health Notices

Hide

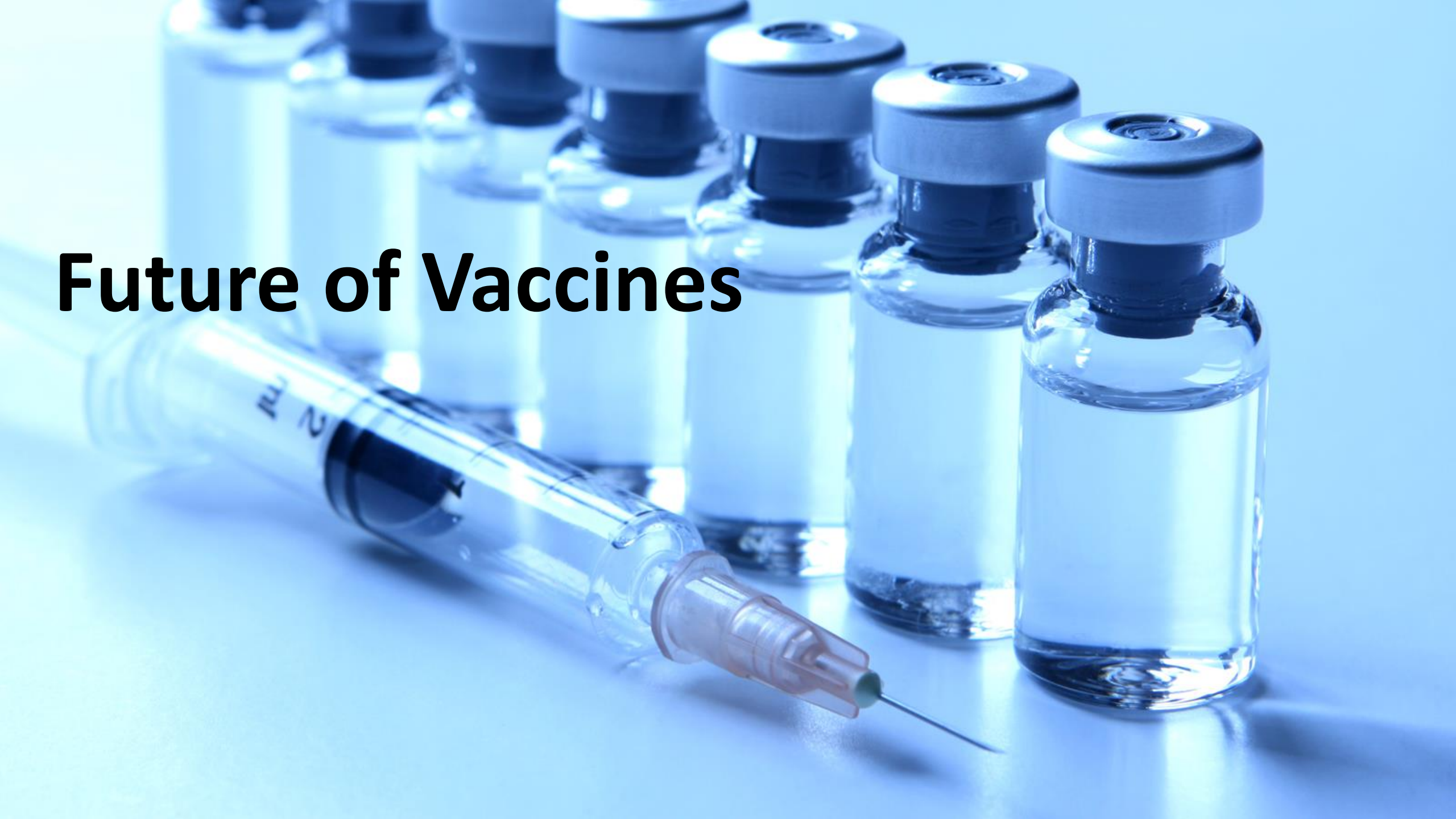
Be aware of current health issues in Chad. Learn how to protect yourself.

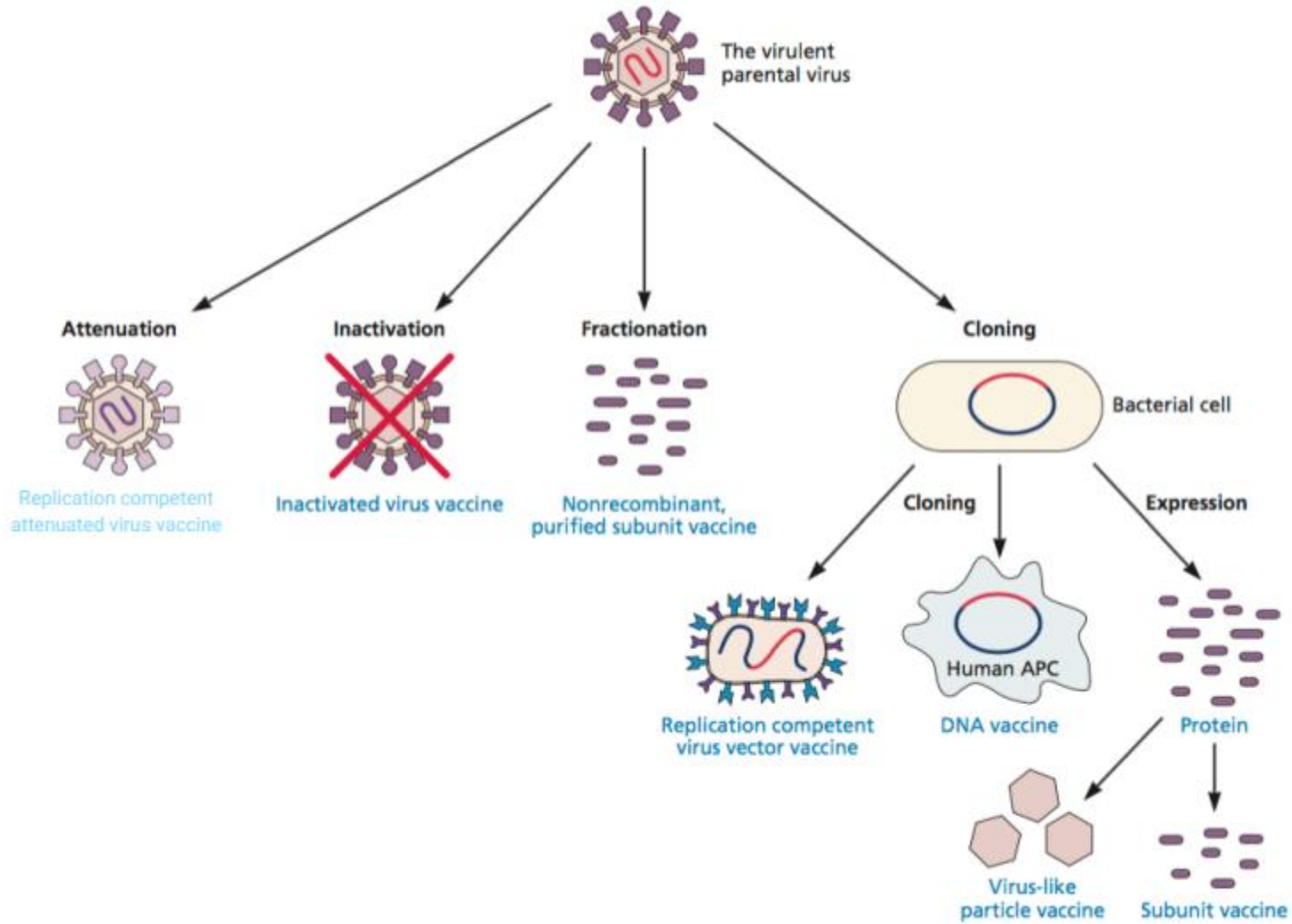
Other Destinations

Where are you going?

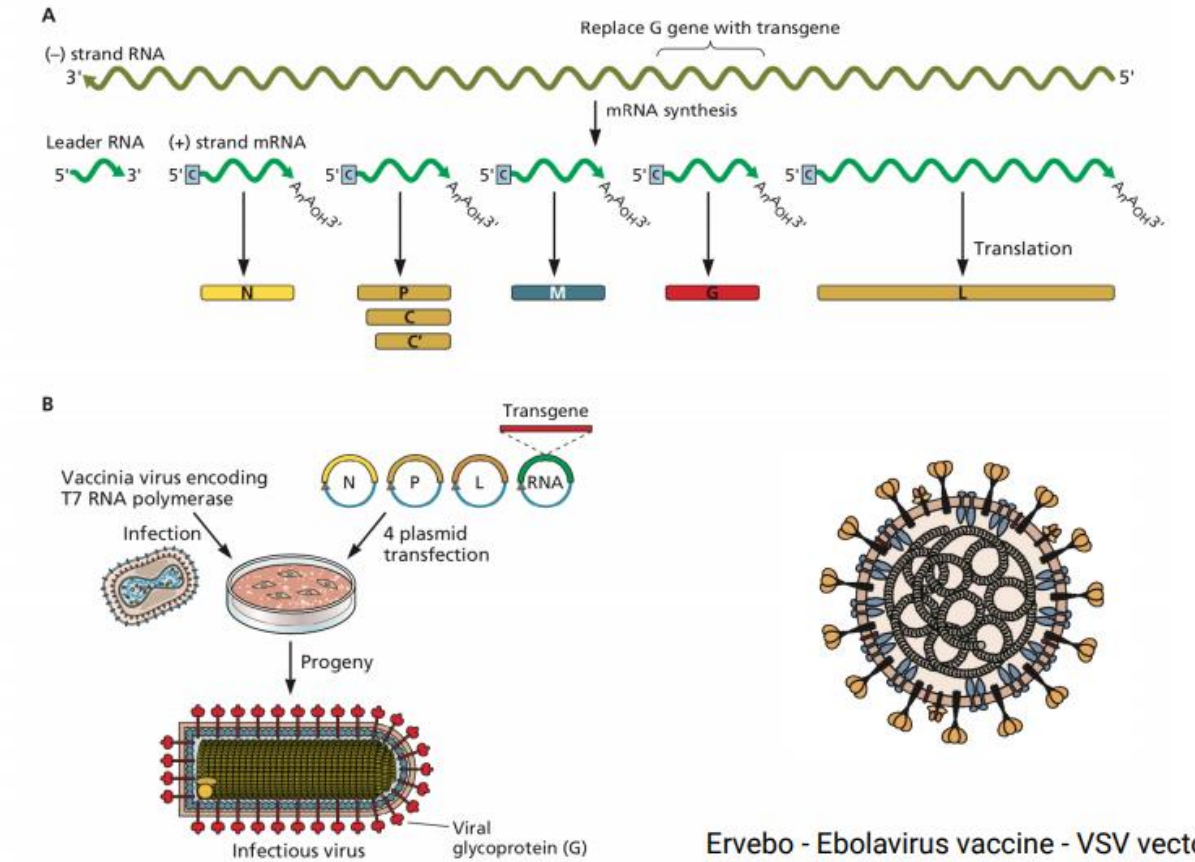
Chad

Future of Vaccines




The virulent parental virus
Attenuation
Inactivation
Fractionation
Cloning
Bacterial cell
Cloning
Expression
Replication competent attenuated virus vaccine
Inactivated virus vaccine
Nonrecombinant, purified subunit vaccine
Replication competent virus vector vaccine
Human APC
DNA vaccine
Protein
Virus-like particle vaccine
Subunit vaccine

Vesicular stomatitis virus vaccine vector



Ervebo - Ebolavirus vaccine - VSV vector

SARS-CoV-2 virus vaccines (62)

Codon deoptimized
Attenuated

Attenuation

Replication competent
natural virus vaccine

Formalin
inactivation

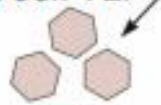
Inactivation

Inactivated virus vaccine

Cloning

Expression

Insect cell VLP
Plant cell VLP



Virus-like
particle vaccine

Subunit vaccine

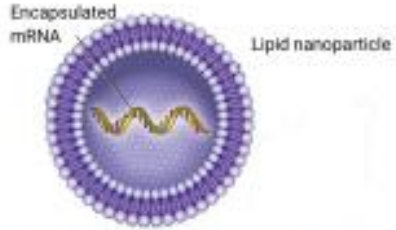
Subunit (20)

Cloning

Cloning

Replication competent
virus vector vaccine

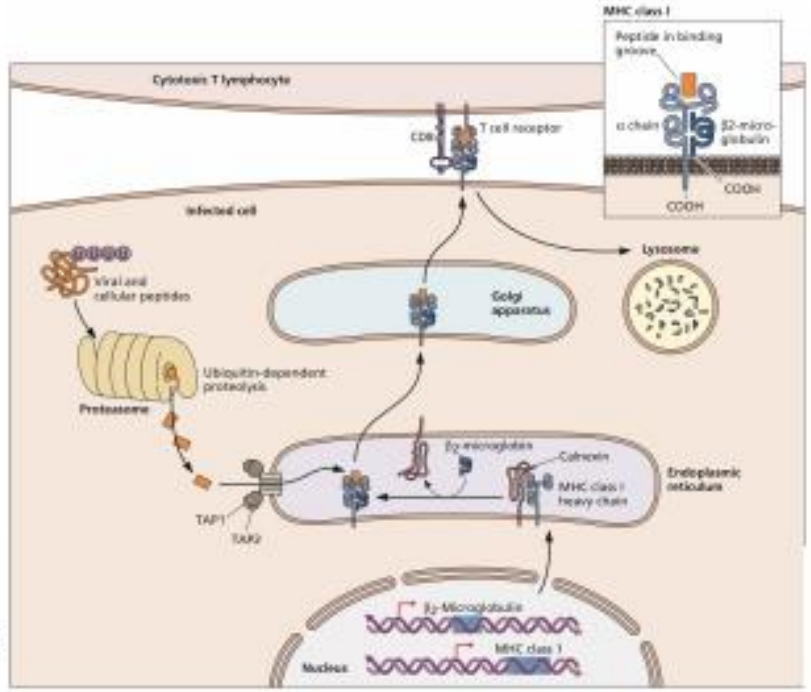
Vectored vaccine
Adenovirus (5)
Influenza virus
Vaccinia virus
Measles virus
Horsepox virus



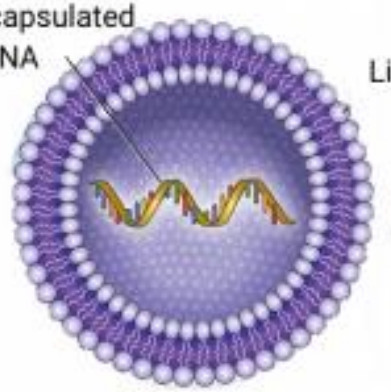
mRNA vaccine (12)
DNA vaccine (3)

https://milkeninstitute.org/covid-19-tracker

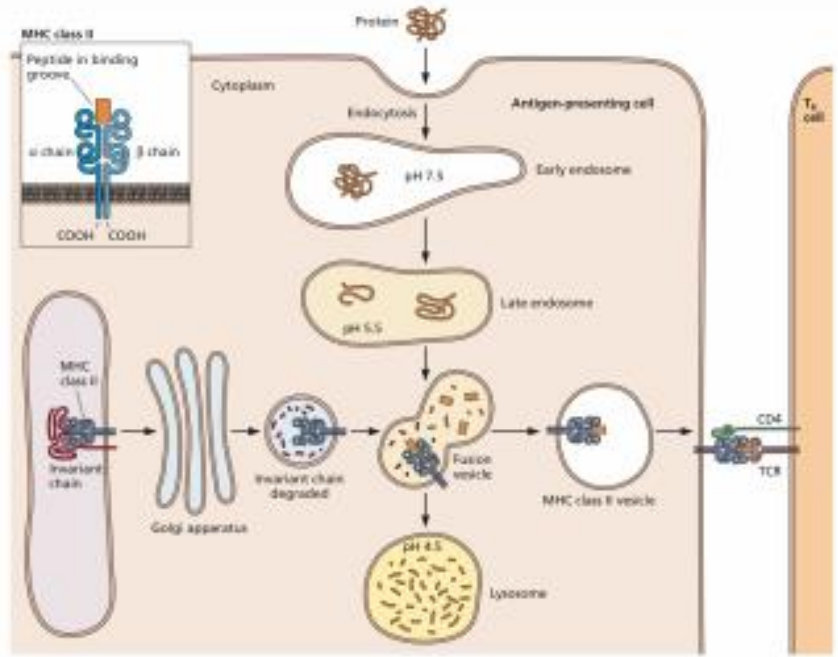
SARS-CoV-2 mRNA vaccine

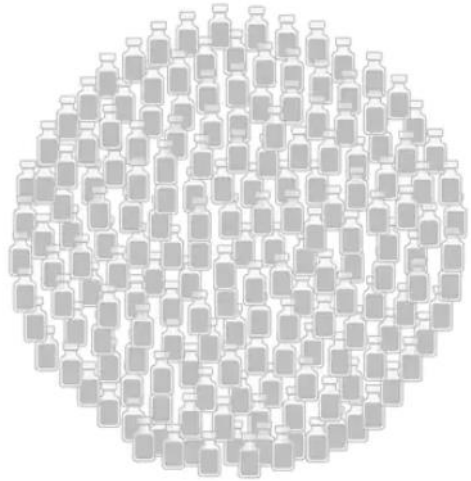


Encapsulated mRNA



Lipid nanoparticle





Vaccines sorted by how far they have progressed

170+ vaccines
are being tested in animals and lab experiments

*Gamaleya Research Institute**

7 vaccines
are being tested in a small number of healthy, young people to assess safety and correct dose

12 vaccines
are broadened to a larger group of people, including people at higher risk of illness

AstraZeneca; University of Oxford

Moderna; National Institutes of Health

*CanSino Biologics; Beijing Institute of Biotechnology**

7 vaccines
are being tested in thousands of people to check their effectiveness and safety

0 vaccines
have been determined to provide benefits that outweigh known and potential risks

**Vaccine currently in distribution that has not been fully tested.*

https://www.washingtonpost.com/politics/2020/09/08/health-202-most-americans-wont-be-allowed-get-coronavirus-vaccine-soon-it-approved/?hpid=hp_hp-top-table-main_health202-vaccine-815am%3Ahomepage%2Fstory-ans

Vaccine Product Approval Process

The U.S. Food and Drug Administration's (FDA's) Center for Biologics Evaluation and Research (CBER) is responsible for regulating vaccines in the United States.

The sponsor of a new vaccine product follows a multi-step approval process, which typically includes

- An Investigational New Drug application
- Pre-licensure vaccine clinical trials
- A Biologics License Application (BLA)
- Inspection of the manufacturing facility
- Presentation of findings to FDA's Vaccines and Related Biological Products Advisory Committee (VRBPAC)
- Usability testing of product labeling

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https://www.cdc.gov/vaccines/basics/test-approve.html

Vaccine Clinical Trials

Phase 1 – Safety & Immunogenicity
Small number of people, monitored

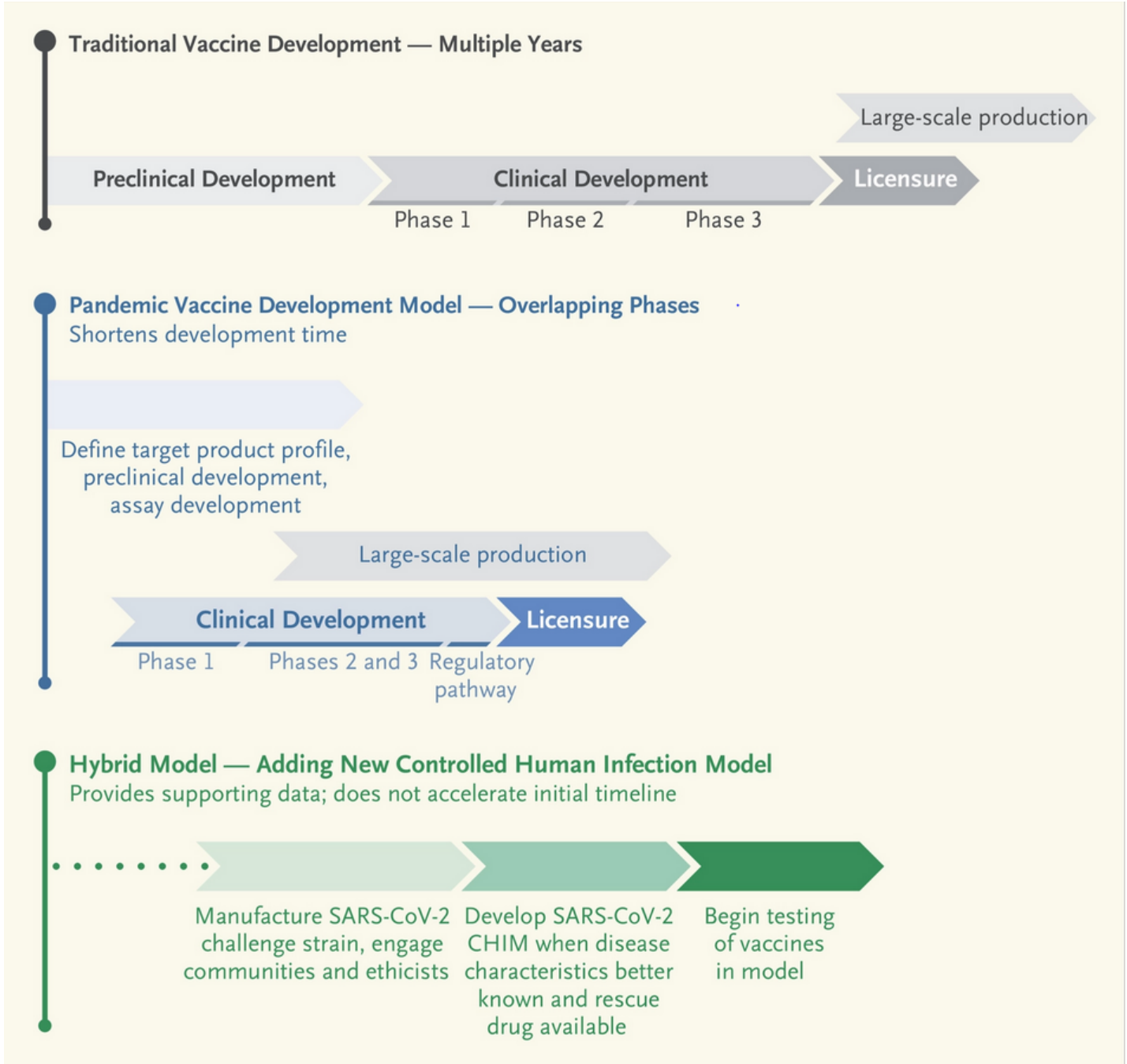
Phase 2 – Dose ranging
Hundreds of subjects

Phase 3 – Effectiveness & more safety
Thousands of subjects

Enhancing Public Trust and Health with COVID-19 Vaccination

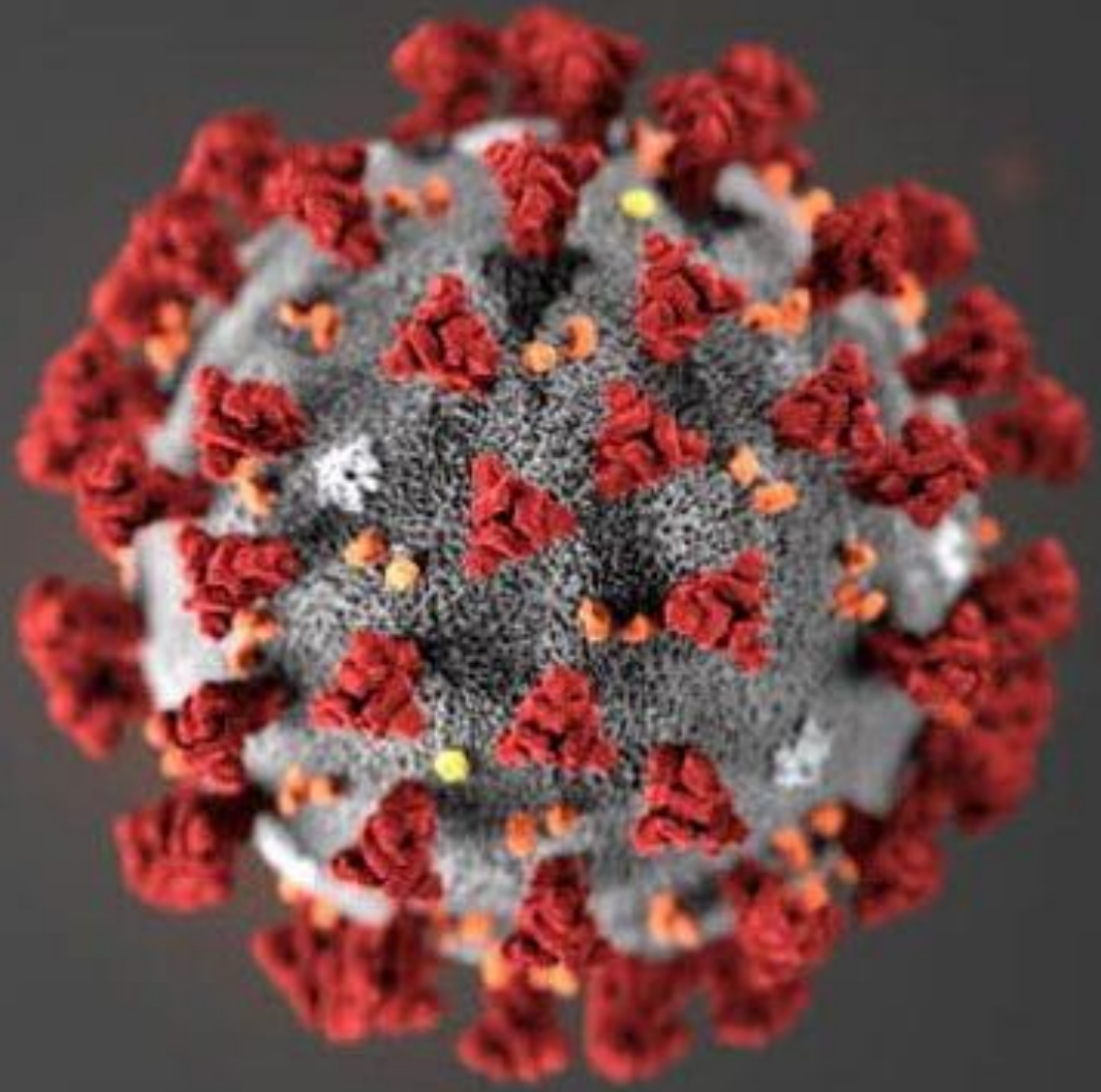
Why "If We Build It/They Will Come" May Not Apply to Humans and Vaccines and What Can Be Done About It

https://www.jhsph.edu/covid-19/articles/enhancing-public-trust-and-health-with-covid-19-vaccination.html



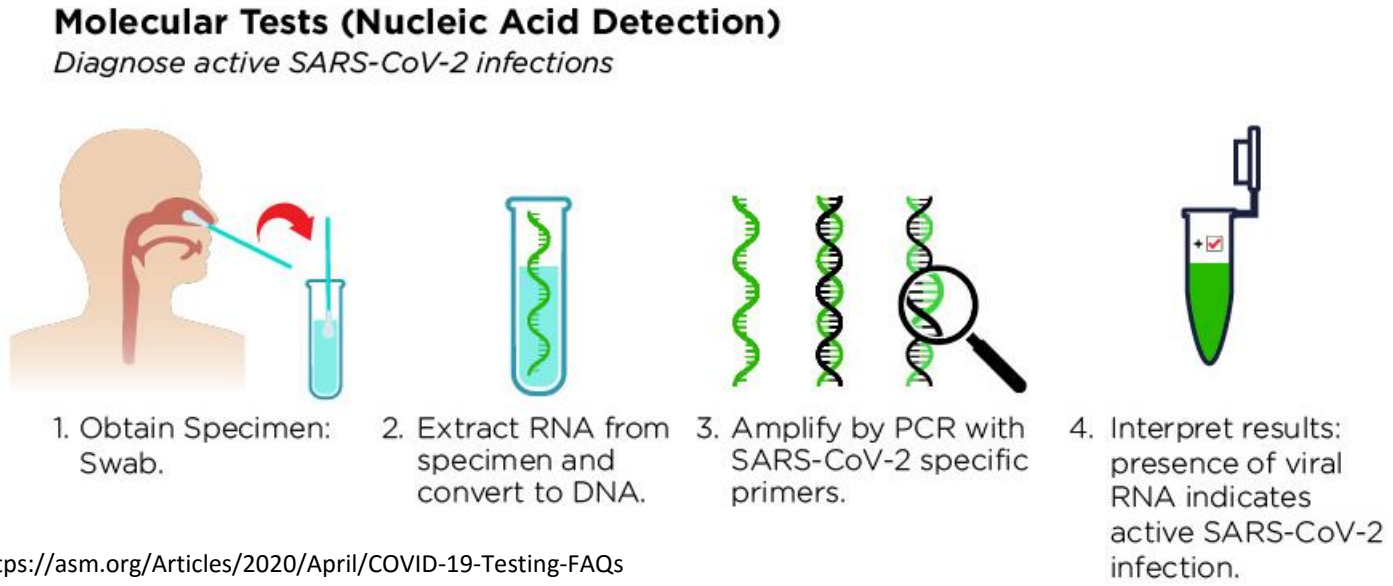
https://www.nejm.org/doi/full/10.1056/NEJMp2020076

COVID Testing

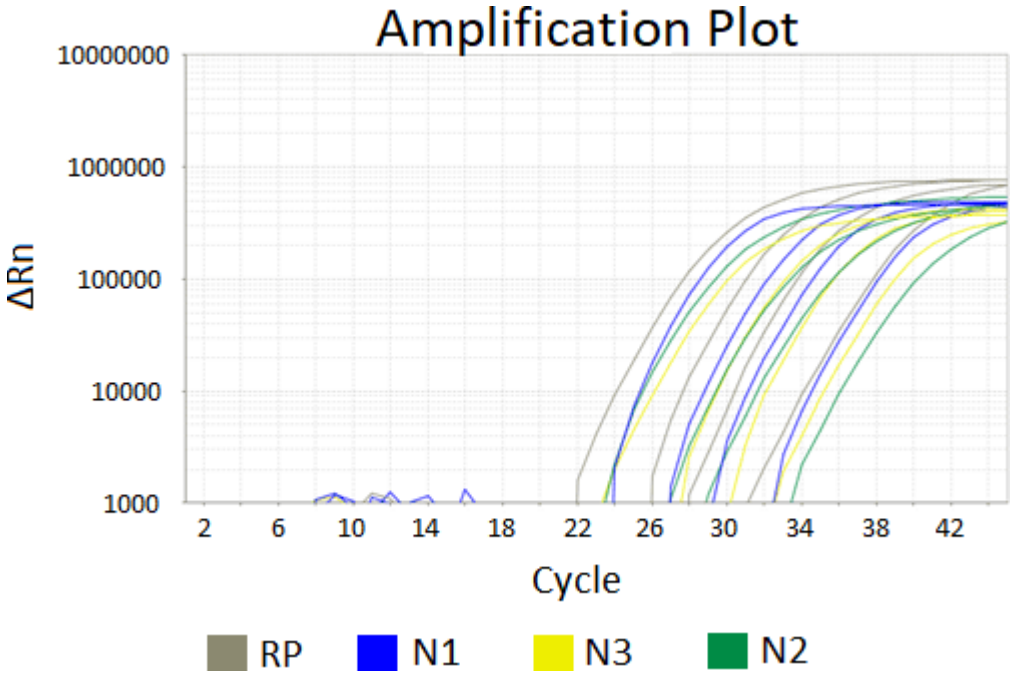


PCR Test

- “Tickle your brain” test – nasopharyngeal swab/nasal swab
- Takes time to process – 2-5 days
- Copies RNA from the virus into DNA
- Makes many, many copies



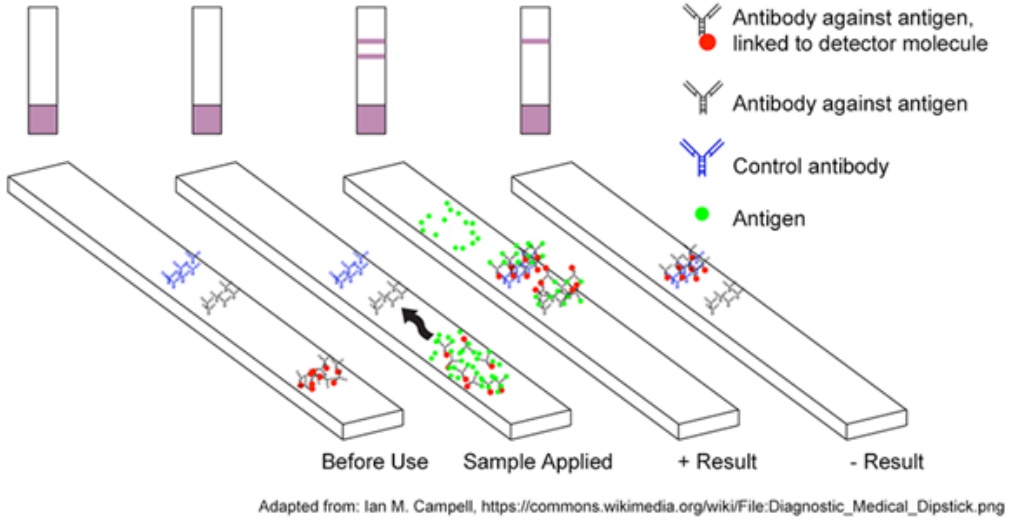
https://asm.org/Articles/2020/April/COVID-19-Testing-FAQs



https://www.raybiotech.com/covid-19-rt-pcr/

Rapid Antigen Test (Ag test)

- Nasal swab or saliva
- Takes about 15 min. to process
- Detects pieces of the virus
- Not as sensitive as PCR – false negatives



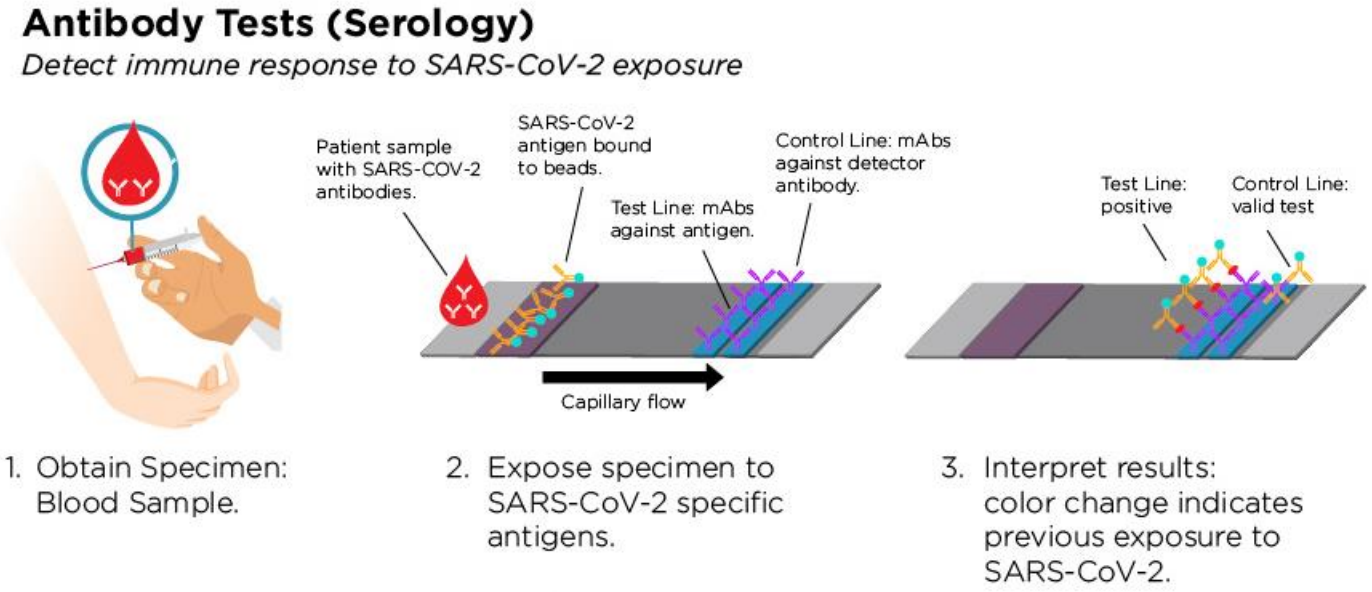
Adapted from: Ian M. Campell, https://commons.wikimedia.org/wiki/File:Diagnostic_Medical_Dipstick.png

https://asm.org/Articles/2020/April/COVID-19-Testing-FAQs

https://www.bd.com/en-us/offerings/capabilities/microbiology-solutions/point-of-care-testing/bd-veritor-plus-system-for-rapid-covid-19-sars-cov-2-testing

Antibody Test

- Detects previous exposure
- May indicate immunity, may not
- Detects 2 different kinds of antibodies



https://www.firstpost.com/health/covid-19-testing-how-antibody-antigen-rt-pcr- truenat-tests-differ-their-strengths-and-limitations-8548691.html

https://asm.org/Articles/2020/April/COVID-19-Testing-FAQs

At Home Test

- “Spit test”
  - In a tube, add paper strip, changes color
  - On the paper, changes color
- Basically instant test
- May have issues with sensitivity

https://6abc.com/rutgers-university-saliva-test-covid-19-fda-testing/6166215/

https://www.nytimes.com/2020/07/03/opinion/coronavirus-tests.html


Questions?