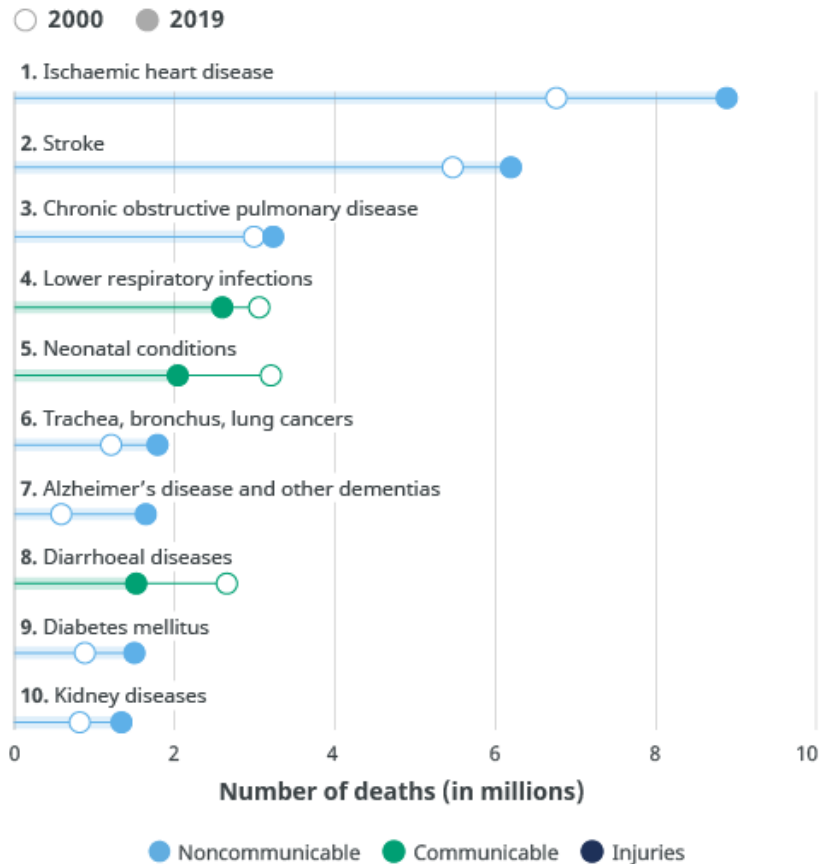


Antiviral therapy and vaccination

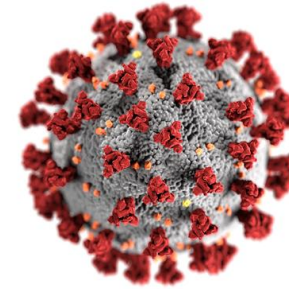
Yannick Brüggemann

Department of Molecular & Medical Virology

Leading causes of death globally



Source: WHO Global Health Estimates.



Illness	Infections	Mortality (year)
Influenza	~5 Mio	~650.000
HIV	39 Mio	~630.000
Diarrhoeal disease (Rota, Adeno....)	1.7 Billion	1.6 Mio
Hepatitis B	296 Mio	820.000
Hepatitis C	58 Mio	290.000

World Health Organization (WHO)

Hygiene etc.



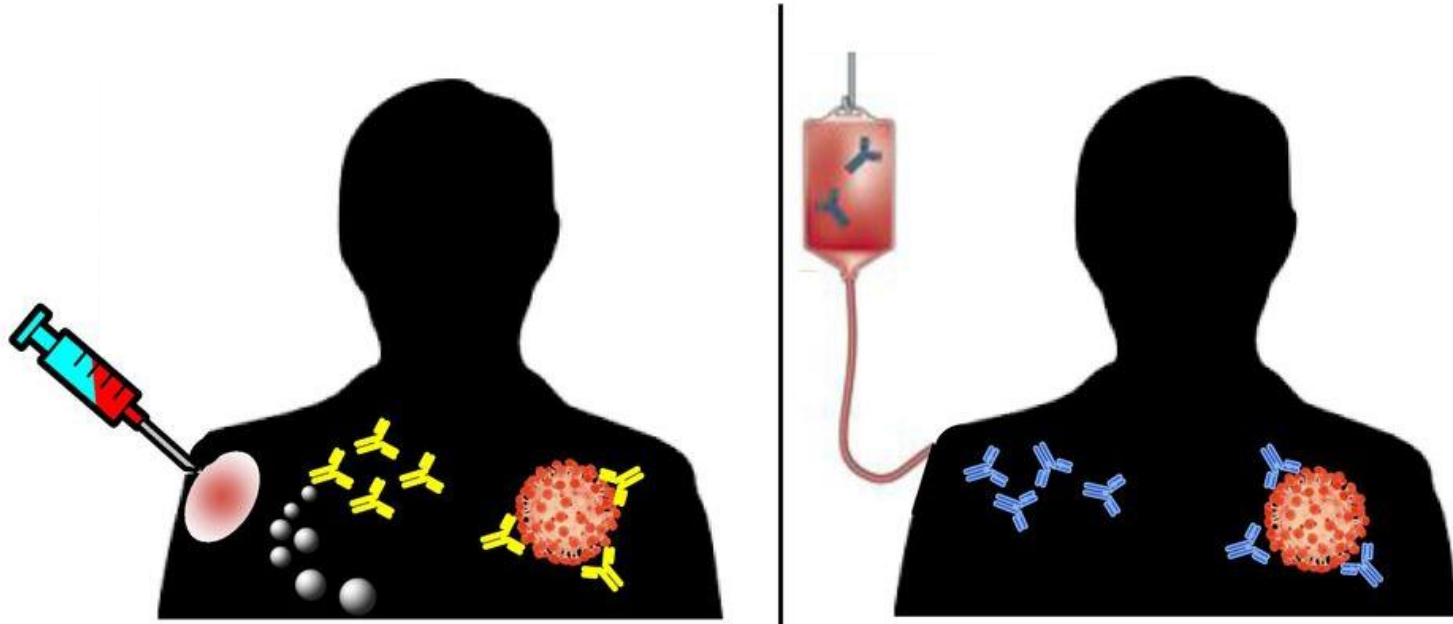
Vaccines



Antiviral drugs



Immunization strategies



Active - modified form of the pathogen – induction of immune response

- ***Long term protection*** after latency (duration variable)

Passive – immune products (antibodies or immune cells)

- ***Short term protection*** (several weeks to 2-3 months)

Maternal passive immunity

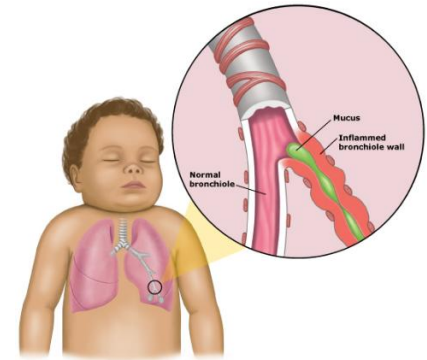


RSV vaccination



Emergency/preventive measure:

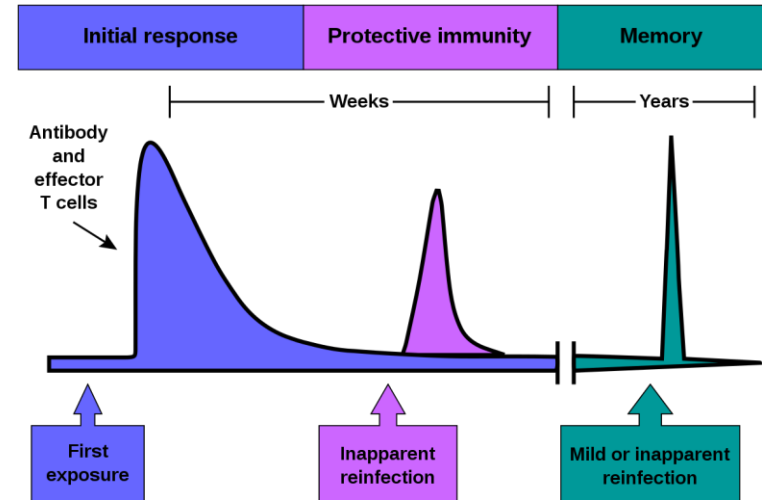
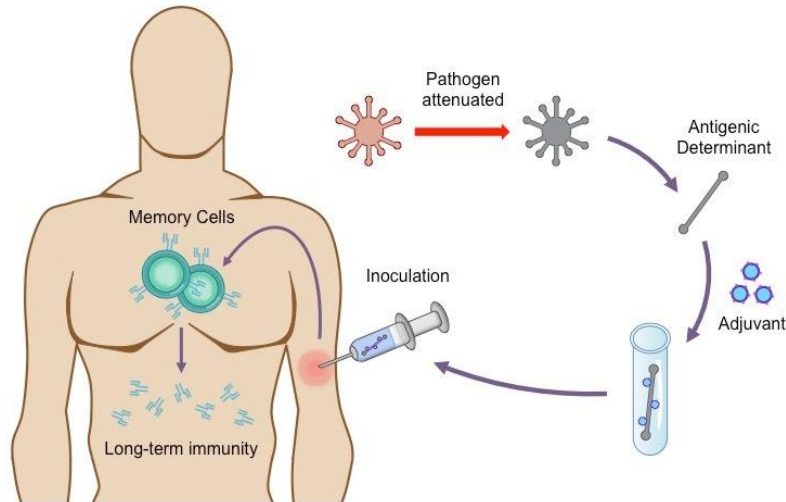
RSV: Prophylaxis with nirsevimab in high-risk groups



Simultaneous vaccination (active + passive) following acute exposure:
Rabies virus; Hepatitis A/B; Tetanus



Active vaccination



Pathogen derived antigens to mobilize host immune system to protect against viral infection or disease (protective immunity).

Establishment of an immune memory (long lived B/T memory cells)

Layers of protection

Individual protection:

Individuals can no longer become (severely) ill

Prevention only possible by individual protection (e.g. FSME; tetanus)

Smallpox



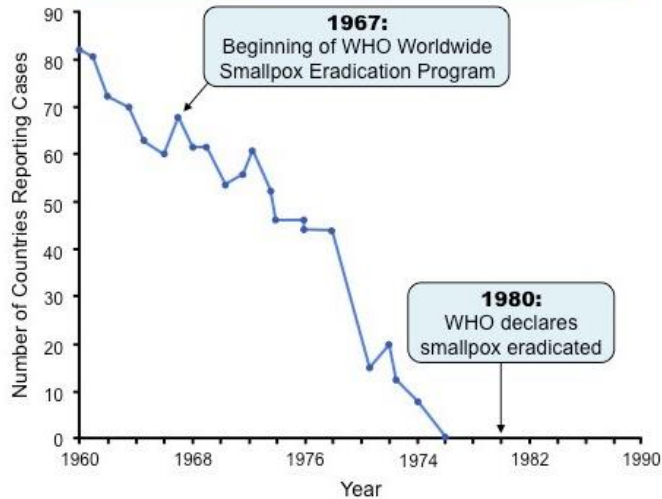
Edward Jenner 1796



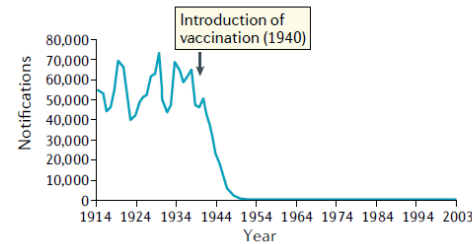
- Variola virus (DNA virus)
- Mortality rate: >30%, >80% in infants
- 300 million deaths during 20th century (eradicated 1980)
- Monkeypox Vaccine



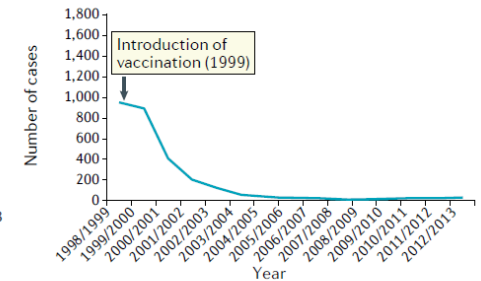
Timeline of the Eradication of Smallpox



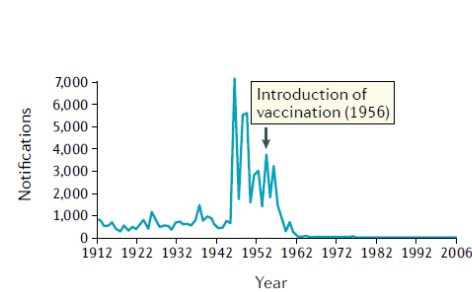
a Diphtheria



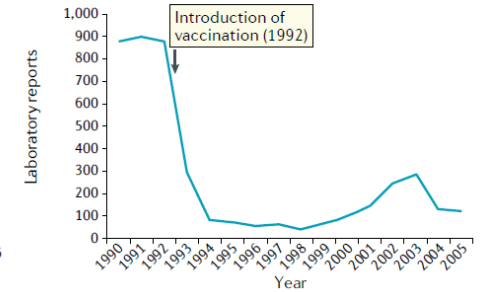
b Capsular group C meningococcus



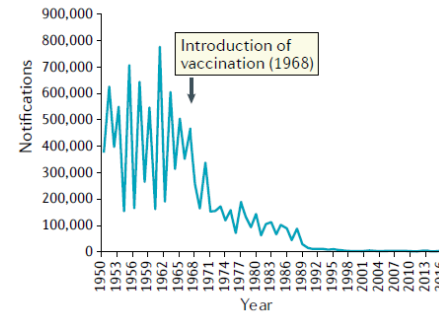
c Polio



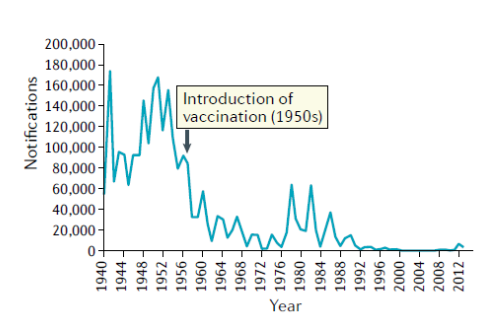
d Haemophilus influenzae type B



e Measles

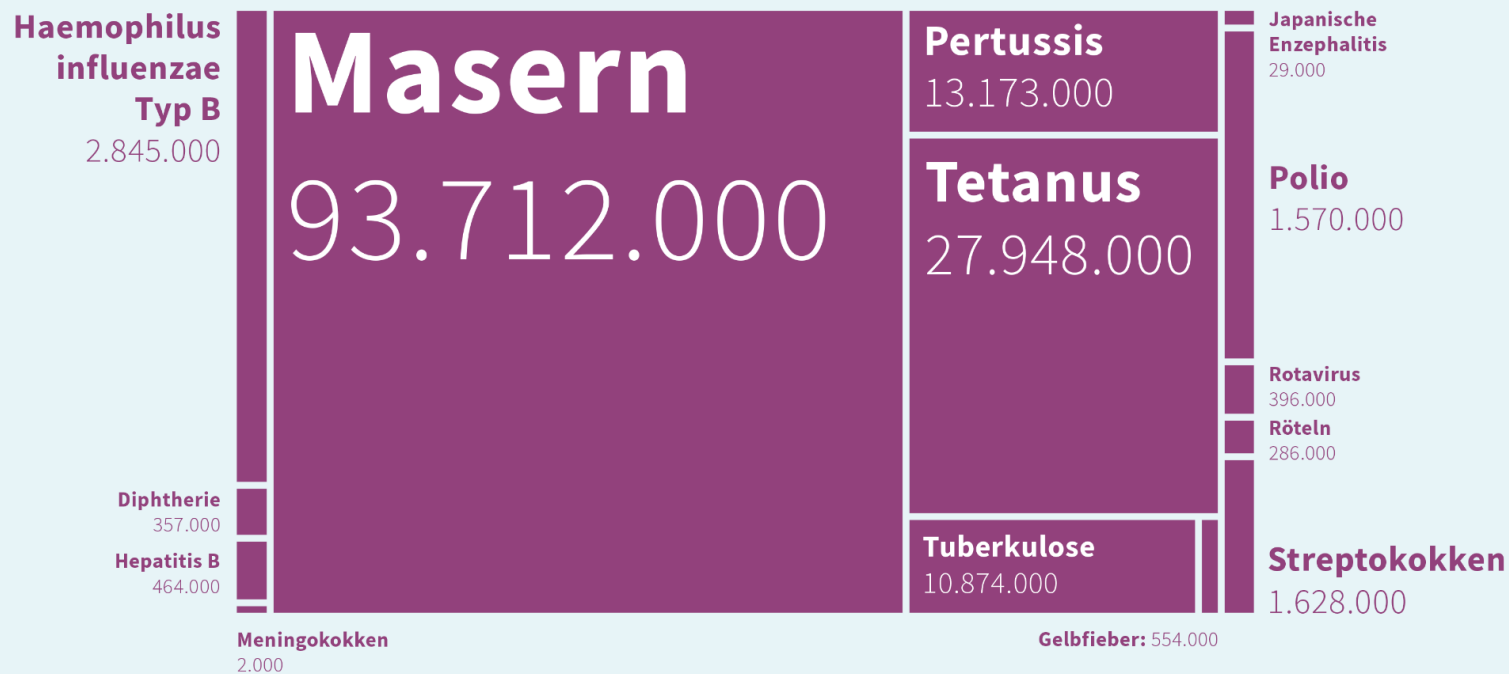


f Pertussis

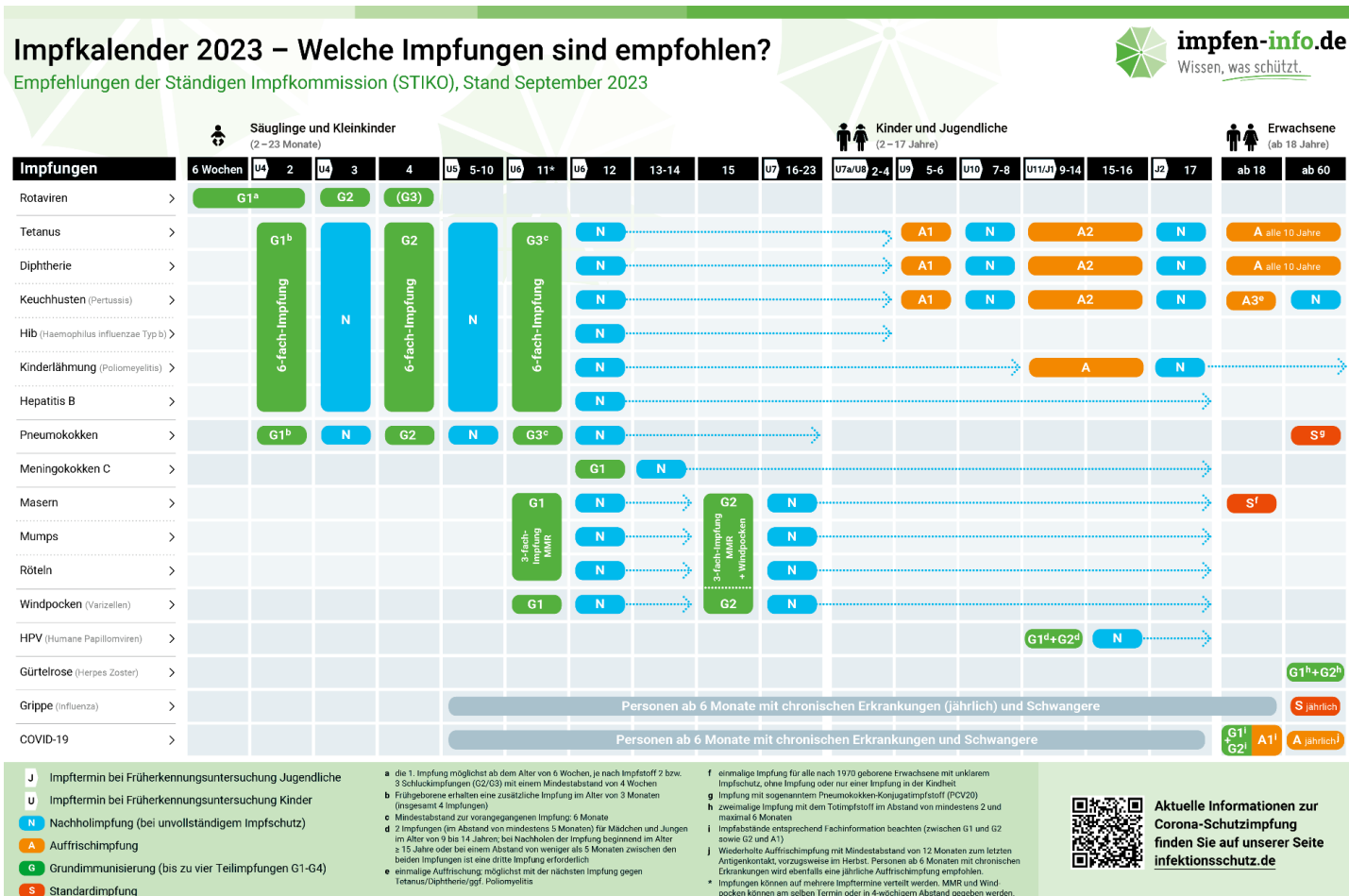


DER EINFLUSS VON IMPFUNGEN WELTWEIT, 1974–2024

Anzahl geretteter Kinderleben durch Impfungen



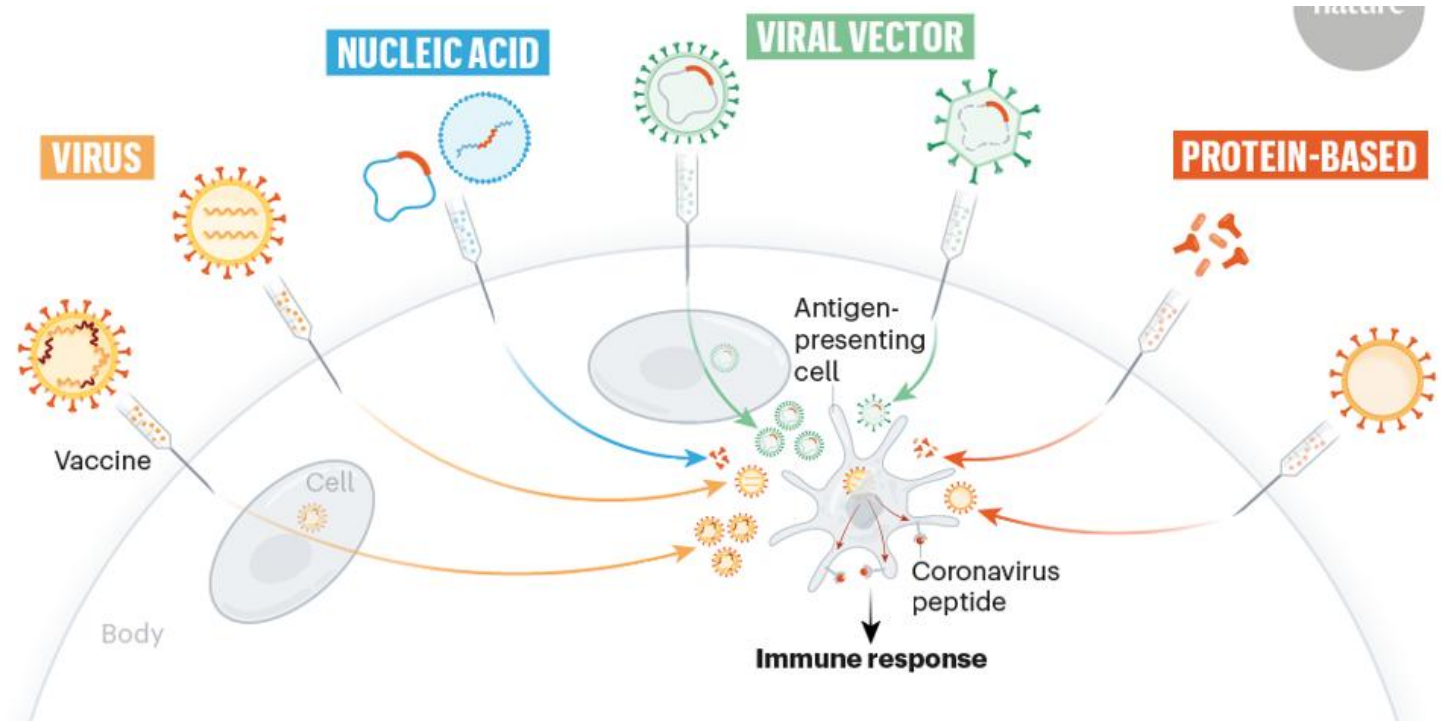
Immunization schedule (STIKO)



Memory depends on vaccine recipient (age etc.), antigen, booster etc.

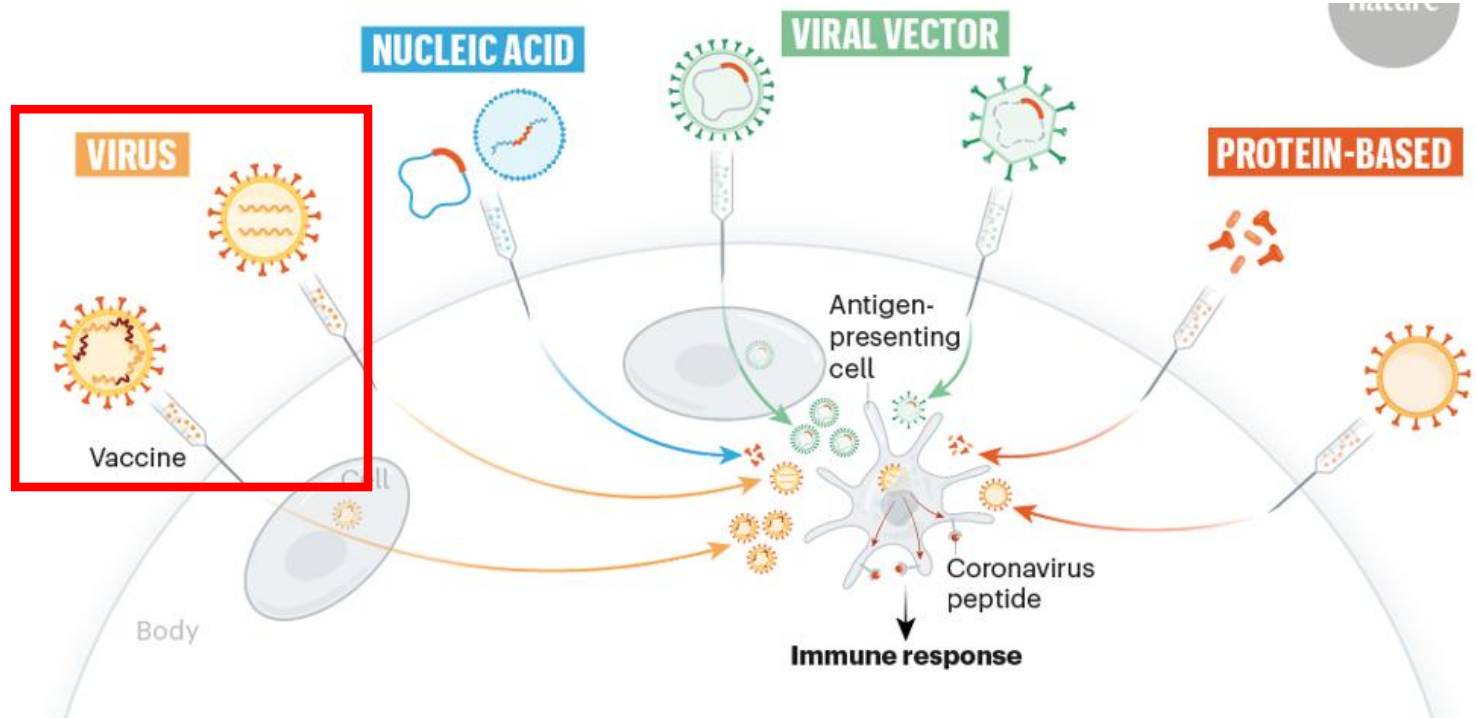
→ Vaccine-dependent administration schedules

Types of vaccines

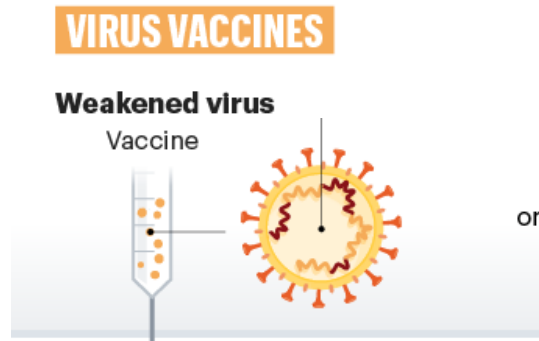


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Types of vaccines



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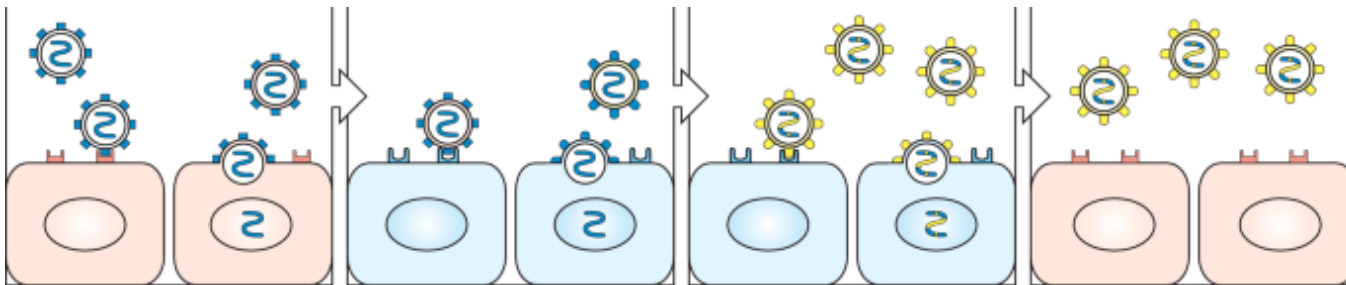


Attenuated virus

- Attenuated viable pathogens
- "Physiological" stimulation of the immune system (long lasting protection)
- Limited use in certain patient groups (immunosuppressed patients)

Mumps, measles, rubella and chickenpox:

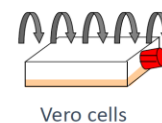
- 3(4)-dose combination vaccine (MMR(V)).
- Attenuated viruses from human cells or embryonic chicken cells
- Contraindications: Immunodeficiency/pregnancy/chicken protein allergy.



Rotavirus

- Attenuated virus from Vero cells
- STIKO recommendation for infants
- Oral vaccination

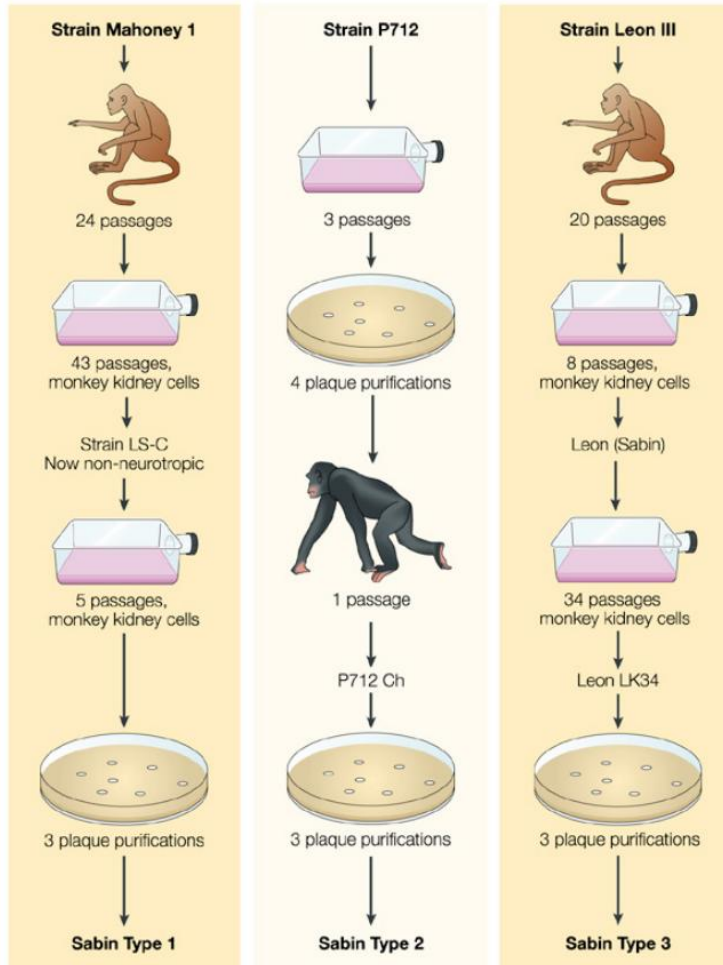
Rotarix®



attenuated strain

2

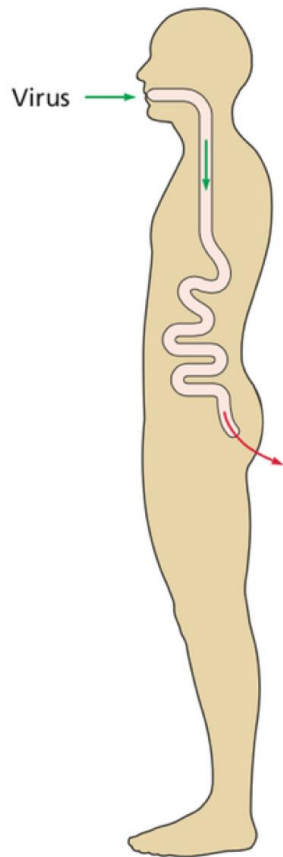




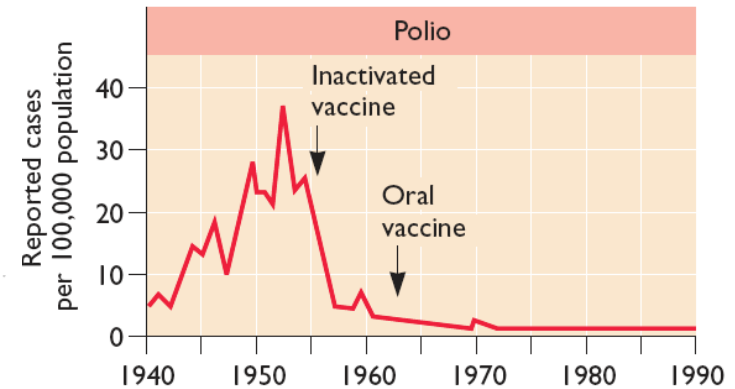
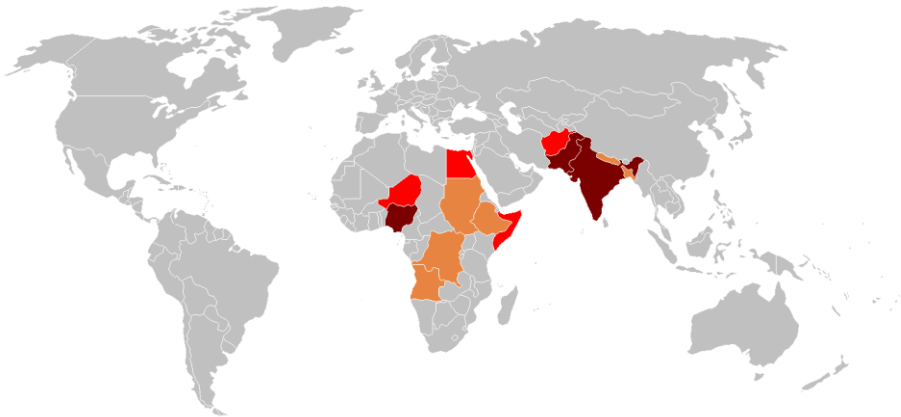
Virus	Mutation
P1/Sabin	5'-UTR nt 480 VP1 aa 1106 VP1 aa 1134 VP3 aa 3225 VP4 aa 4065
P2/Sabin	5'-UTR nt 481 VP1 aa 1143
P3/Sabin	5'-UTR nt 472 VP3 aa 3091



Oral poliovirus vaccine



Vaccine-induced polio if vaccine strains revert (1 in 2.7 million)



Oral polio vaccines (Sabin)

- Attenuated poliovirus types 1, (2) and 3
- Better immune response
- Lower cost, easier to use

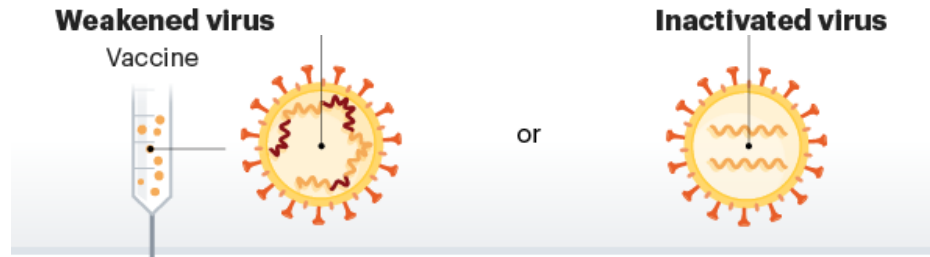
Inactivated poliovirus vaccine (Salk)

- Injection, routinely used
- Inactivation with formaldehyde
- Not STIKO recommended

Live vaccines

Disease	Vaccine type	Administration
Measles, Mumps, Rubella (MMR)	Live vaccine (combination)	Injection
Chickenpox (Varicella)	Live vaccine	Injection
Yellow fever	Live vaccine	Injection
Typhoid	Live vaccine	Oral vaccine
Rotavirus	Live vaccine	Oral vaccine
Polio (formerly)	Live vaccine	Oral vaccine

VIRUS VACCINES

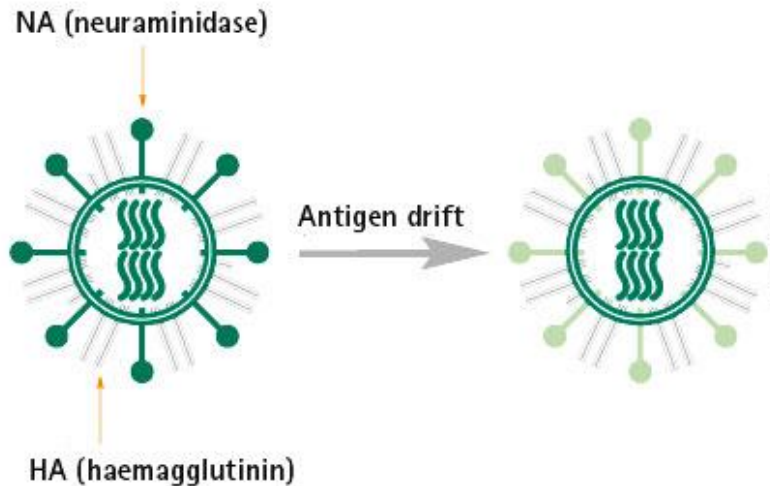


Attenuated virus

- Attenuated viable pathogens
- "Physiological" stimulation of the immune system (long lasting protection)
- Limited use in certain patient groups (immunosuppressed patients)

Inactivated virus

- Chemical inactivation → No danger of infection
- Basic immunization with 2-3 injections
- Adjuvants
- Examples: HAV; Rabies, Polio, Influenza

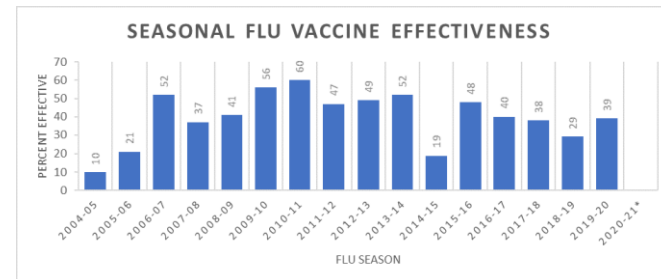


Recommended composition of influenza virus vaccines for use in the 2019-2020 northern hemisphere influenza season

21 February 2019 (updated on 21 March 2019)

It is recommended that egg based quadrivalent vaccines for use in the 2019-2020 northern hemisphere influenza season contain the following:

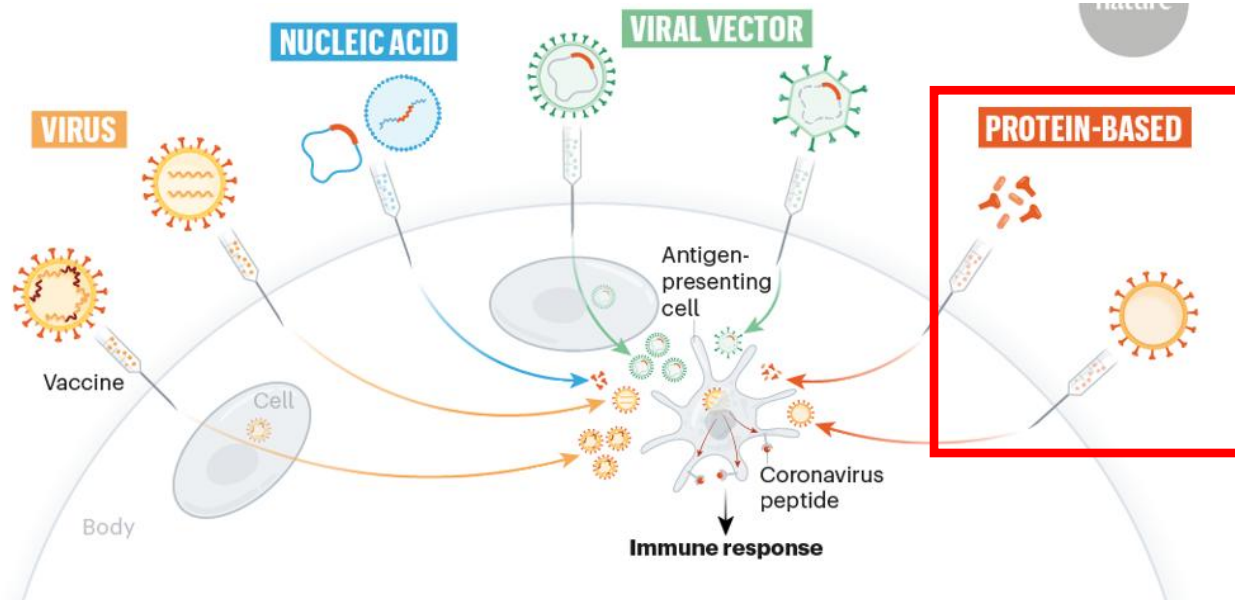
- an A/Brisbane/02/2018 (H1N1)pdm09-like virus;
- an A/Kansas/14/2017 (H3N2)-like virus; *
- a B/Colorado/06/2017-like virus (B/Victoria/2/87 lineage); and
- a B/Phuket/3073/2013-like virus (B/Yamagata/16/88 lineage).



estimates from the U.S. Flu VE Network

- Inactivated virus
 - Envelope proteins continuously change (Antigen Drift)
- Annual adaptation to circulating virus types (variable protection)

Vaccine types

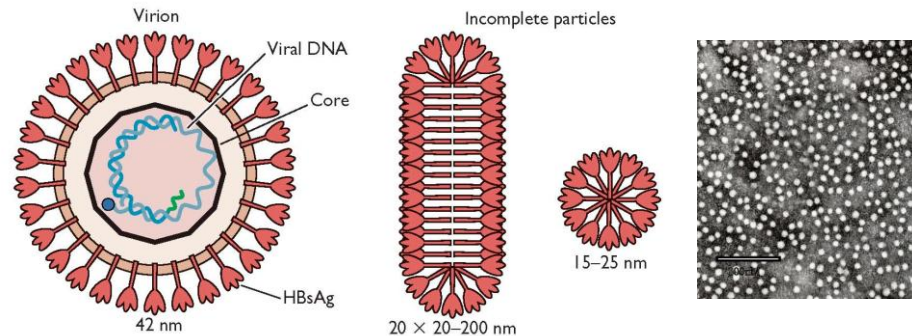


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Subunit vaccines

- Recombinant or purified protein vaccines (No virus cultivation)
- No live components → no risk of the vaccine triggering disease

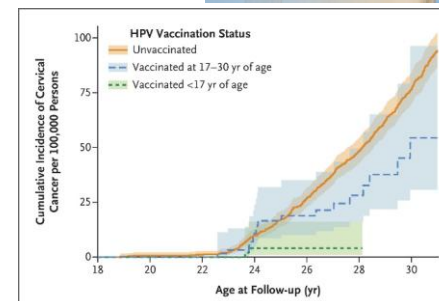
Hepatitis B Virus



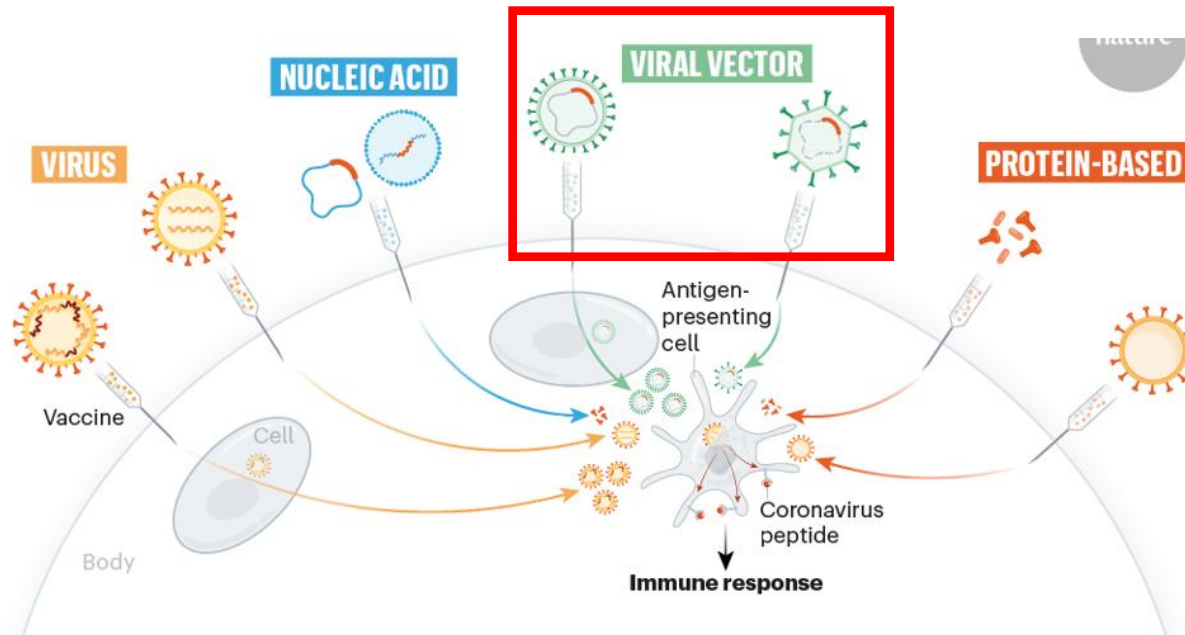
HBsAg produced in yeast → Assembly into empty particles (VLP)

Human papillomaviruses (HPV)

- Capsid of four papillomavirus types
→ empty HPV viral envelopes
- Cancer prevention (cervical cancer)



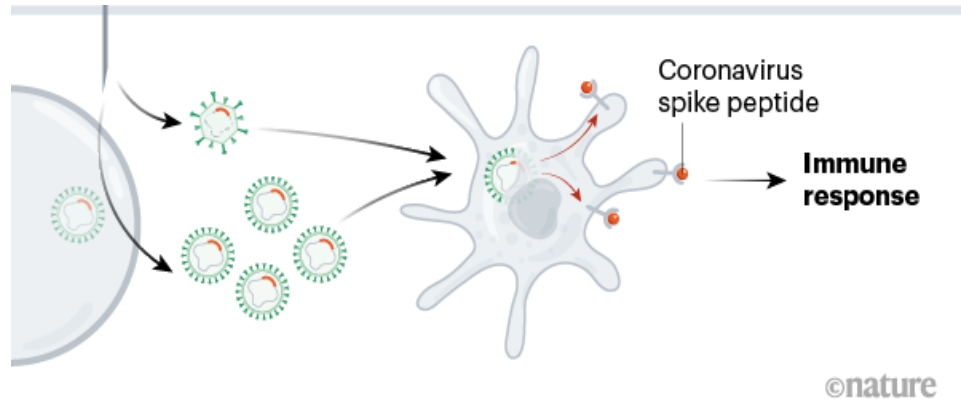
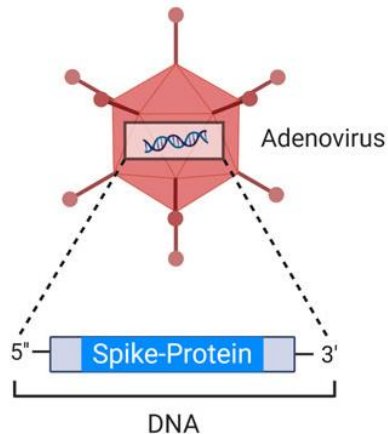
Vaccine types



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Vector vaccines:

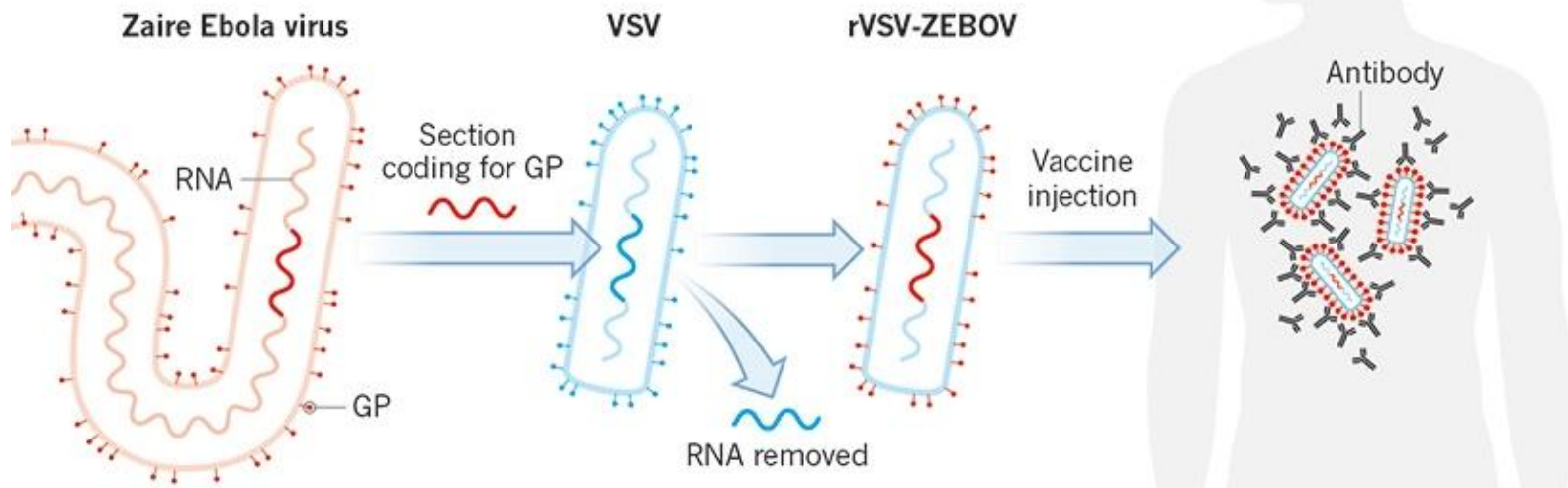
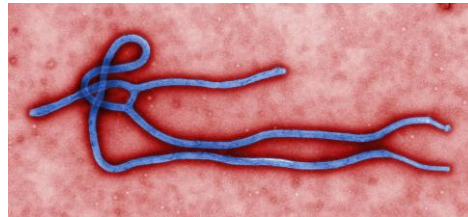
- Recombinant carrier virus encoding for antigen(s) of the target pathogen
- Replicating and non-replicating



©nature

- Ad26.COVS.2.S (Johnson&Johnson)
- Vaxzevria (Astra Zeneca)
- Sputnik V (Russia)
- Adenoviruses with SARS-CoV2 spike (not replication-competent)
- Strong immune response (cellular + humoral).

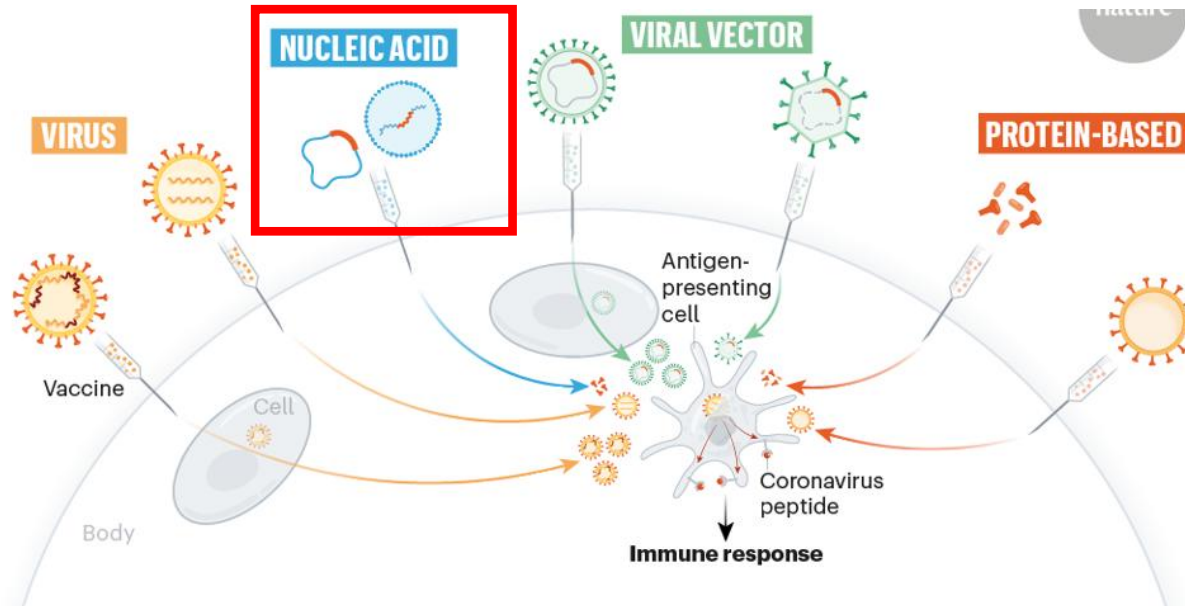
Ebola vector vaccine



rVSV-ZEBOV

- Pseudotyped VSV (common laboratory virus)
- Recombinant, replication-competent vaccine
- Approved in 2019 (highly effective (70-100%))

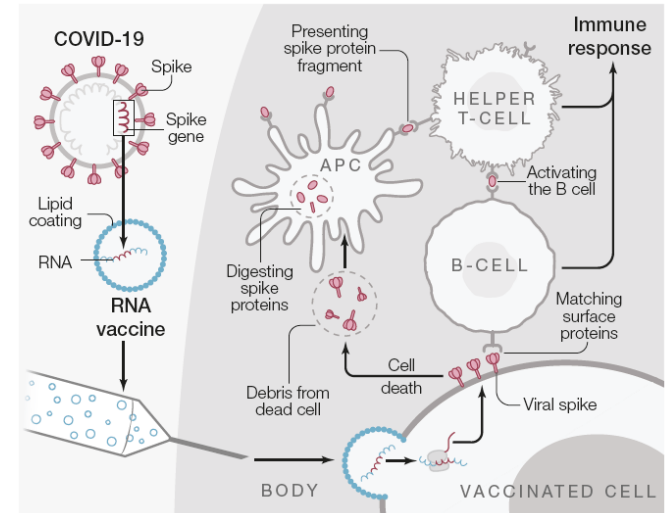
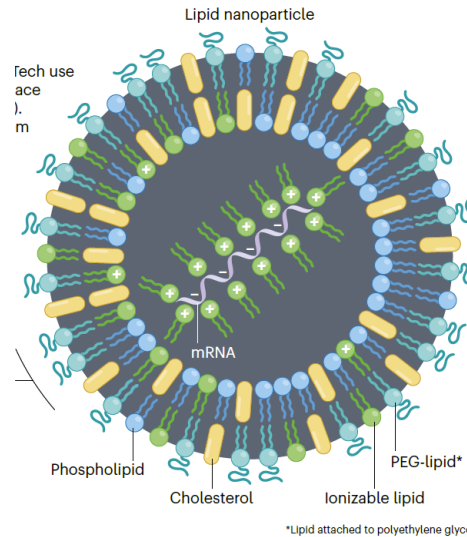
Vaccine types



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Gene-based vaccines:

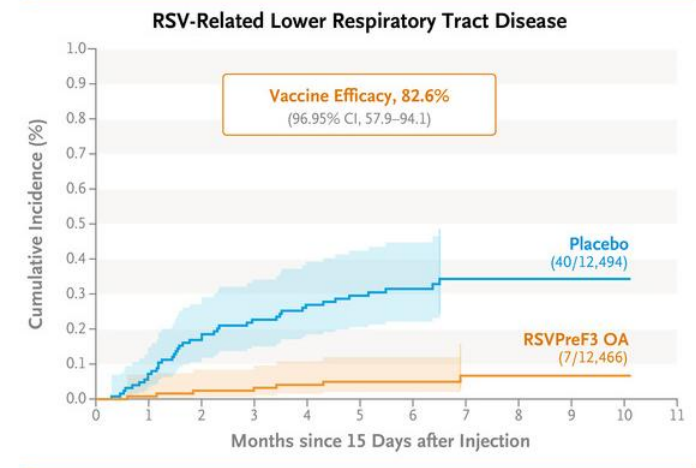
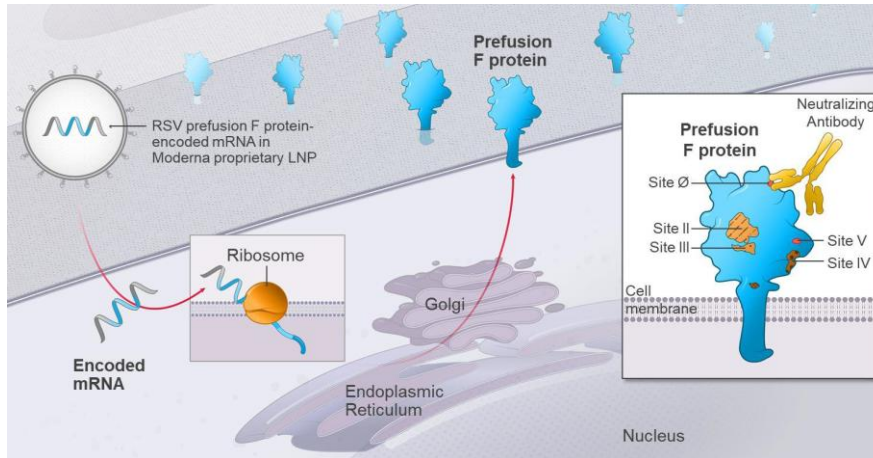
- Genetic information for target antigens of the pathogens (DNA/mRNA)



BNT162b2 (Biontech) and mRNA-1273 (Moderna)

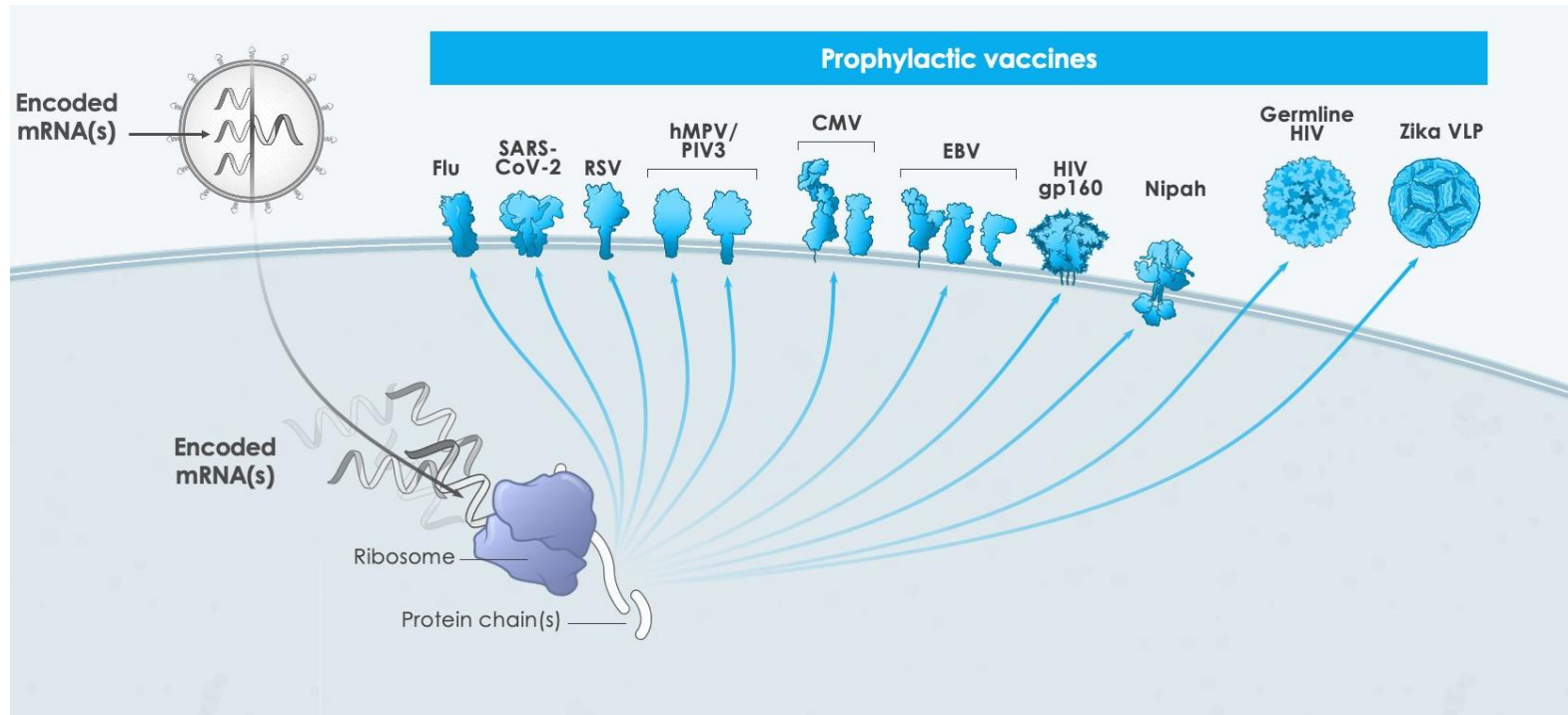
- modRNA-based SARS-CoV-2 vaccine (Spike Glycoproteins).





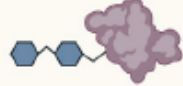
Papi et al. 2023

- Respiratory syncytial virus (RSV)
- FDA approved mRNA vaccine based on prefusion form of F (Key antigen) on May 03, 2023 for people +60
- First attempts since 1966 (formalin-inactivated vaccine)



Types of vaccines

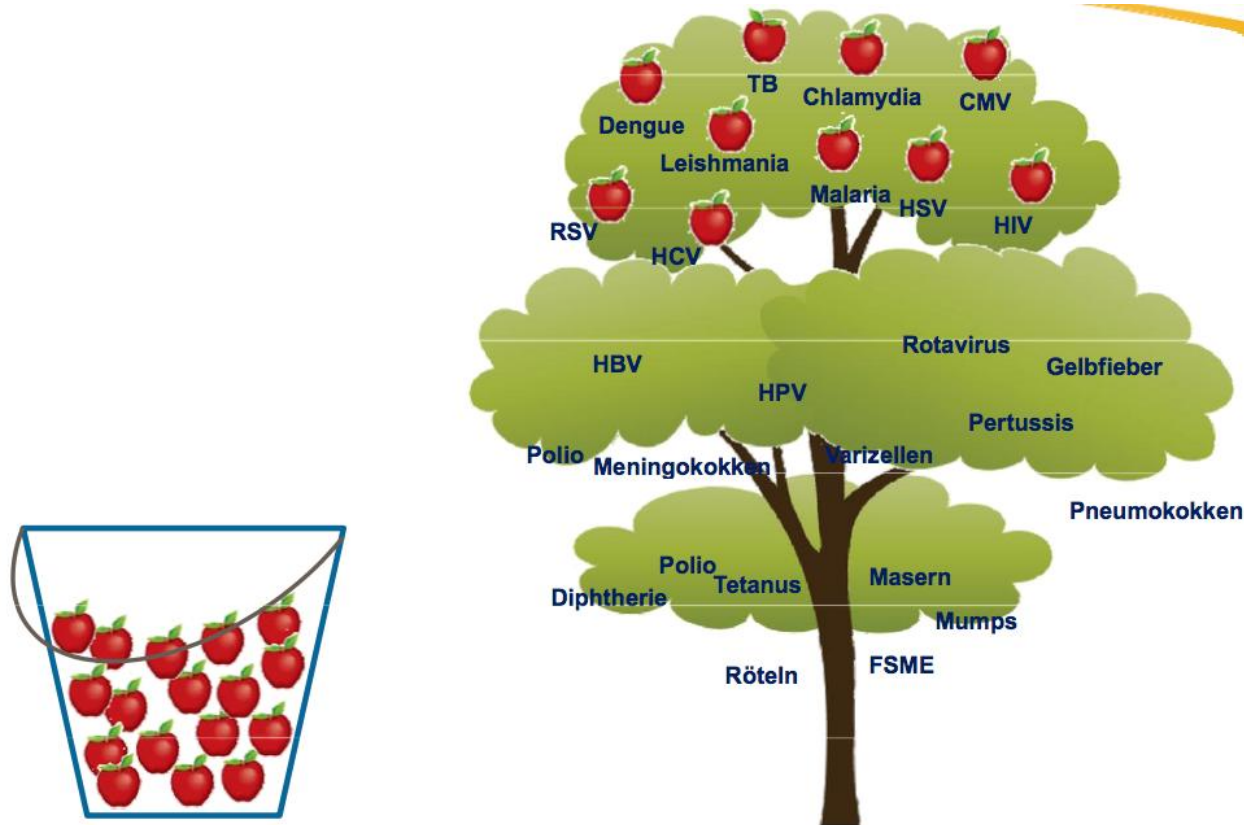
A Licensed for use				
Vaccine type	PAMP	Examples (route if not IM/ID)	Adjuvant	Booster
Live attenuated 	Endogenous 	Measles Mumps Rubella Rotavirus (oral) Yellow Fever Chicken pox Polio Sabin (oral) Live zoster BCG Influenza (nasal: FluMist)	None None None None None None None None None None	Yes Yes Yes Yes No Yes Yes No No Annual
Killed 	Intrinsic 	Whole cell pertussis Polio Salk	None None	Yes Yes
Split 	Intrinsic 	Seasonal influenza Fluad for > 65 yr.	None MF59	Annual Annual

A Licensed for use				
Vaccine type	PAMP	Examples (route if not IM/ID)	Adjuvant	Booster
Virus like particles 	Incorporated*	HPV Guardasil 9 HPV Cervarix	Alum AS04	Yes Yes
Toxoid 	None	Diphtheria Tetanus	Alum Alum	Yes Yes
Recombinant subunit 	None	Hep A Havrix Hep A Vaqta Hep B Engerix-B Hep B Recombivax HepA/Hep B Twinrix Hep B Heplisav-B Acellular pertussis Zoster Shingrix Influenza Flublock	Alum Alum Alum Alum Alum CpG Alum AS01B None	Yes Yes Yes Yes Yes Yes Yes Yes Annual
Conjugate 	None	MenB Bexsero MenB Trumenba Pneumococcal Prevnar 13 HiB	Alum Alum Alum Alum	Yes Yes Yes Yes
Polysaccharide 	None	Pneumococcal polysaccharide PPSV23	None	Yes

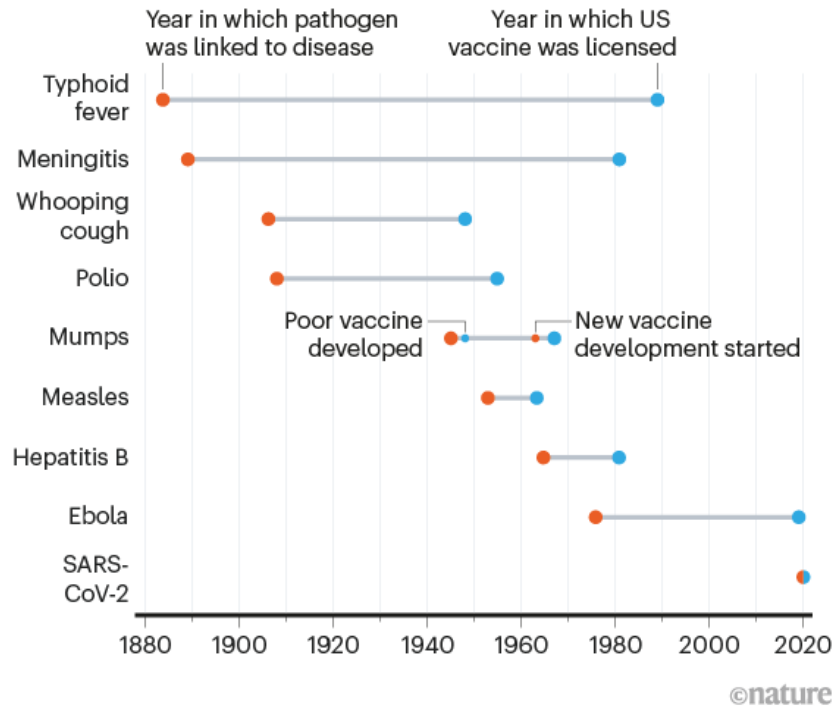


[https://individuelle-
impfentscheidung.de/standp
unkte/podcasts.html](https://individuelle-impfentscheidung.de/standpunkte/podcasts.html)

Vaccine development



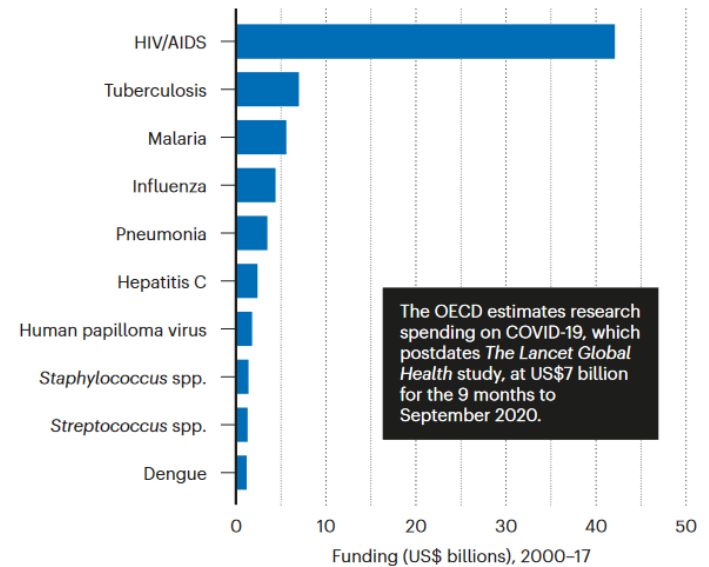
- Vaccines for approximately 30 pathogens available



WHICH DISEASES GET THE MOST RESEARCH FUNDING?

In 2000–17, HIV/AIDS received six times more funding than tuberculosis, according to a 2020 study in *The Lancet Global Health*. The study examined grants made for infectious-disease research from public and philanthropic funders in G20 countries.

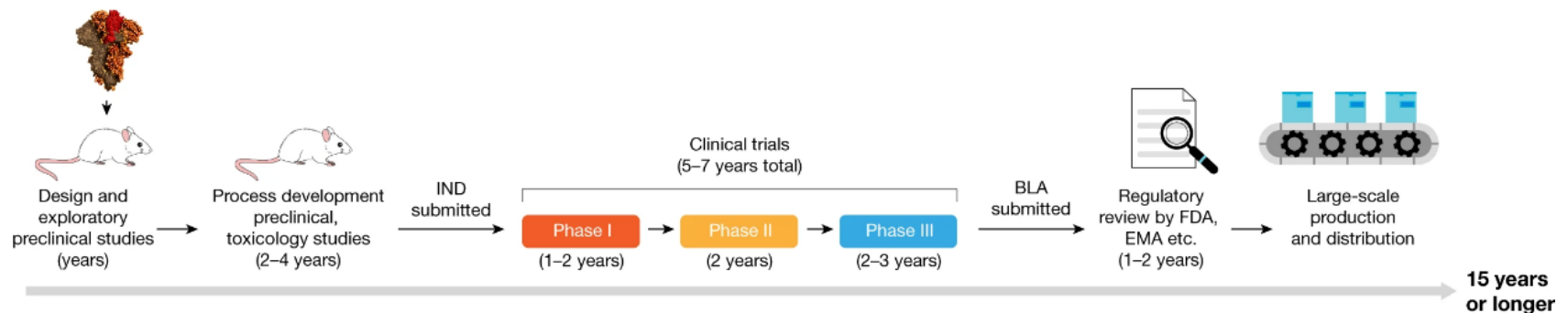
Top 10 Infectious diseases tracked by funding

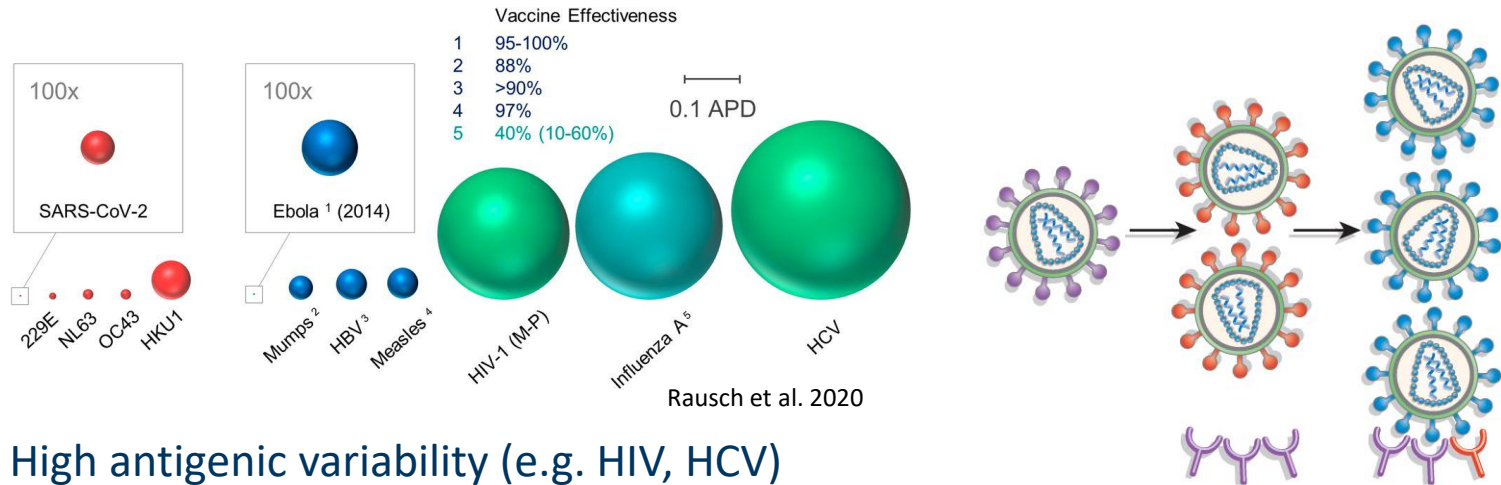


Requirements of an effective vaccine:

- 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)
- Safety: no disease, minimal side effects
- Protection must be long-lasting
- Genetic stability
- Ideally: Low cost, easy to store/deliver (oral vs. needle)

Traditional development





HIV Vaccine trials

Vaccine	Trial	1998 – 2001	2002 – 2005	2006 – 2009	2010 – 2013	2014 – 2017	2018 – 2021
Bivalent gp120	VAX 004: AIDSVAX B/B in alum, US, discordant couples, age 18–60						
	VAX 003: AIDSVAX B/E in alum, Thailand, IDU, age 20–60						
Ad5, internal proteins	HVTN 504 (STEP): US, MSM, age 18–45						
	HVTN 503 (Phambili): RSA, heterosexual, age 18–35			STOP			
Canarypox/ bivalent gp120	RV144: ALVAC vCP1521-AIDSVAX B/E, Thailand, community-based, age 18–30				31.2% protection		
DNA/Ad5, internal proteins + Env	HVTN 505: US, MSM, TGSM, age 18–50				STOP		
Canarypox/ bivalent gp120	HVTN 702 (P5): ALVAC vCP2438 – bivalent clade C gp120, RSA, heterosexual, age 18–35						
Ad26 (mosaic)/ trimeric gp140	HVTN 705/HPX2008, 4 mosaic sequences – clade C gp140, Sub-Saharan African women, age 18–35						

Robinson 2018

LATEST NEWS

Janssen and Global Partners to Discontinue Phase 3 Mosaico HIV Vaccine Clinical Trial

Independent, scheduled review of Phase 3 Mosaico study finds investigational vaccine regimen lacks efficacy in preventing HIV

Correlates of protection

TABLE 2. Quantitative correlates and surrogates of protection after vaccination

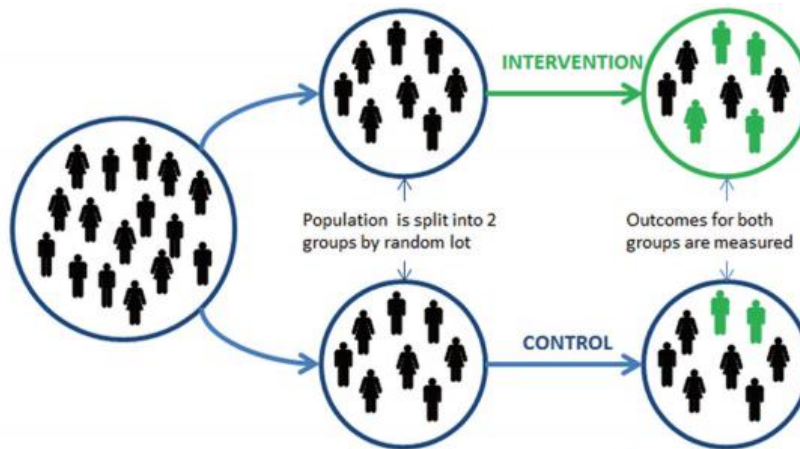
Vaccine	Test	Level required
Anthrax	Toxin neutralization	1,000 IU/ml
Diphtheria	Toxin neutralization	0.01–0.1 IU/ml
Hepatitis A	ELISA	10 mIU/ml
Hepatitis B	ELISA	10 mIU/ml
Hib polysaccharides	ELISA	1 µg/ml
Hib conjugate	ELISA	0.15 µg/ml
Human papillomavirus	ELISA	ND ^b
Influenza	HAI	1/40 dilution
Japanese encephalitis	Neutralization	1/10 dilution
Lyme disease	ELISA	1,100 EIA U/ml
Measles	Microneutralization	120 mIU/ml
Meningococcal	Bactericidal	1/4 (human complement)
Mumps	Neutralization?	ND
Pertussis	ELISA (toxin)	5 units
Pneumococcus	ELISA; opsonophagocytosis	0.20–0.35 µg/ml (for children); 1/8 dilution
Polio	Neutralization	1/4–1/8 dilution
Rabies	Neutralization	0.5 IU/ml
Rotavirus	Serum IgA	ND
Rubella	Immunoprecipitation	10–15 mIU/ml
Tetanus	Toxin neutralization	0.1 IU/ml
Smallpox	Neutralization	1/20
Tick-borne encephalitis	ELISA	125 IU/ml
Tuberculosis	Interferon	ND
Varicella	FAMA gp ELISA	≥1/64 dilution; ≥5 IU/ml
Yellow fever	Neutralization	1/5
Zoster	CD4 ⁺ cell; lymphoproliferation	ND

^a Also see the text.

^b ND, not defined.

- Immune response must be of adequate strength and quality for efficient protection
- Measurable signs that a person (or other potential host) is immune (i.e. antibodies)
- Without knowing the correlates of immunity, one cannot know exactly what sort of immune response a vaccine would need to stimulate (→ only P3 studies possible)

randomized clinical trial



100 μ g of
mRNA-1273

2X

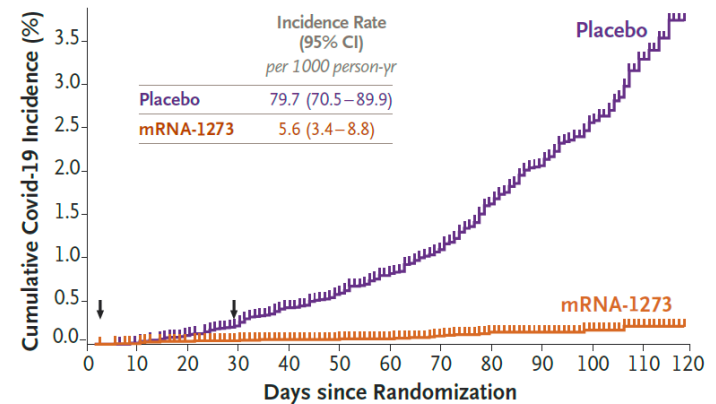


28 days apart

SUN	MON	TUE	WED	THU	FRI	SAT
						
						
						
						
						

Placebo

2X



	mRNA-1273 Vaccine N=14,550	Placebo N=14,598
Symptomatic Covid-19	11	185
Severe Covid-19	0	30

Vaccine efficacy of 94.1% (95% CI, 89.3–96.8%; P<0.001)

CONCLUSIONS

Two doses of a SARS-CoV-2 mRNA-based vaccine were safe and provided 94% efficacy against symptomatic Covid-19 in persons 18 or older.

Vaccine efficacy is generally reported as a relative risk reduction (RRR)

Challenge Study For Hepatitis C?

Diagram of an HCV vaccine efficacy CHIM

Step 1

Recruit volunteers and randomly assign them to placebo and vaccine groups



Step 2

Later, infect all volunteers with a specific volume of HCV



Step 3

Monitor and gather data, provide DAA treatment at 6 months or earlier



Step 4

See if the group that received the real vaccine was better protected



Total timeline: <1-2 years



Hygiene etc.



Vaccines



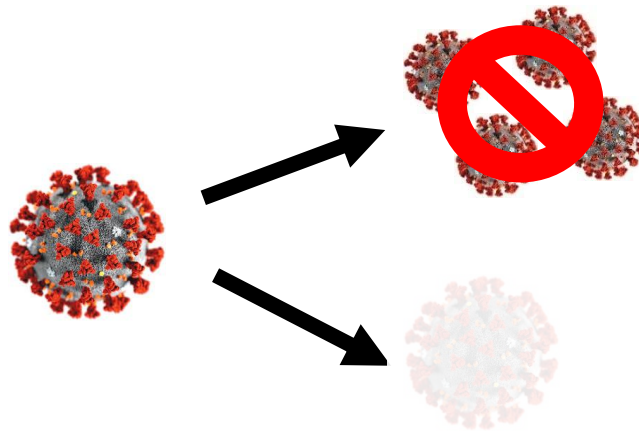
Antiviral drugs



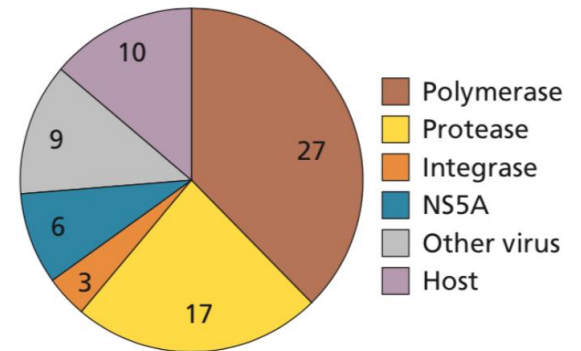
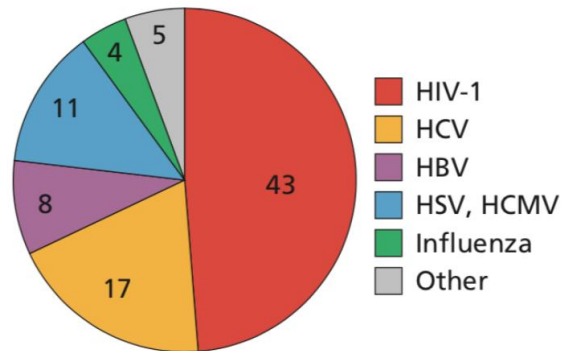
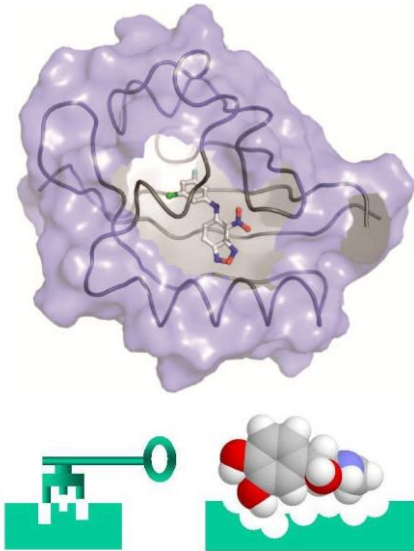
Vaccines can prevent viral diseases. **BUT:** only modest or no therapeutic effect if a person is already infected.

Antivirals are drugs to treat people who have already been infected by a virus.

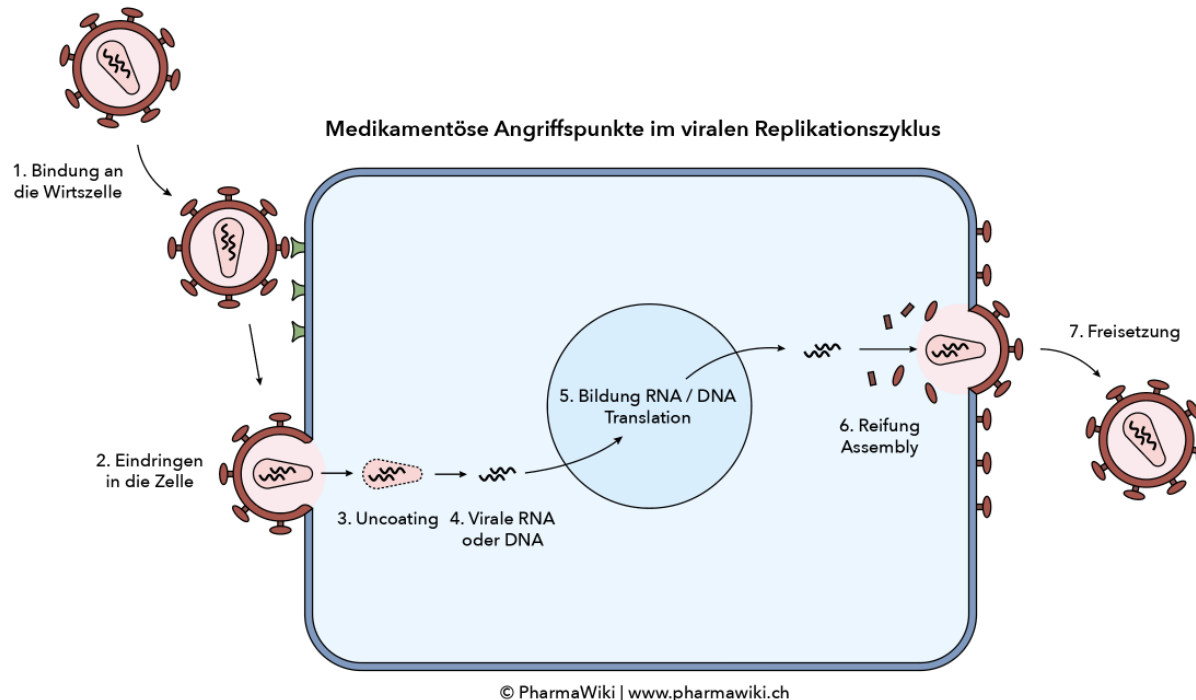
HOWEVER, antiviral substances only inhibit the reproduction of a virus. → virostatic, not virucidal (killing).



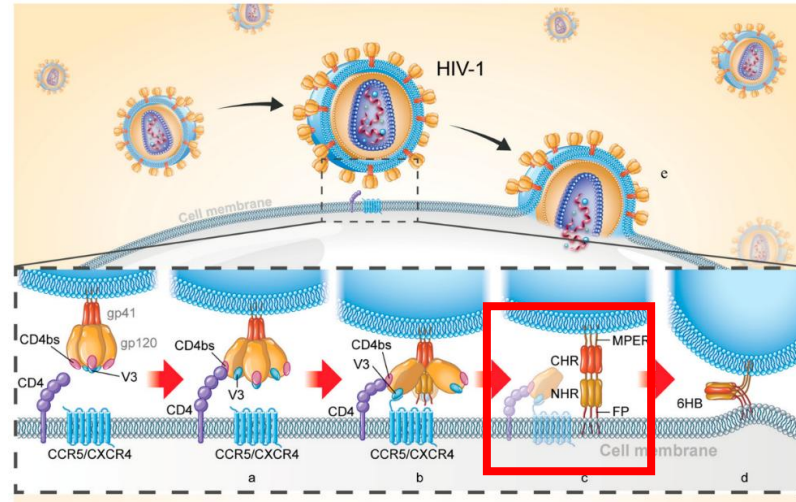
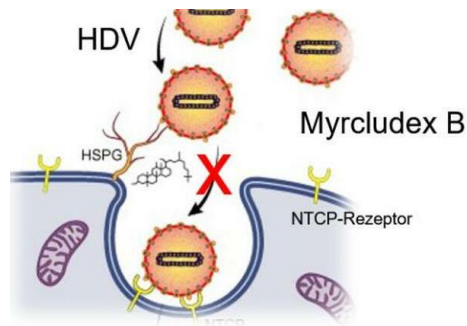
→ Host immune response remains essential.



- Small molecule inhibitors for viral / host proteins to perturb essential steps of the viral live cycle
- Frequent targets are viral polymerases and proteases
- Unlike bacteria, there are **no broad-spectrum antivirals**



1. Docking, entry into the host cell
2. Viral enzymes (e.g. reverse transcriptase, DNA/RNA polymerases, integrase)
3. Maturation/assembly
4. Release of viral particles
5. (inhibition of cellular proteins)

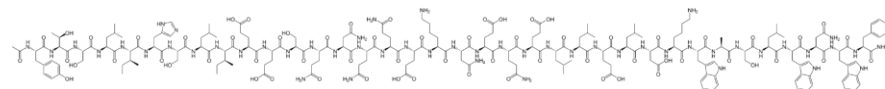


Entry Inhibitor - HDV

- Myrcludex: blocks the entry receptor (sodium/bile acid cotransporter (NTCP))

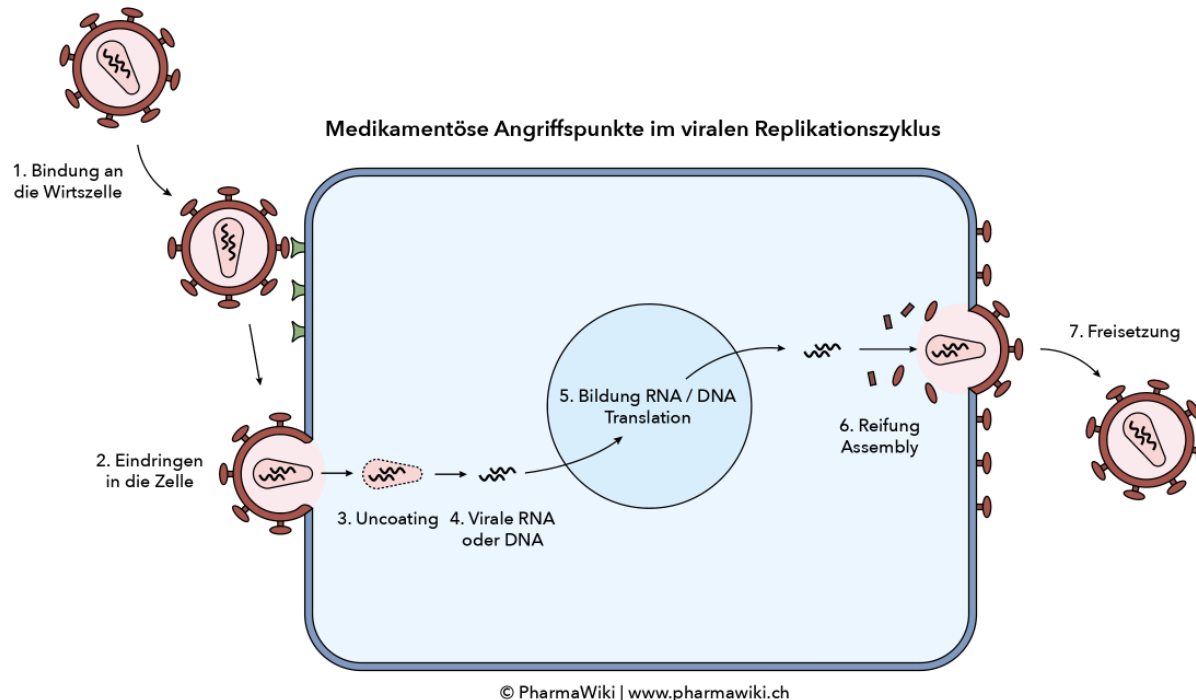
Attachment-/ Fusion-Inhibitor - HIV

- Fostemsavir, Ibalizumab (mAb): Block virus attachment
- Enfuvirtid: Block virus fusion

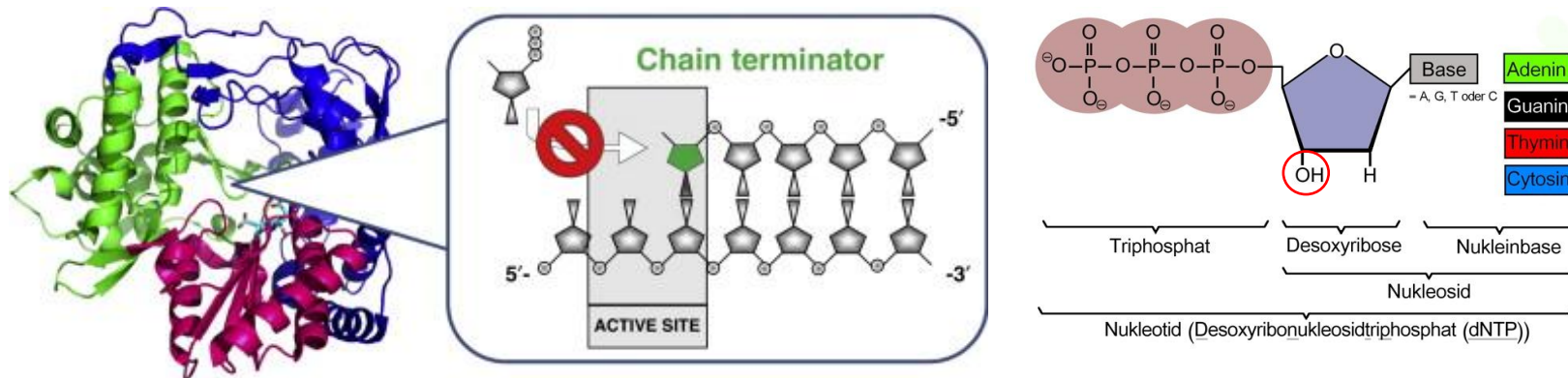


Release-Inhibitor - Influenza

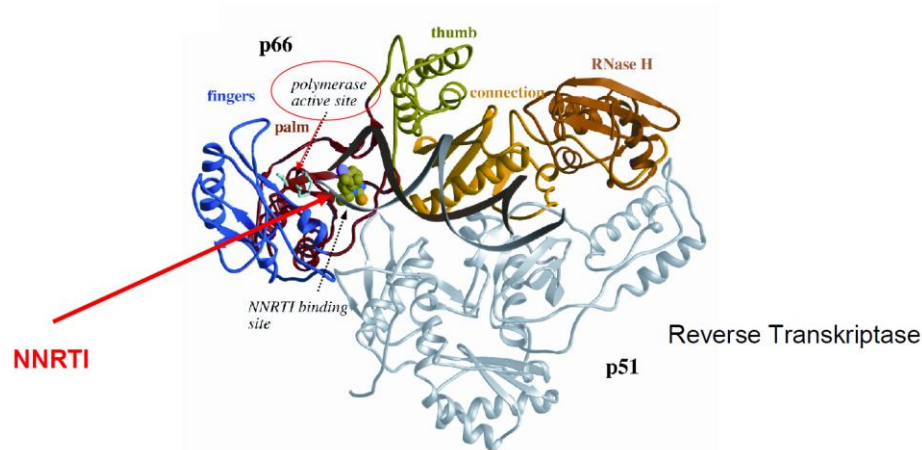
- Ion channel inhibitor → Inhibits the release of the viral genome



1. Docking, entry into the host cell
2. Viral enzymes (e.g. reverse transcriptase, DNA/RNA polymerases, integrase)
3. Maturation/assembly
4. Release of viral particles
5. (inhibition of cellular proteins)



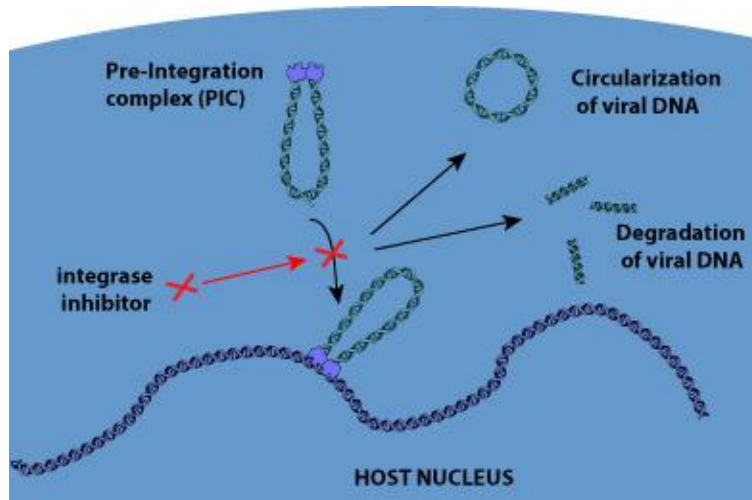
- Polymerases need free 3'-hydroxy end to synthesize complementary strand
- Nucleoside/nucleotide analogues chain termination
- Danger: cytotoxicity
- Activation: production of triphosphate by cellular enzymes (prodrug)
 - Aciclovir (HSV)
 - Ganciclovir (CMV)



Empfohlene Erstlinientherapie der deutsch-österreichischen HIV-Fachgesellschaft zur Behandlung der HIV-Infektion bei Erwachsenen^{*1}

Kombinationspartner 1		Kombinationspartner 2
N(t)RTI Nukleosid-/Nukleotidkombinationen – Tenofovir/Emtricitabin – Abacavir ^{*5} /Lamivudin	+	NNRTI – Efavirenz ^{*2} – Nevirapin ^{*3} Proteasehemmer ^{*4} – Atazanavir/r – Darunavir/r – Fosamprenavir/r – Lopinavir/r – Saquinavir/r (Alternative, BII) Integrasehemmer – Raltegravir

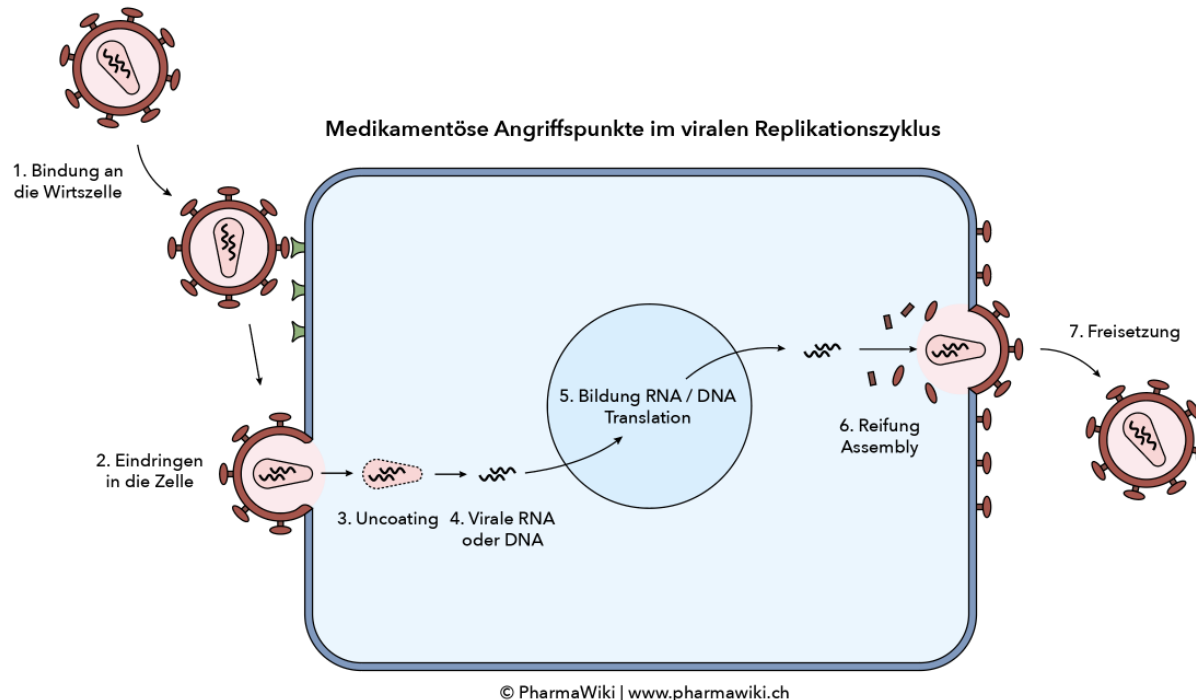
- Binding to outside the active site (e.g. reverse transcriptase (HIV)).
- No incorporation during nucleic acid synthesis
 - Allosteric inhibition by blocking RT structure
- Non-competitive inhibitors
- Combination with NRTI in HIV



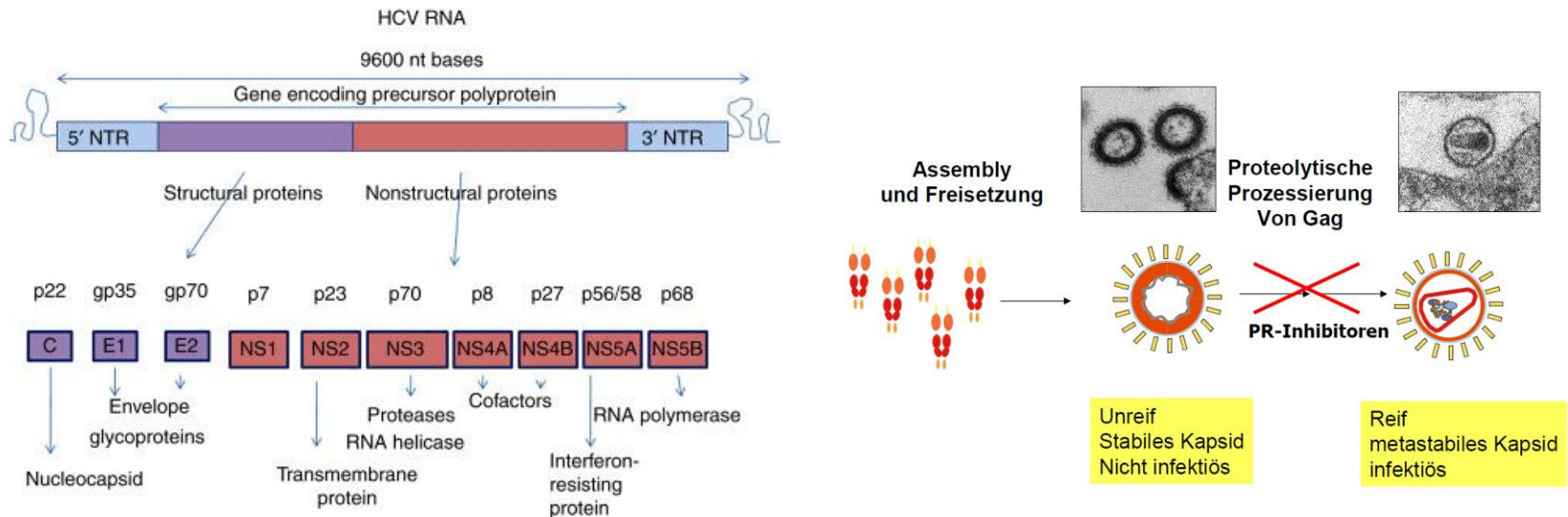
Für die Primärtherapie werden empfohlen:

Eintablettenregime	
Integraseinhibitor-basiert	BIC/TAF/FTC DTG/ABC/3TC DTG/3TC EVG/c/TAF/FTC
NNRTI-basiert	DOR/TDF/3TC RPV/TAF/FTC oder RPV/TDF/FTC ²
PI-basiert	DRV/c/TAF/FTC
Mehrtablettenregime	
Integraseinhibitor-basiert	DTG + TAF/FTC oder DTG + TDF/FTC RAL ³ + ABC/3TC ⁴ oder RAL + TAF/FTC oder RAL + TDF/FTC
NNRTI-basiert	DOR + TDF/FTC oder DOR + TAF/FTC oder DOR + ABC/3TC
PI-basiert	DRV/r + ABC/3TC oder DRV/r + TAF/FTC

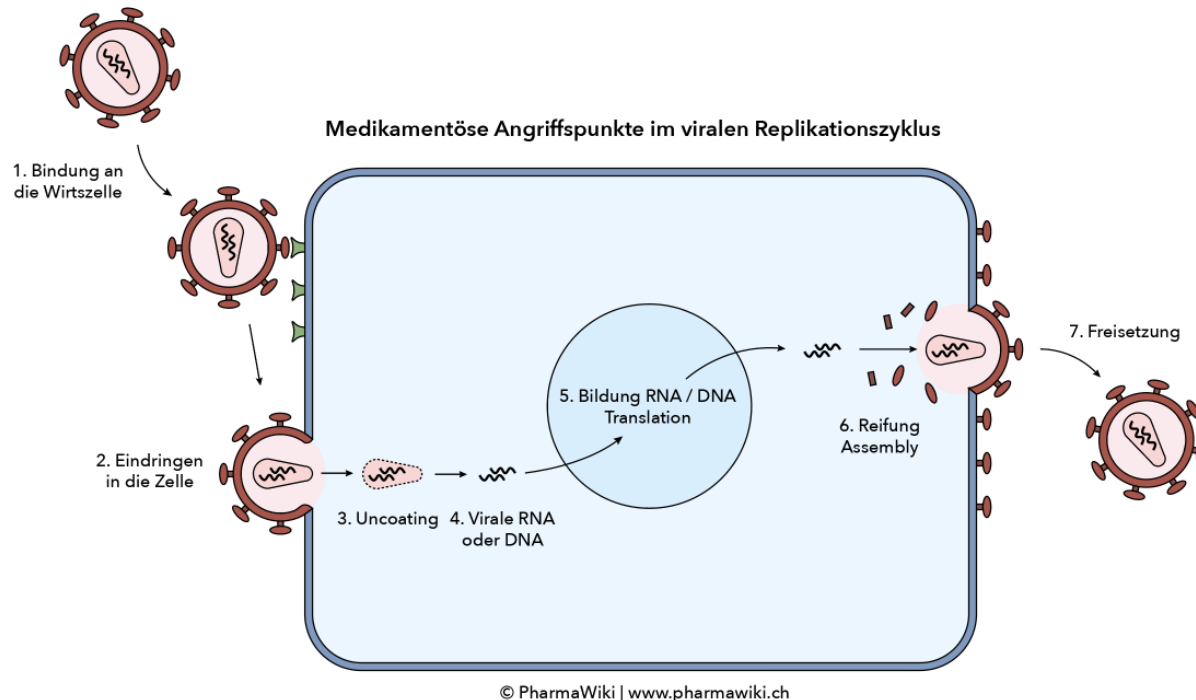
- Inhibition of integration of HIV DNA into the genomic DNA of the host cell
- Often rapid and effective reduction of viral load
- High resistance barrier
- Current ART guidelines primarily recommend integrase inhibitors in initial therapy



1. Docking, entry into the host cell
2. Viral enzymes (e.g. reverse transcriptase, DNA/RNA polymerases, integrase)
3. Maturation/assembly
4. Release of viral particles
5. (inhibition of cellular proteins)

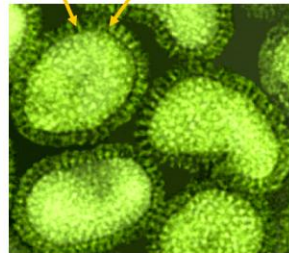


- Virus-derived proteases cut polypeptide precursors into mature enzymes and structural proteins → Essential during viral live cycle
- Binding in the active site (peptide-like structure)
- Example: HIV, HCV and SARS-CoV-2 (Paxlovid)



1. Docking, penetration into the host cell
2. Viral enzymes (e.g. reverse transcriptase, DNA/RNA polymerases, integrase)
3. Maturation/assembly
4. Release of viral particles
5. (inhibition of cellular proteins)

Oberflächenproteine
Hämagglutinin
Neuraminidase

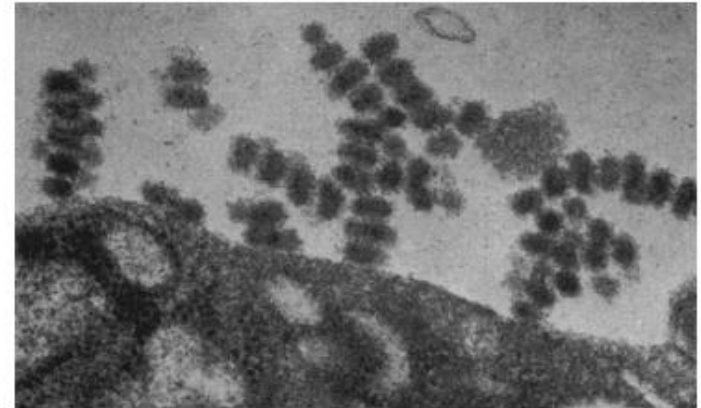


Hämagglutinin bindet an
Sialinsäure auf der Wirtszelle
Neuraminidase spaltet
Sialinsäure

Neuraminidase
löst Viren von der
Wirtszelle

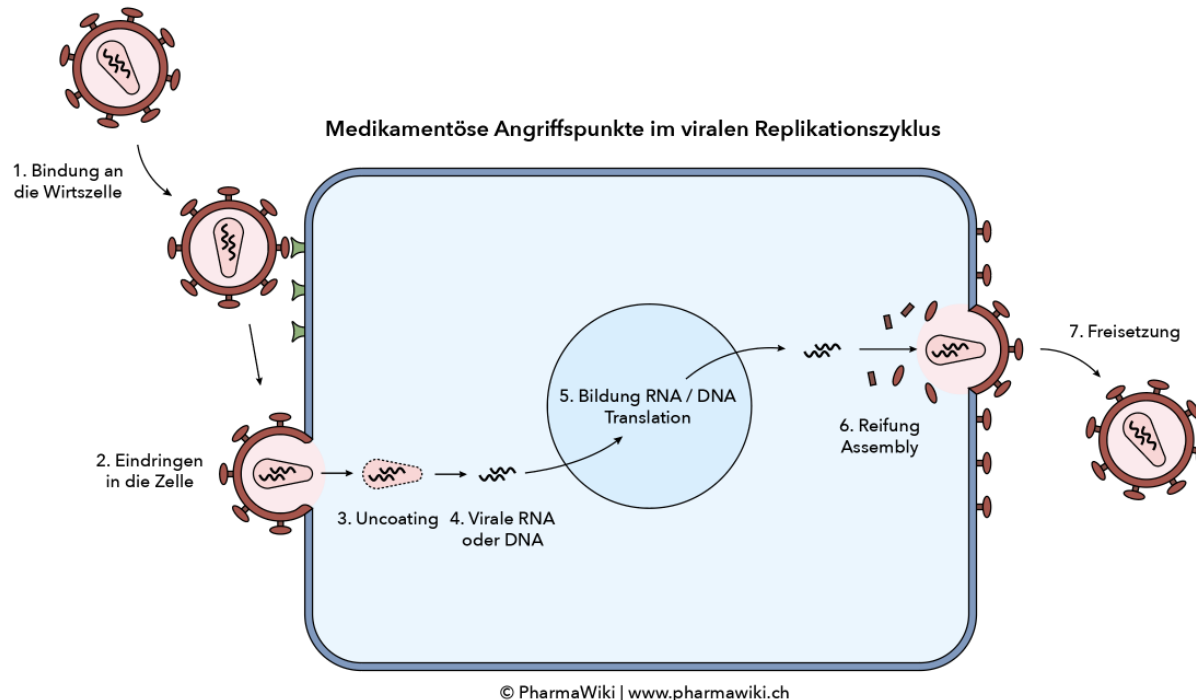


Viren verkleben mit
der Zelle und
miteinander



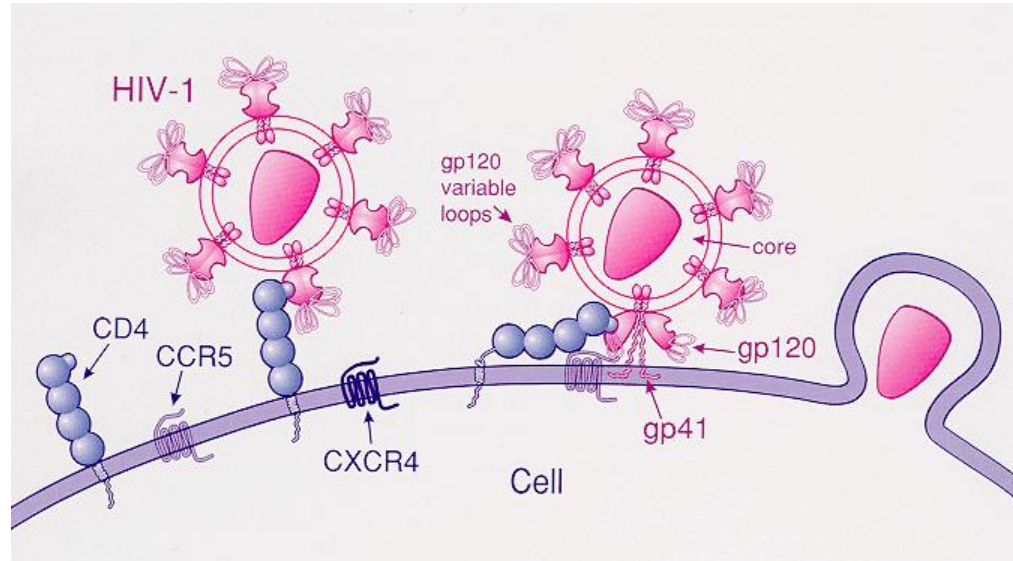
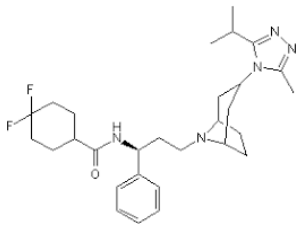
Neuraminidase inhibitors block the release of influenza viruses (oseltamivir; zanamivir).

Prophylaxis in high-risk patients → Alleviation of symptoms, shortening of illness duration and reduction of complications



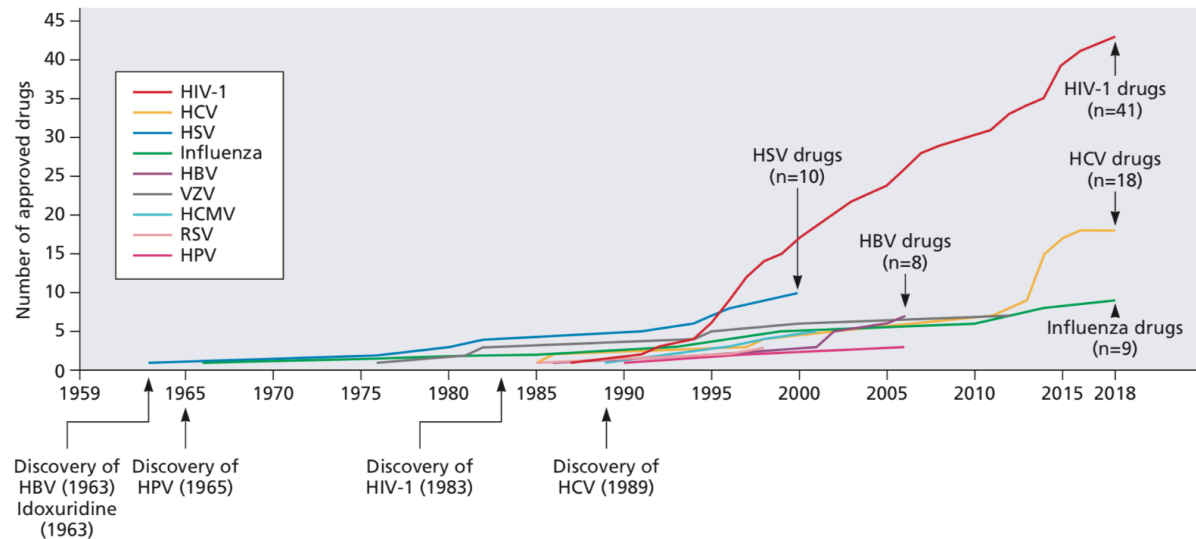
1. Docking, entry into the host cell
2. Viral enzymes (e.g. reverse transcriptase, DNA/RNA polymerases, integrase)
3. Maturation/assembly
4. Release of viral particles
5. (inhibition of cellular proteins)

Host-targeting agents



- Maraviroc - HIV entry inhibitor
- Inhibition of fusion by inhibition of the coreceptor CCR5
- Use only with CCR5-tropic HIV-1 (not CXCR4-tropic)
- Combination therapy

Approved antiviral drugs

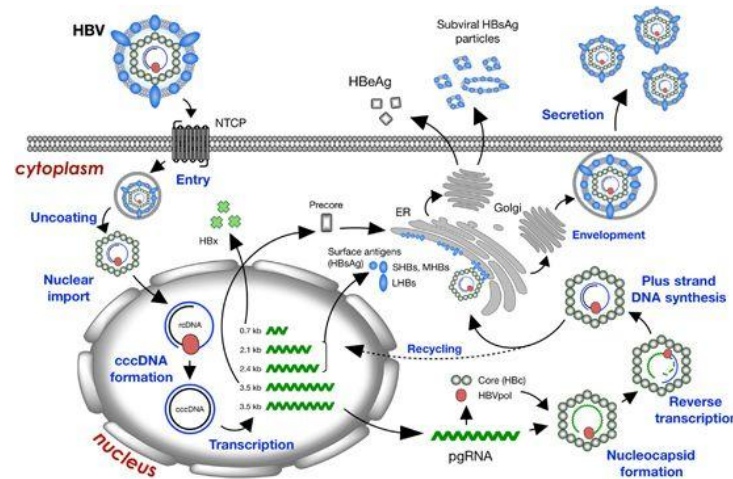


- Only ~120 approved antiviral drugs since 1959
- Most against HIV, HCV, herpesviruses - Persistent infections
- Current antiviral agents do not eliminate non-replicating or latent virus

Why are there so few antiviral drugs?

Compounds interfering with virus growth can adversely affect the host cell

- *Side effects are common (unacceptable)*
- *Every step in viral life cycle engages host functions (selectivity)*



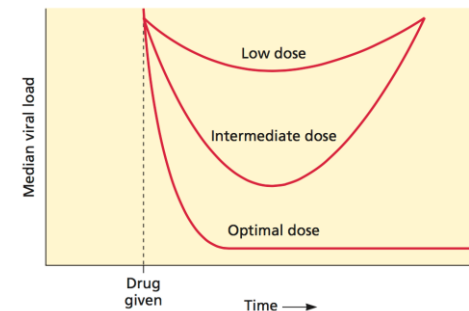
Some medically important viruses can't be propagated, have no animal model, or are dangerous

- *HBV, HPV*
- *Ebola, Lassa*

Why are there so few antiviral drugs?

Compounds must be highly potent

- Partial inhibition is not acceptable - resistant mutants will arise
- Most compounds are **virostatic**, there are no antiviral drugs which are a **virucide**



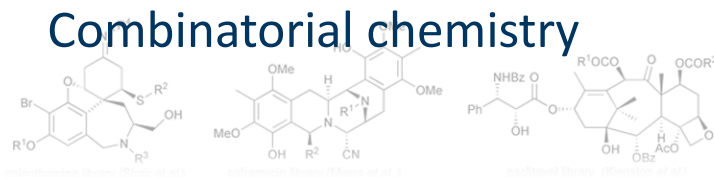
Acute

- Rhinovirus
- Rotavirus
- Influenza virus

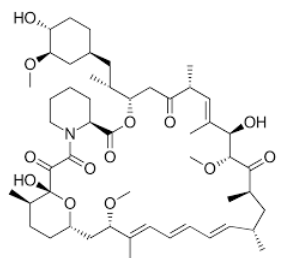
Many **acute infections** are of short duration

- By the time the patient feels ill, it is too late to impact clinical disease
- Lack of rapid diagnostics

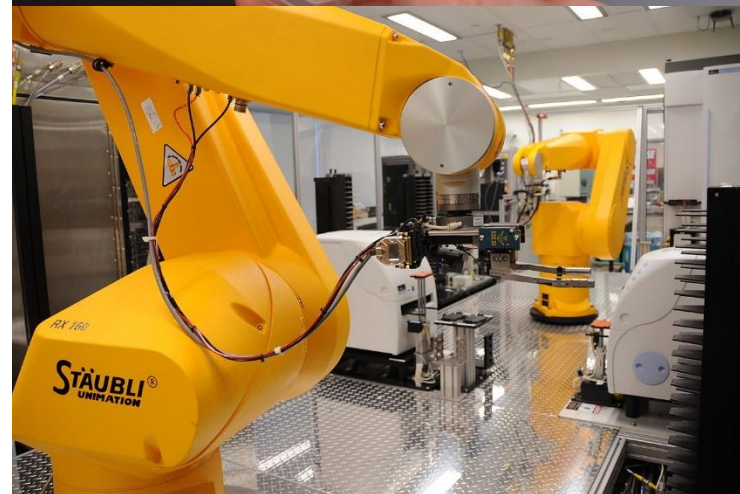
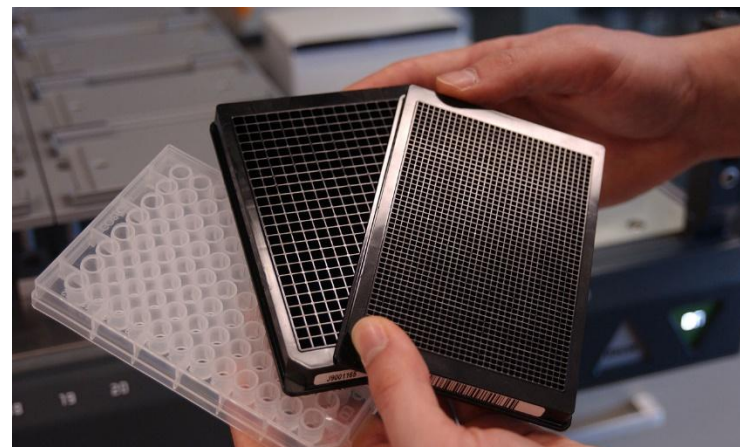
Examples of screening compounds



Rapamycin

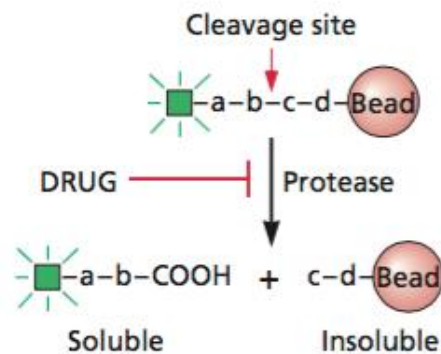


High throughput screening



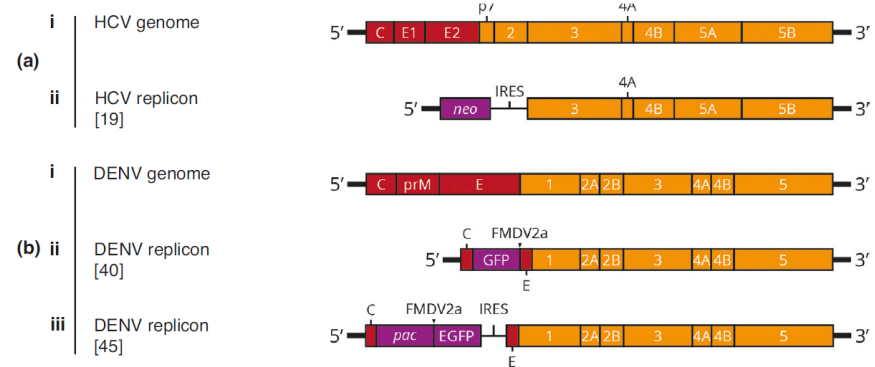
10,000 compounds/day

Mechanism-Based Screen



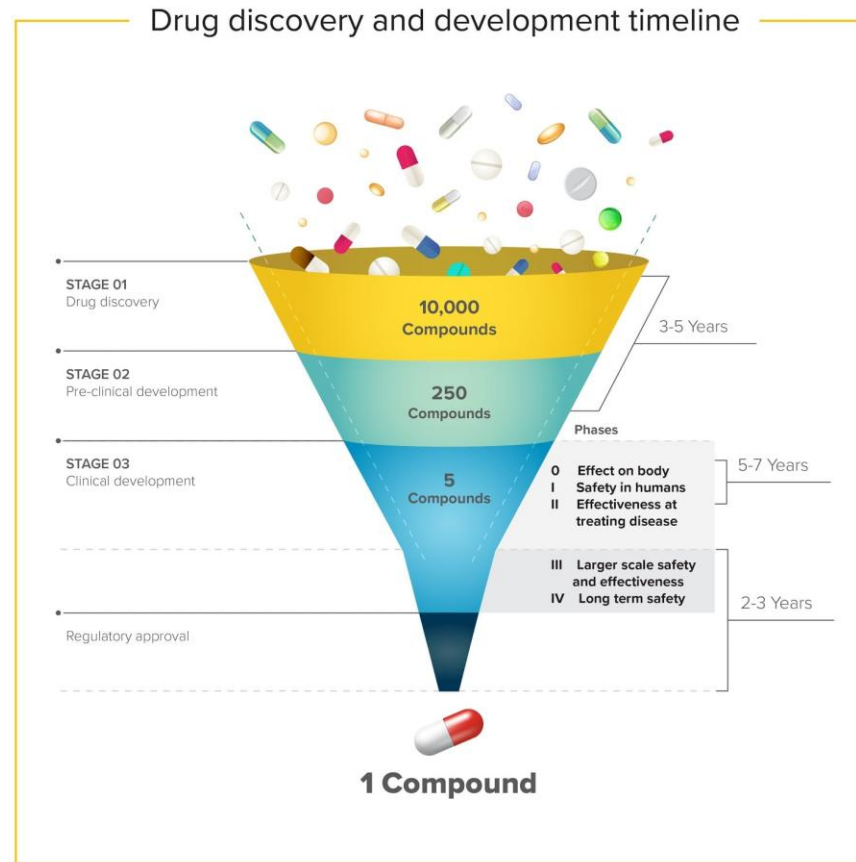
- Inhibition of a specific viral enzyme or molecular interaction
- Low safety requirements

Replicon systems



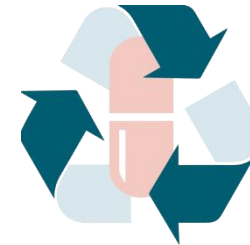
- Subgenomic replicons and mini genome systems
- Self-amplifying recombinant RNA molecules
- Cheap; quick and efficient

The path of drug discovery

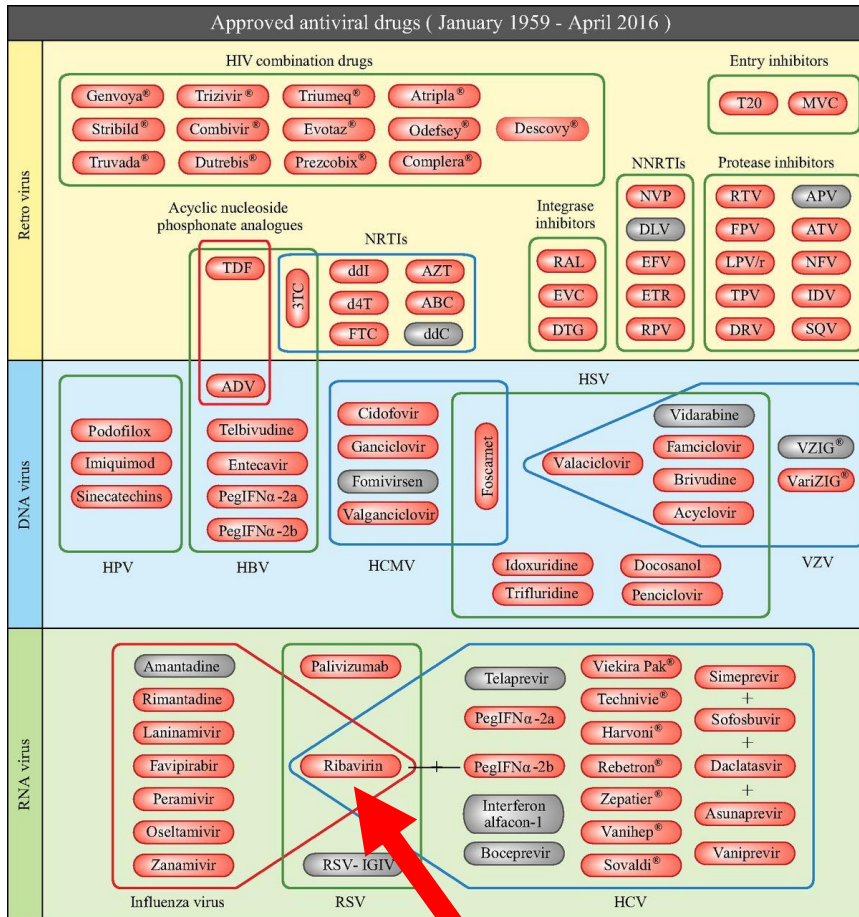


- Very low success rate
- Estimated costs ~1 Bio USD
- Time consuming process (10-15 years)

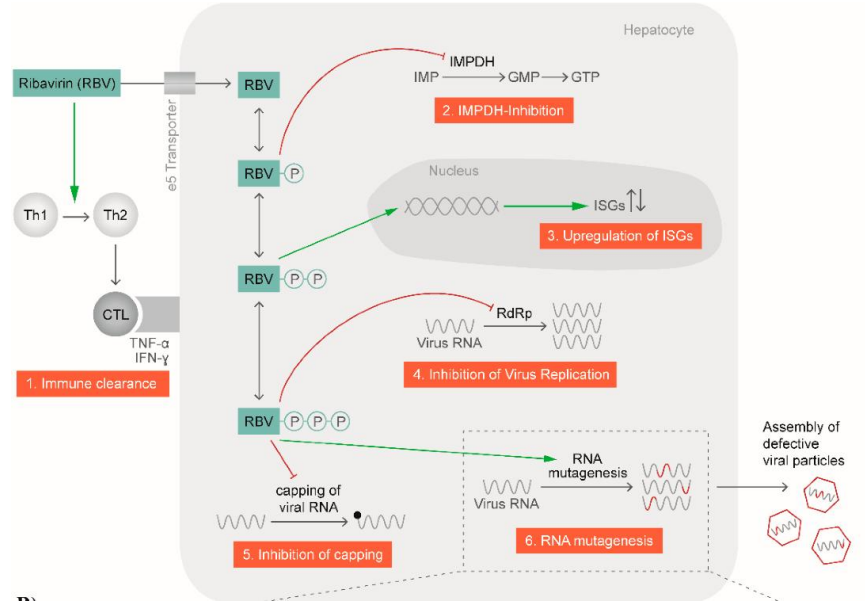
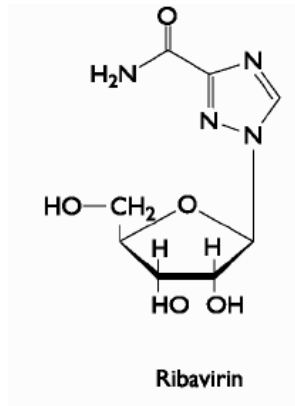
Drug repurposing



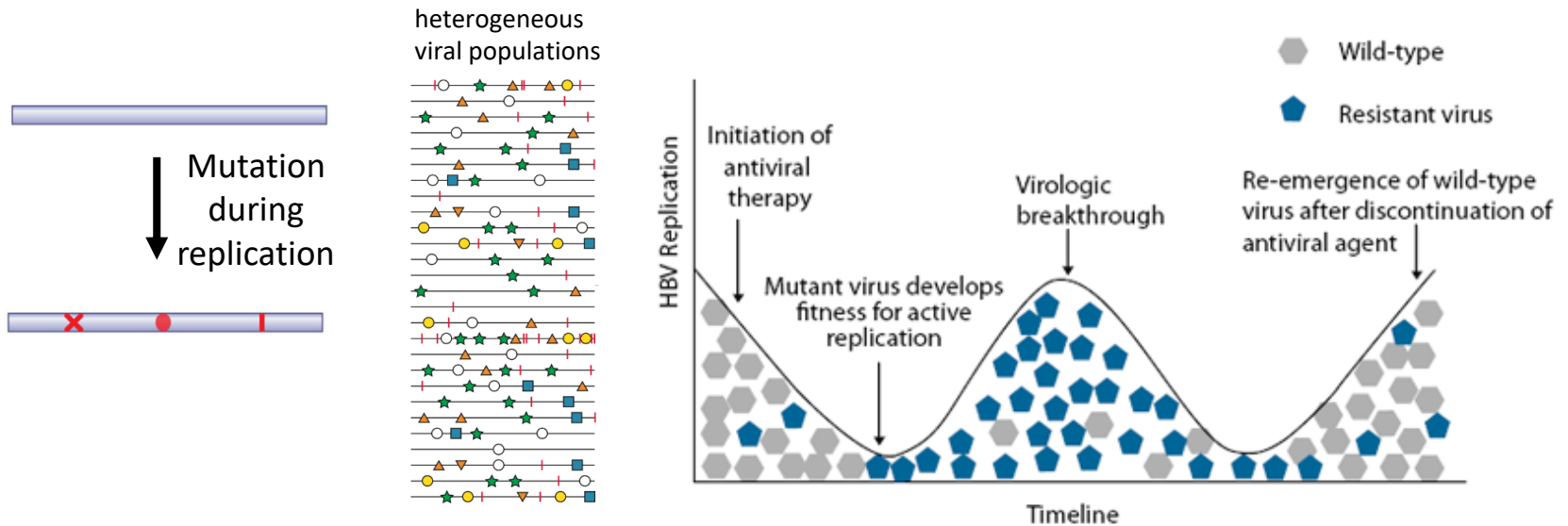
Use existing drugs for new therapeutic purposes



Ribavirin



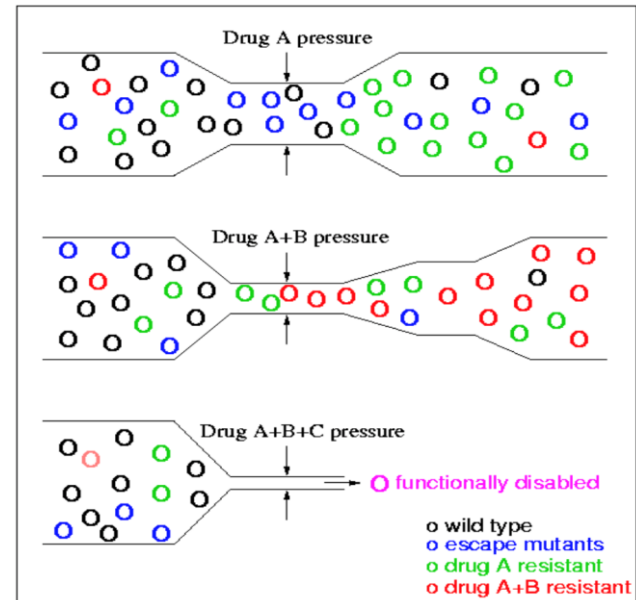
- Guanosine analog
- Relatively unspecific effect (including inhibition of capping, IMPDH inhibition (GTP depletion), RNA mutagenicity)
- Use against various DNA and RNA viruses (e.g. HCV; RSV; Lassa virus; influenza)
 - Currently Off-label use against hepatitis E virus



RNA viruses: error prone RNA polymerase → heterogeneous viral populations

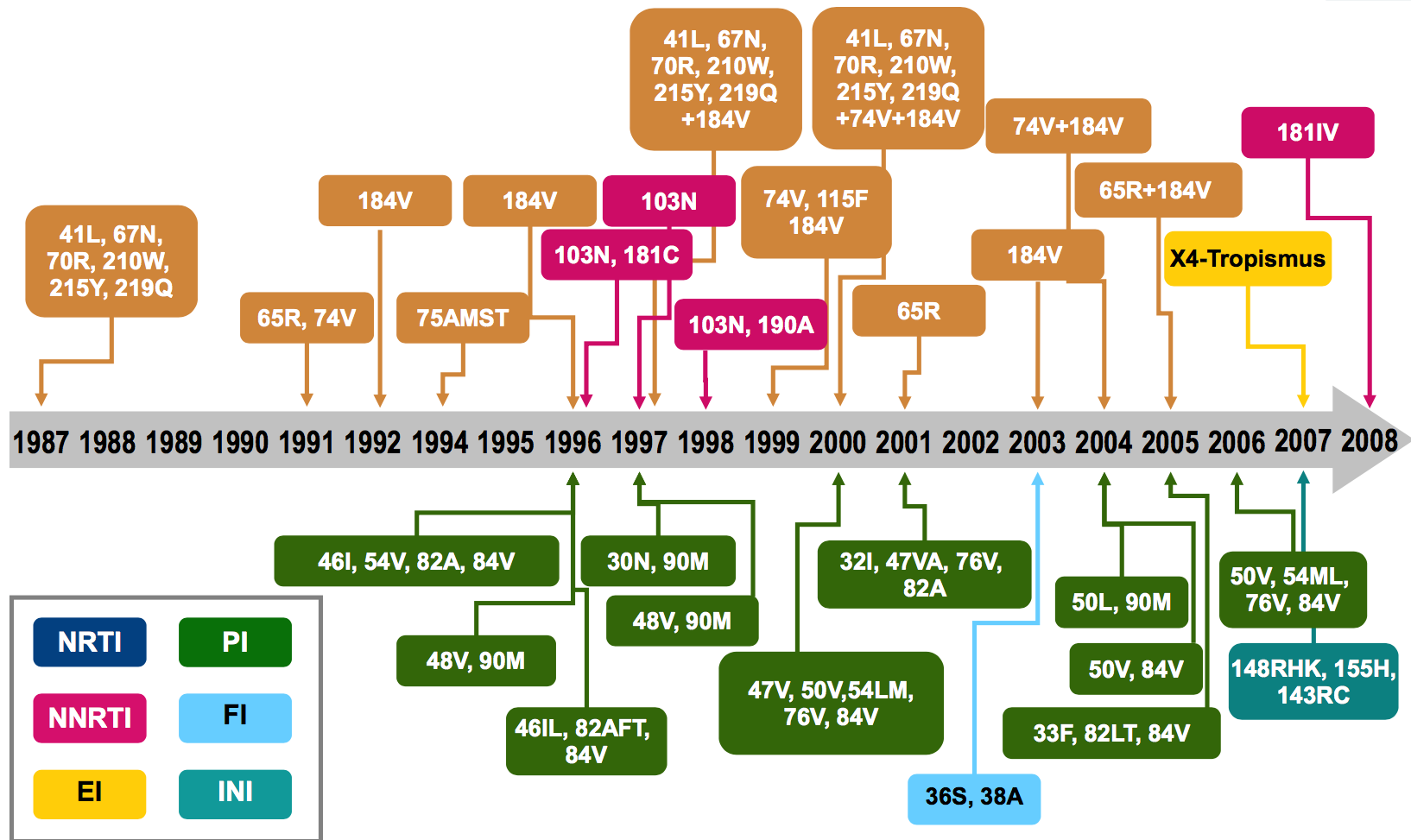
DNA viruses: most DNA polymerases have proofreading function → evolve slower

Combination therapy



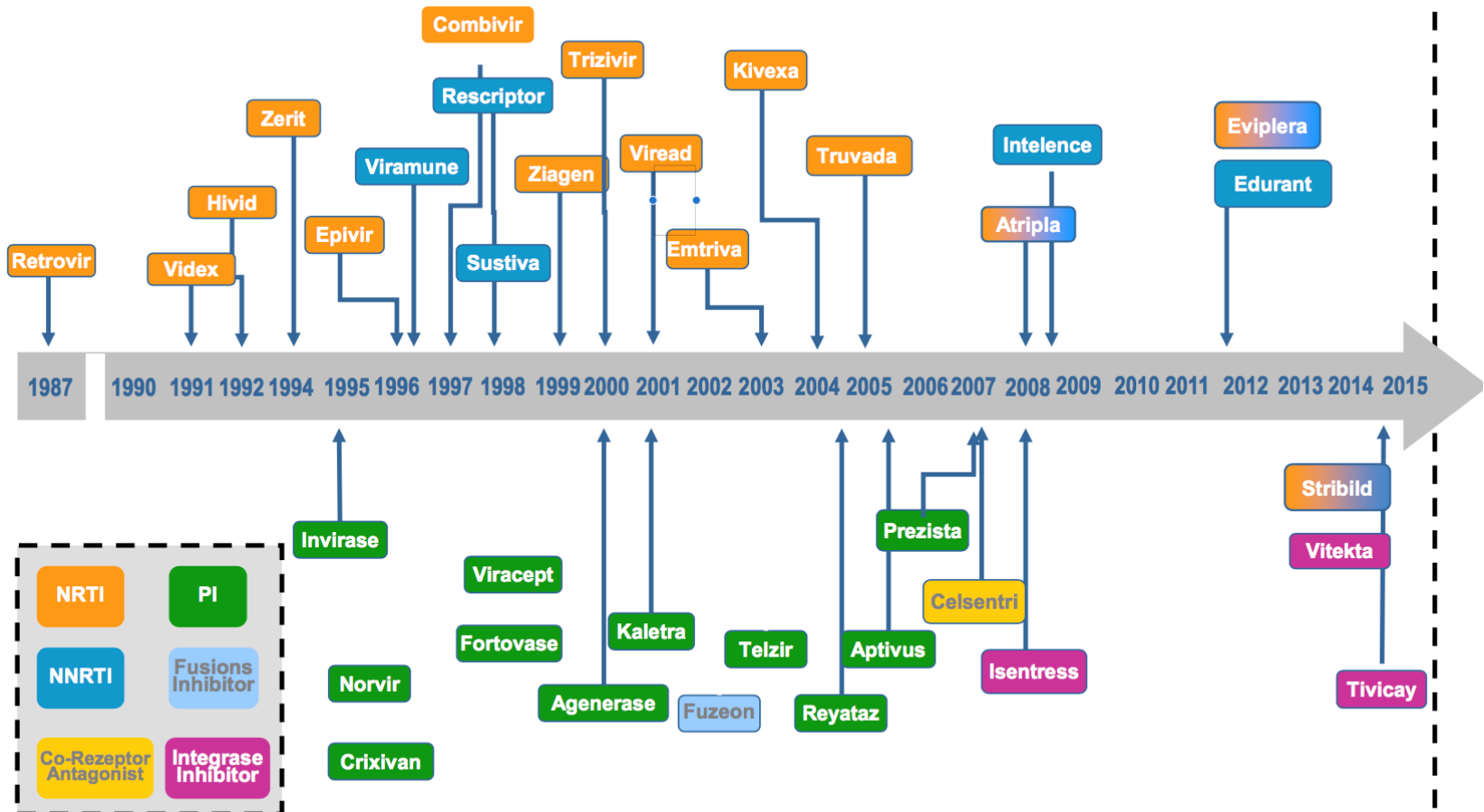
- Stronger selective pressure → Hinders evolution of drug resistances in viruses, bacteria, and cancers

HIV resistance mutations

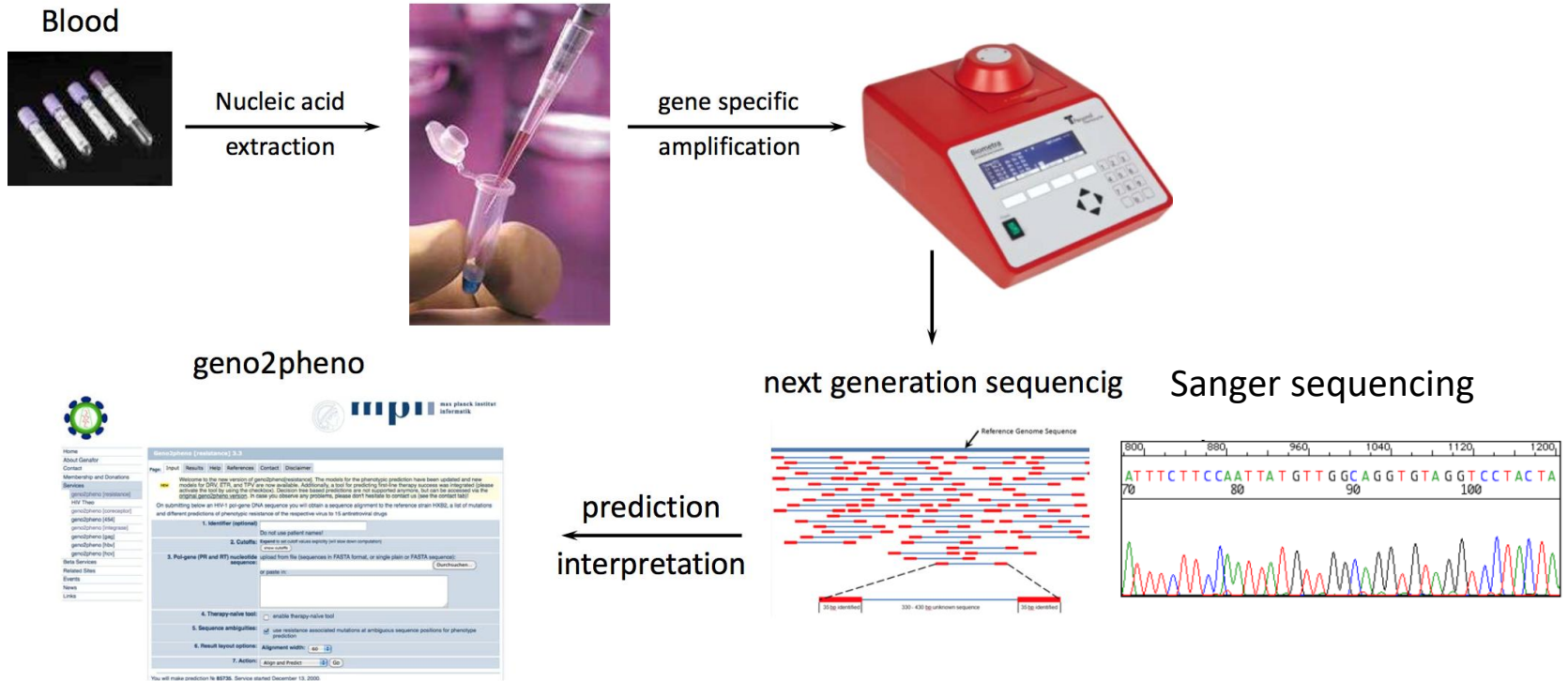


→ more than 200 resistance conferring mutations

HIV drugs



→ Approximately 30 HIV drugs



HIV combination therapy

Combivir® +
Crixivan® + Norvir®



Videx® + Zerit® +
Viracept®



Combivir® +
Norvir® +
Agenerase®

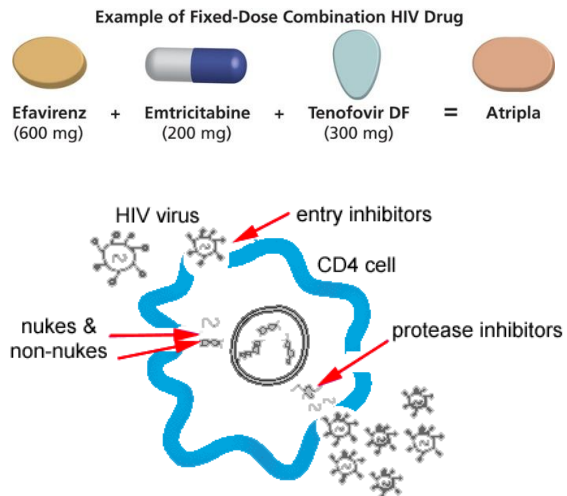


First combination therapies from 1996 (2 RT inhibitors + protease inhibitor)

Initial therapies often with severe side effects

Poor adherence probably most important factor for treatment failure

HIV

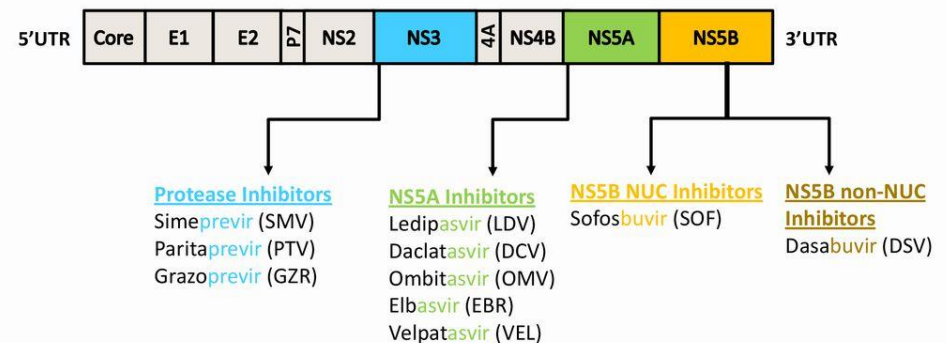


Increasingly better HAART approaches minimize adverse drug effects

Almost normal life expectancy with early HAART

HCV

Approved HCV Direct-acting Antiviral (DAA) Agents



Bertino G. *World Journal of Hepatology*. 2016;8(2):92-106.

Direct-acting antivirals (DAAs)

- 95% of chronic infections can be cured
- First chronic virus infection that can be cured

5g of diamonds

25 1-carat (\$1900 each)

Cost = \$48,000



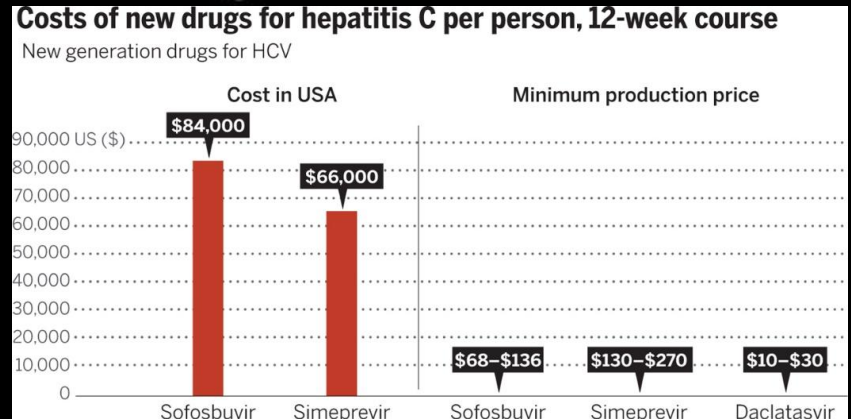
5g of daclatasvir

12 weeks of treatment, 60mg/day

Cost = \$63,000 (US price)



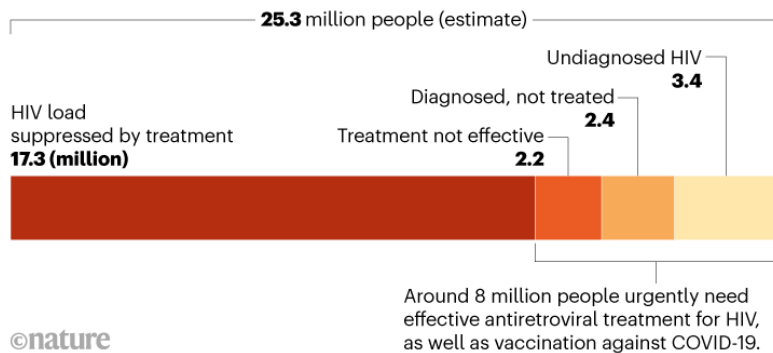
Drug	U.S. Patent Expiration	E.U. Patent Expiration
Sovaldi® (sofosbuvir)	2029	2028
Harvoni® (sofosbuvir/ledipasvir)	2030	2030
Epclusa® (sofosbuvir/velpatasvir)	2032	2032



Andrew Hill

AFRICA'S HIV TREATMENT GAP

Around one-third of people living with HIV in sub-Saharan Africa in 2020 were not getting effective antiretroviral treatment.



Around 8 million people urgently need effective antiretroviral treatment for HIV, as well as vaccination against COVID-19.

Msomi et. al Nature 2021

ACCESS TO HEPATITIS C TREATMENT 2016

Of **80 million** people infected - over **1 million** had access to Hep C treatment



Vaccines

- Stimulation of the adaptive immune system to establish immune memory without pathogenic events
- Active and passive vaccines
- Different types of active vaccines (attenuated virus; inactivated virus.....)

Antivirals

- Targeting of viral proteins or host factors with small molecules
- Various targets for antiviral drugs (Polymerase; Protease)
- Error-prone viral replication → drug resistance → combination therapy

Thank you for your
attention

