Tumor Antigens and Cancer Vaccines

MCBO Core Lecture II

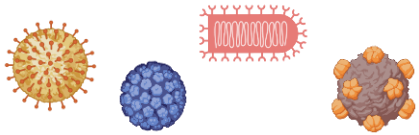
Guido Wollmann

Internal Medicine V – Hematology/Oncology

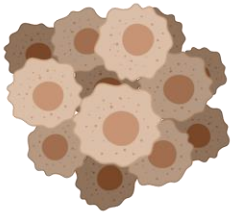
Institute of Virology

History

pathogen



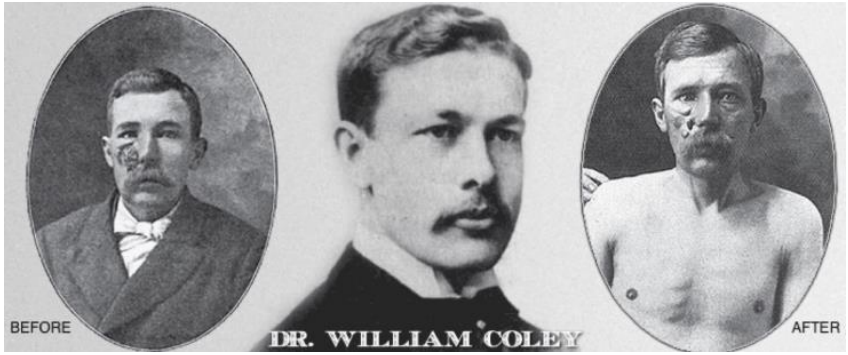
tumor



Edward Jenner

1796

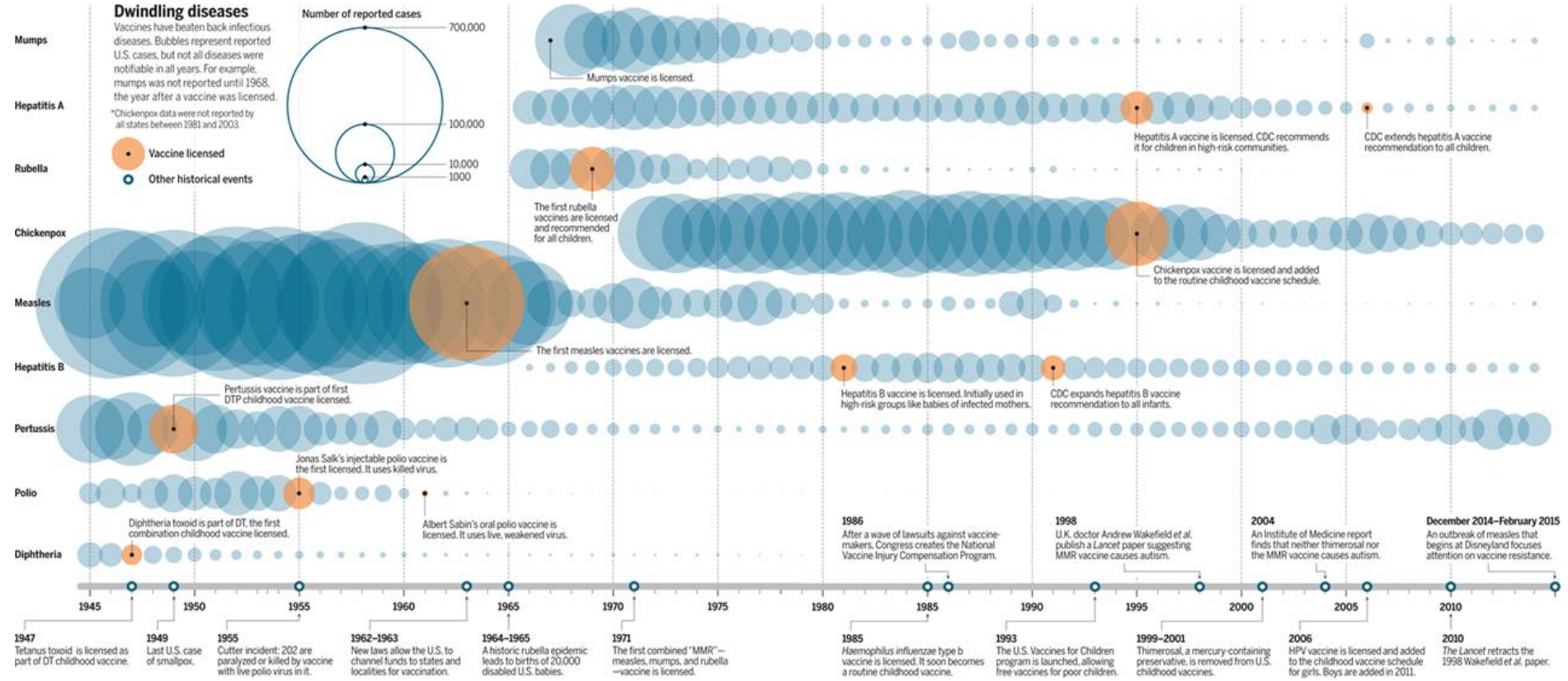
William Coley



1893

History

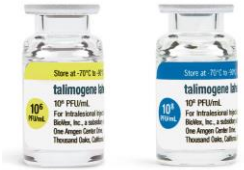
Century of vaccines!



highly successful development to fight pathogen disease burden

Wadman and You, Science 2017

History



Evolution of Immunotherapy

circa 1000 years BC – first anecdotal reports about spontaneously disappearing tumours (ancient Egypt)

2nd century AD – cancer might evolve from inflammatory lesions (Galen)

1718 – first attempts to popularise inoculation in England (Lady Mary Wortley Montague)

1765 – report about the effectiveness of inoculation (John Fewster)

1796 – immunity against smallpox through inoculation with common cowpox virus demonstrated for the first time (Edward Jenner)

1866 – significant tumour regression after erysipelas infection was noted (Fehleisen and Busch)

1883 – identification of the bacterial strain responsible for the erysipelas and tumour shrinkage as Streptococcus pyogenes (Fehleisen)

1890 – the discovery of antibodies (Ehrlich, von Behring and Shibasaburo)

1891 – first attempt to harness the immune system for treating bone cancer (William Bradley Coley)

1893 – Coley's successful clinical results were first described

1896 – The first description of the spontaneous tumour remission after severe influenza infection (Dock)

1899 – "Coley's toxin" is now available commercially

1902 – the first attempts to create cancer vaccine (Blumenthal and E. von Leyden)

1908 – Ehrlich confirmed Coley's observations

1914 – a genetic explanation for the rejection of transplanted tumours in animal models (Clarence Little)

1915 – nonspecific stimulation of immune cells can provide a treatment for cancer (Murphy and Morton)

1948 – the first report on histocompatibility antigens being involved in transplant rejection (Gorer and Snell)

1957 – the theory of cancer immunosurveillance (Thomas and Burnet)

1959 – the first ever cancer vaccine (Ruth and John Grahams)

1959 – the anti-tumour effects of the BCG bacteria in mice with bladder cancer (Old)

1967 – the existence of T cells and their crucial role in immunity (Jacques Miller)

1973 – dendritic cells were discovered (Steinman)

1974 – Immune surveillance theory re-emerged (Stutman)

1975 – the first description of NK cells activity (Klein)

1975 – the first production of monoclonal antibodies in the laboratory (Milstein and Köhler)

1976 – the use of BCG as a way of treating bladder cancer (Morales)

1976 – IL-2, the T-cell growth factor interleukin 2 (Morgan)

1982 – monoclonal antibodies used to achieve the first biochemical identification and description of tumour-specific antigen in a mouse model of T-cell lymphoma (Allison)

1983 – IL-2 was cloned (Devos)

1986 – The world's first recombinant vaccine, HBV, vaccine was created (Valenzuela)

1987 – The first immune checkpoint molecule was discovered CTLA-4 (Brunet)

1989 – The first use of genetically engineered T cells derived and modified in this way to target cancer cells was reported in 1989 (Gross and Eshhar)

1991 – proof: the first human tumour antigen to be recognised by T lymphocytes (van der Bruggen)

1991 – The US FDA approved the use of IL-2 as an immunotherapeutic treatment in metastatic kidney cancer

1997 – Rituximab became the first monoclonal antibody approved by the FDA for the treatment of cancer (Nadler) 4-1BB (CD137) molecule as the first evidence for T cell anti-tumour immune response (Melero)

1998 – The US FDA approved the use of IL-2 as an immunotherapeutic treatment for metastatic melanoma

2000 – the first ipilimumab clinical trial was launched

2004 – T cells were able to provide anti-tumour surveillance (Schreiber, Dunn, Old)

2010 – the FDA approved sipuleucel-T for treatment of castration-resistant prostate cancer

2011 – The first checkpoint inhibitor, ipilimumab, approved by the FDA

2014 – nivolumab, the first PD-1 molecule inhibitor, approved by the FDA

2015 – The first oncolytic virus, T-VEC, approved by the FDA for the treatment of metastatic melanoma

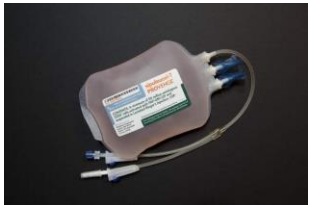
2016 – Atezolizumab, another checkpoint inhibitor of the PD-L1 protein, approved by the FDA

2017 – relapsed B-cell acute lymphoblastic leukaemia in children as the first disease to be FDA approved for CAR T-cells therapy

2018 – FDA approval of CART cells therapy for diffuse large B-cell lymphoma and certain other types of lymphoma

2018 – The Nobel Prize for their discovery of cancer therapy by inhibition of negative immune regulation (James P. Allison and Tasuku Honjo)

2019 – Atezolizumab, the checkpoint inhibitor of the PD-L1 protein, approved by the FDA for triple-negative breast cancer treatment



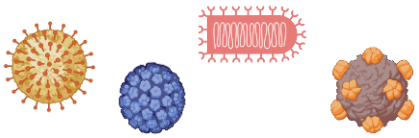
challenge to apply vaccines as tumor immunotherapies

Dobosz and Dzieciątkowski, Frontiers Immunol. 2019

fundamental difference

pathogen vaccine

A pathogen is a foreign invader.
The invader or parts of it can be directly used.



vaccine is based on **MATERIAL**

vector vaccines are the <u>exception</u>

tumor vaccine

A tumor is part of oneself.
The tumor cannot be directly used

vaccine is based on **INFORMATION**

vector vaccines are the <u>rule</u>

Cancer vaccines work! ..... in mice

nature COMMUNICATIONS

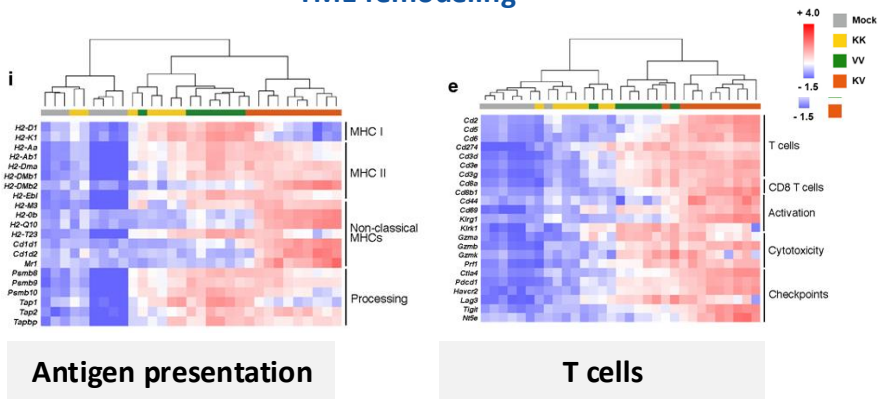
ARTICLE

https://doi.org/10.1038/s41467-021-25506-6 OPEN

A modular self-adjuvanting cancer vaccine combined with an oncolytic vaccine induces potent antitumor immunity

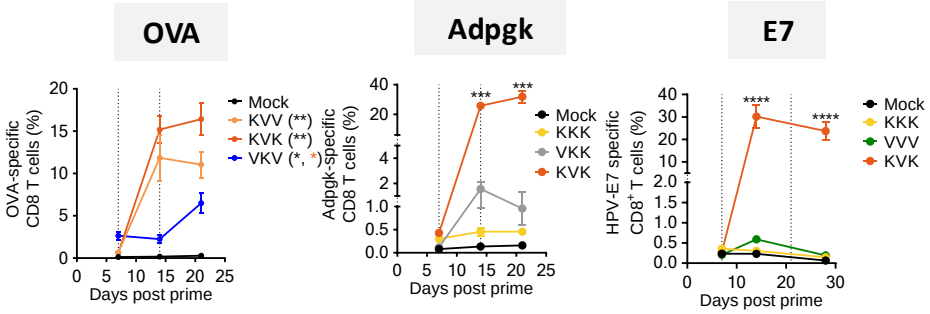
Krishna Das[1,2,8], Elodie Belnoue[3,4,8], Matteo Rossi[3,4], Tamara Hofer[1,2], Sarah Danklmaier[1,2], Tobias Nolden[4,5], Liesa-Marie Schreiber[1,2], Katharina Angerer[1,2], Janine Kimpel[2], Sandra Hoegler[6], Bart Spiesschaert[4,5], Lukas Kenner[6,7], Dorothee von Laer[2], Knut Elbers[4,5], Madiha Derouazi[3,4✉] & Guido Wollmann[1,2✉]

TME remodeling

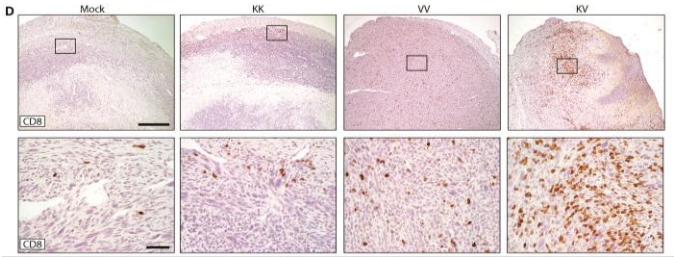


Antigen presentation **T cells**

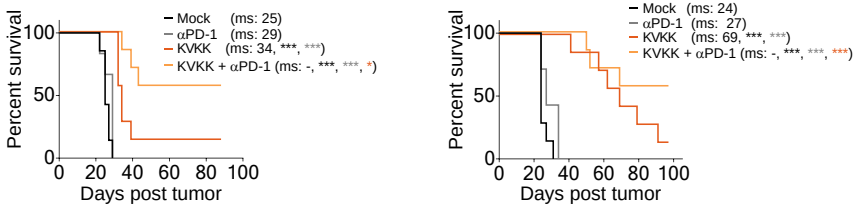
Antigen-specific T cell induction



TILs infiltration



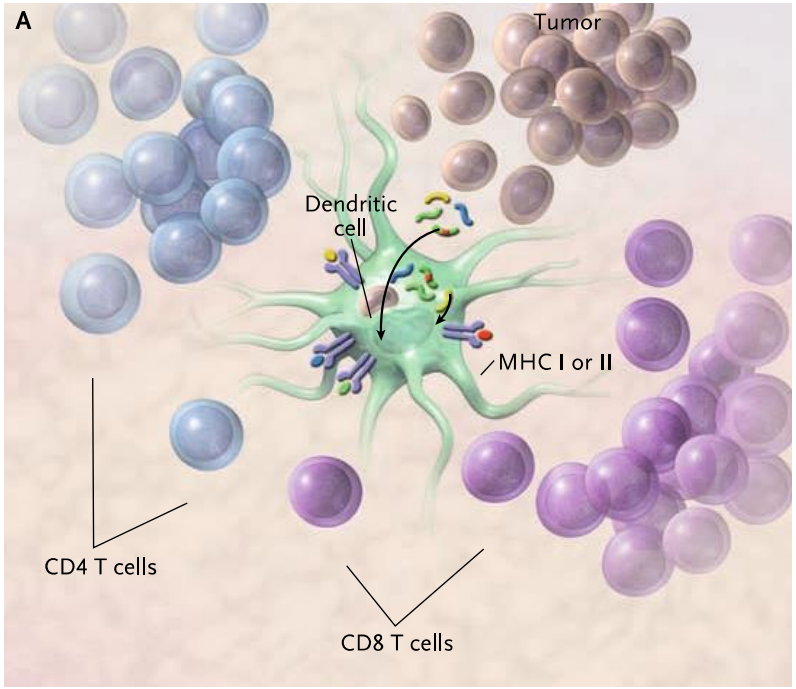
Effect on CPI failures



Vaccine

Platform vs Target

Vaccine platforms



General requirements

- target: antigen presenting cells (DCs)
- MHC-1 presentation = intracellular proteins
- immune adjuvanticity

Finn, NEJM, 2008

Vaccine platforms

Inside the body

DNA vaccine

IM or electroporation

DNA

- Built-in adjuvants such as CpG (TLR9)
- Co-expression of chemokines to target specific DC subsets

Transcription

RNA vaccine

Intranodal and IV or lipoplex

mRNA

Vesicle

- Built-in adjuvants such as ssRNA and dsRNA
- IV lipoplex vaccine can access DCs globally

Translation

Peptide vaccine

SC or IM

Protein

- No built-in adjuvants
- Short peptides can be directly presented on MHC
- SLPs yield best results with adjuvants and $CD4^+$ T cell-activating helper peptides

Processing and cross-presentation

DC — MHC class I or II

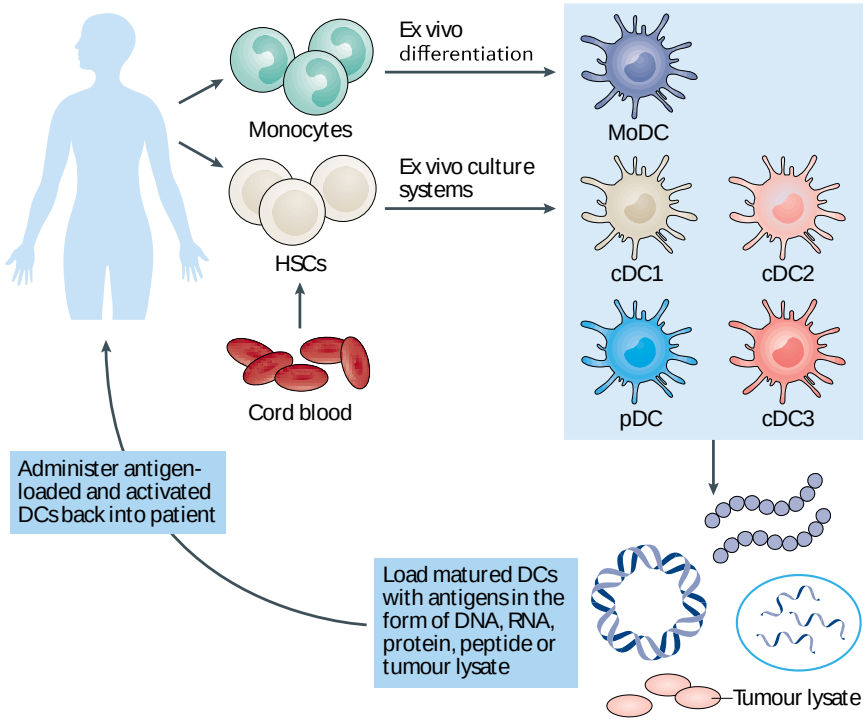
Viral vector vaccine

IM or IV

DNA or RNA

- Intrinsic adjuvanticity
- Potential to directly kill cells -> antigen spread
- $CD4^+$ + $CD8^+$ activation

outside the body



Modified: Saxena et al., Nature Rev Cancer, 2021

Vaccine platforms

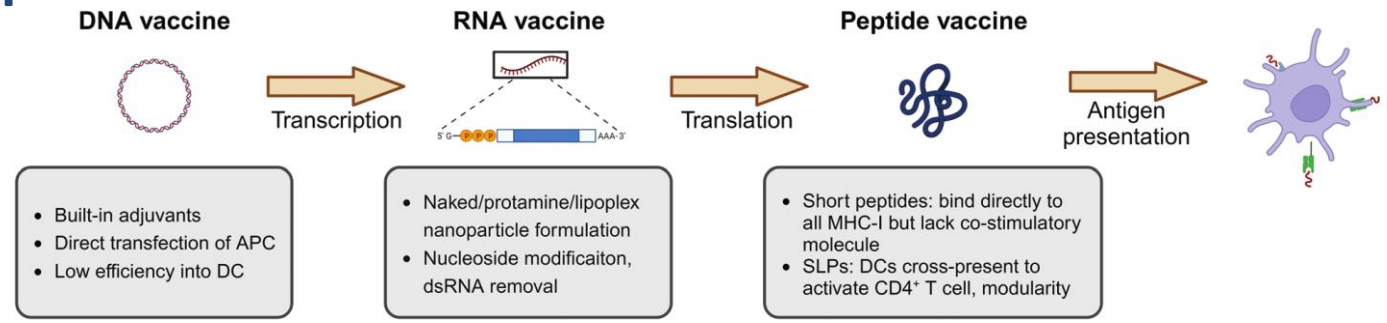


Fig. 5 Direct delivery of antigen. TAA or TSA, which are the antigens with tumor immunogenicity, could be delivered directly into the body as DNA, RNA, or peptides using different adjuvants. DNA and RNA vaccines provide the potential for more efficient delivery and sustained expression of the target antigen, while peptide vaccines are generally easier to produce and have a strong safety profile. TAA Tumor-associated antigen, TSA Tumor-specific antigen, APC Antigen presentation cell, DC Dendritic cell, MHC-I Major histocompatibility complex-I, SLPs Synthetic long peptides; dsRNA, Double-stranded RNA

Table 1. Advantages and disadvantages of different forms in neoantigen cancer vaccine

Vaccine types	Advantages	Disadvantages
DNA vaccine	● Low cost; ● Cell-independent production; ● Long-lasting immune response ● potential for targeting multiple neoantigens	● Risk of integration into host genome; ● Risk of autoimmune reactions ● Low transfection efficiency
RNA vaccine	● Rapid development and easy modification; ● High immunogenicity; ● Cell-independent production; ● Intrinsic adjuvant effect; ● High efficiency into DCs	● Fast degradation speed; ● Potential for inflammatory reaction
Peptide vaccine	● High specificity and safety; ● Cell-independent production; ● Low risk of autoimmunity; ● Direct presentation on MHC in short peptides; ● Proven clinical activity in SLP	● High cost; ● Complex manufacture; ● Requirement for suitable adjuvants; ● Potential for HLA-restriction
Cell-based vaccine	● Strong immune stimulation; ● Multi-form antigen loading	● High cost; ● Potential for immunogenicity of the cells; ● Need for patient-specific customization
Viral and bacterial vector vaccine	● High immunogenicity; ● Long-lasting immune response; ● Self adjuvanticity	● Potential for vector immunogenicity; ● Need for specialized storage conditions

Fan et al., 2023. Sig Transduct Target Ther

Vaccine platforms

We don’t have a shortage on effective vaccine platforms !!!

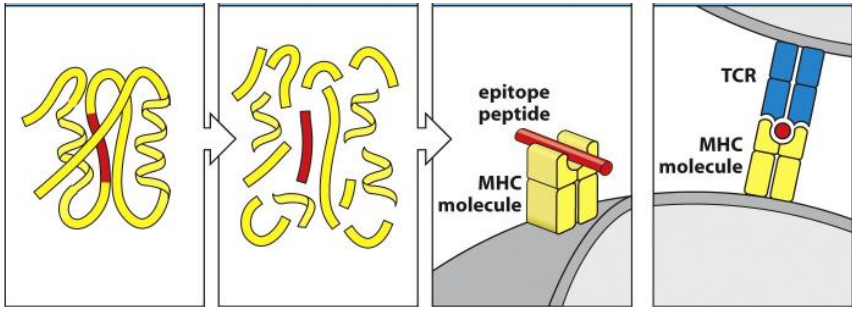
vaccine targets

=

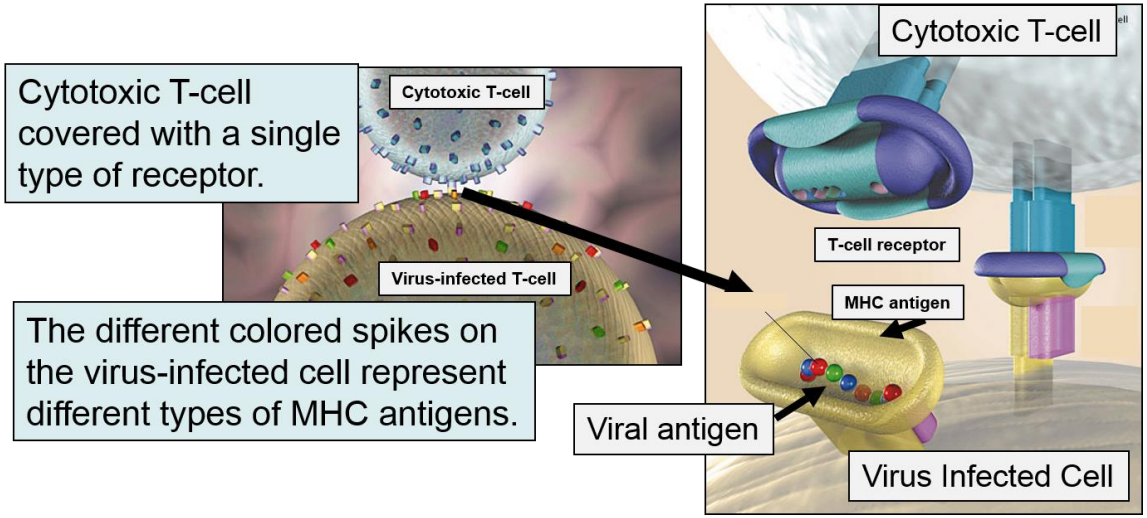
tumor antigens

Antigen presentation and recognition

antigen = only a SMALL PART of a protein



T cell recognition is HIGHLY specific for certain epitopes



Janeway Immunologie, 2018, Springer

Boston University School of Public Health

Perfect world tumor antigen

- selective expression in tumor cells

- homogenous expression in all tumor cells

- essential expression in tumor cells

- high immunogenicity

Perfect world tumor antigen

- selective exp
- homogenous
- essential exp
- high immun

Tumor antigen classes

	tumor SPECIFIC antigen		tumor ASSOCIATED antigen		
	Neoantigen	Oncoviral	Cancer Testis	Overexpression	Lineage
Foreignness	high	high	low		
Immunogenicity	high	high	low		
Tolerance	low	low	high		
Shared	rarely	mostly*	mostly		
Personalized	mostly	yes (HLA)/no	rarely		
Cost	high	medium	medium		

=TSA

=TAA

* only few tumor entities

Non-personalized tumor antigens – examples

oncoviral	cancer testis (> 140 CTA)	lineage	overexpression
• HPV E6/7	• NY-ESO-1	• HER2/Neu	• MUC1
• LMP1/LMP2	• MAGE-A	• MUC1	• WT1
	• SAGE	• gp100	• EGFR
	• LY6K		
	• CDCA1		
	• PRAME		

Oncoviral tumor antigens

Antigen	Oncovirus	Associated cancer
E6, E7	HPV	cervix CA, head-neck SCC
LMP1, LMP2	EBV	Nasopharingeal CA, B cell lymphoma
Large T, small T	Merkel Polyomavirus	skin CA
Tax	HTLV1 retrovirus	T cell leukaemia

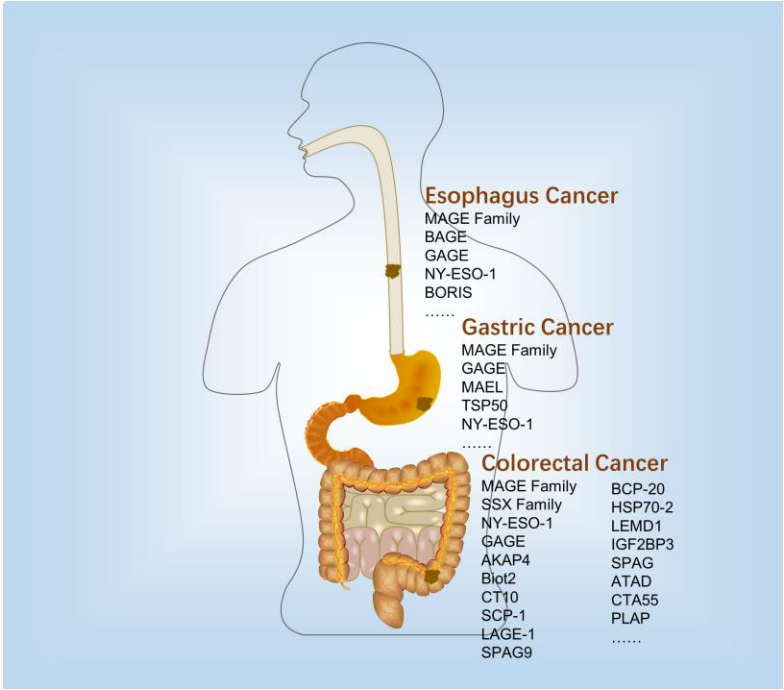
Cancer testis antigens

over 140 cancer testis antigens (CTA) known to date

CTA main examples

Antigen	Associated cancer
NY-ESO-1	melanoma
MAGE-A	melanoma, lung
BAGE	melanoma, other cancers
PRAME	melanoma, other cancers
XAGE1B	multiple cancers
WT1	multiple cancers

CTA examples gastro-intestinal tumors



Ai et al., Frontiers Immunology, 2023

Cancer testis antigens

Tumor-associated antigen clinical trials in lung cancer

Platform	Name	TAA	Phase	Patients		Signs of efficacy
cellular vaccine	GVAX	Autol. tumor cells	I/II	86	NCT00074295	negative
	Belagenpumatucel- L	Allogenic NSCLC	III	532	NCT00676507	negative
	1650-G	Allogenic NSCLC	II	12	NCT00654030	n.a.
peptide	MAGE-A3	MAGE-A3	III	2312	MAGRIT, NCT00480025	negative
	CIMAvax-EGF	EGF	III	579		negative
	Racotumomab-alum	NeuGcGM3	III	1082	NCT01460472	low
	Tecemotide (L-BLP25)	MUC-1	III	1513	NCT00409188	negative
	PRAME	PRAME	I	60	NCT01159964	negative
virus	TG4010	MUC-1	II	65	NCT00415818	positive
	LV305	NY-ESO-1	I	47	NCT02122861	positive
DNA	V934/935	hTERT	I		NCT00753415	
RNA	CV9201	NY-ESO-1, MAGE-C1,2, Survivin, 5T4, MUC	I/II	46	NCT00923312	immunogenicity
	CV9202	NY-ESO-1, MAGE-C1,2, Survivin, 5T4, MUC	I	26		immunogenicity
	mRNA-5671/V941	KRAS (G12D, G12V, G13D, G12C)	I	100	NCT03948763	

=> few signs of efficacy

= vector based gene transfer

Cancer testis antigens

THE LANCET
Oncology

ARTICLES | VOLUME 17, ISSUE 6, P822-835, JUNE 01, 2016

Efficacy of the MAGE-A3 cancer immunotherapeutic as adjuvant therapy in patients with resected MAGE-A3-positive non-small-cell lung cancer (MAGRIT): a randomised, double-blind, placebo-controlled, phase 3 trial

Prof Dr Johan F Vansteenkiste, MD • Byoung Chul Cho, MD • Tonu Vanakesa, MD • Tommaso De Pas, MD • Prof Marcin Zielinski, MD • Moon Soo Kim, MD • Prof Jacek Jassem, MD • Masahiro Yoshimura, MD • Jubrail Dahabreh, MD • Haruhiku Nakayama, MD • Libor Havel, MD • Haruhiko Kondo, MD • Prof Tetsuya Mitsudomi, MD • Prof Konstantinos Zarogoulidis, MD • Oleg A Gladkov, MD • Katalin Udud, MD • Hirohito Tada, MD • Prof Hans Hoffman, MD • Anders Bugge, MD • Paul Taylor, MD • Prof Emilio Esteban Gonzalez, MD • Prof Mei Lin Liao, MD • Jianxing He, MD • Prof Jean-Louis Pujol, MD • Jamila Louahed, PhD • Muriel Debois, MSc • Vincent Brichard, MD • Channa Debruyne, MD • Patrick Therasse, MD • Nasser Altorki, MD • Show less

Published: April 27, 2016 • DOI: https://doi.org/10.1016/S1470-2045(16)00099-1 • Check for updates

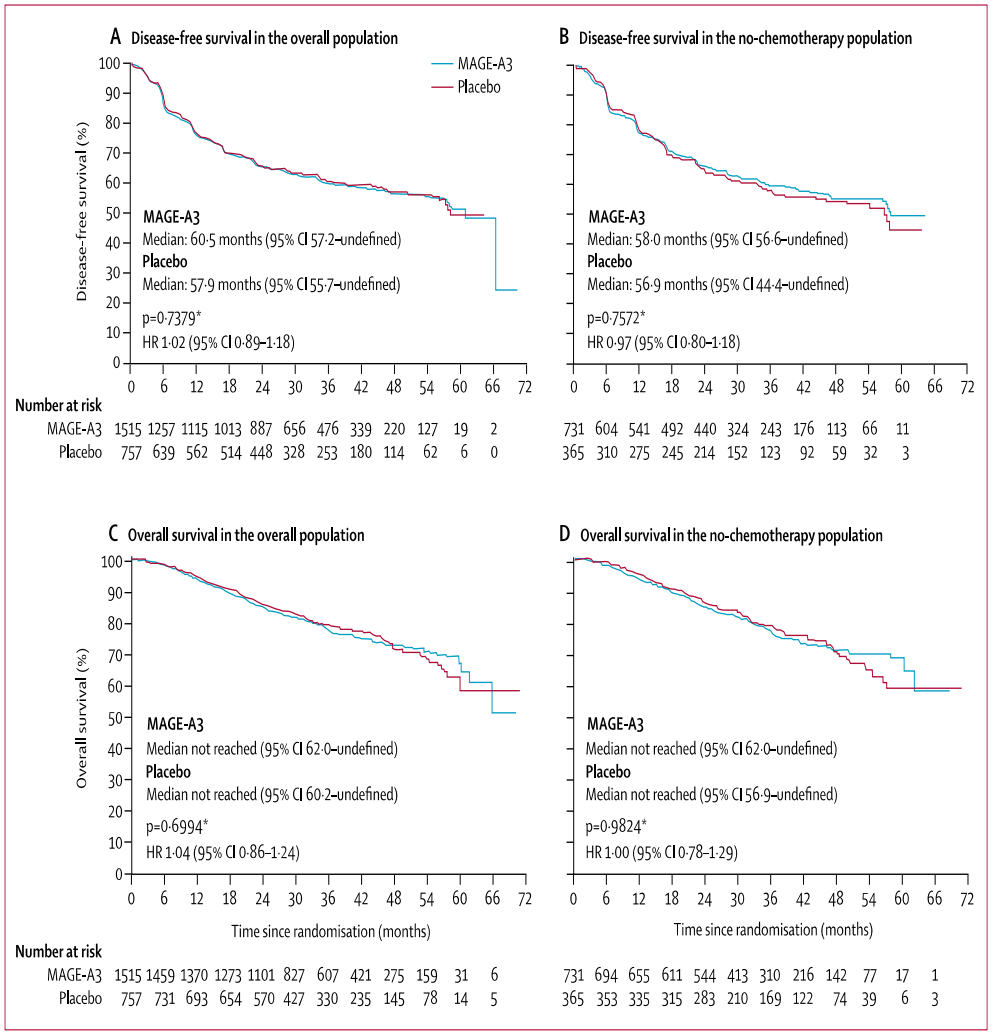


Figure 2: Disease-free survival and overall survival in the overall population and in the population that did not receive adjuvant chemotherapy

=> no signs of efficacy

Lineage / differentiation antigens

main examples

Antigen	Associated cancer
mesothelin	multiple CA
gp100	melanoma
tyrosinase	melanoma
PSA/ PSMA	prostate CA
CEA	gastric cancer, pancreatic CA
CA19-9	gastric cancer
MUC1	multiple cancers
CA125	ovarian CA

Overexpression antigens

main examples

Antigen	Associated cancer
MUC1	multiple CA
WT1	multiple CA
EGFR	multiple CA
PSA/ PSMA	prostate CA
MUC1	multiple cancers

TAA combinations

NY-ESO-1, MAGE-C1, MAGE-C2, survivin, 5T4, and MUC-1

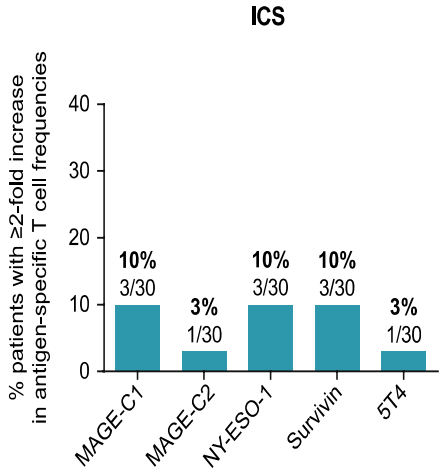
Cancer Immunology, Immunotherapy (2019) 68:799–812
https://doi.org/10.1007/s00262-019-02315-x

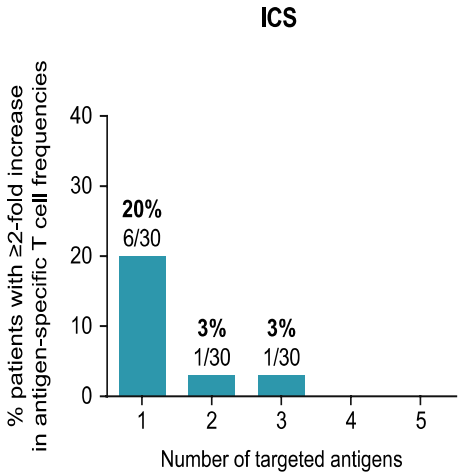
CLINICAL TRIAL REPORT

Check for updates

A phase I/IIa study of the mRNA-based cancer immunotherapy CV9201 in patients with stage IIIB/IV non-small cell lung cancer

Martin Sebastian[1,13] · Andreas Schröder[2,14] · Birgit Scheel[2] · Henoch S. Hong[2,14] · Anke Muth[2] · Lotta von Boehmer[3,15] · Alfred Zippelius[4] · Frank Mayer[5,16] · Martin Reck[6] · Djordje Atanackovic[7,17] · Michael Thomas[8] · Folker Schneller[9] · Jan Stöhlmacher[10,18] · Helga Bernhard[11] · Andreas Gröschel[12,19] · Thomas Lander[2] · Jochen Probst[2,20] · Tanja Strack[2] · Volker Wiegand[2] · Ulrike Gnad-Vogt[2] · Karl-Josef Kallen[2,21] · Ingmar Hoerr[2] · Florian von der Muelbe[2] · Mariola Fotin-Mleczek[2] · Alexander Knuth[3,22] · Sven D. Koch[2,23]





=> limited immunogenicity

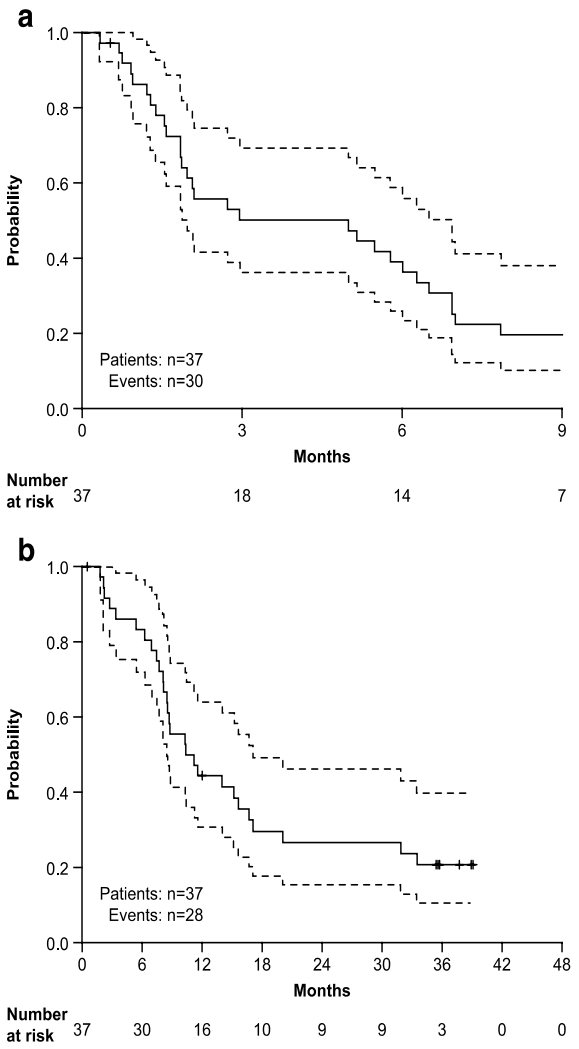


Fig. 4 Kaplan–Meier **a** PFS and **b** overall survival (OS) curves from initiation of treatment for the phase IIa cohort ($N=37$; 86% with stage IV disease). Dashed lines represent 95% CI. Median PFS was 5.0 months (95% CI 1.8–6.3 months) and the 6- and 12-month PFS rates were 38.9% and 16.7%, respectively. Median OS was 10.8 months (95% CI 8.1–16.7 months) and survival rates at 1, 2, and 3 years were 44.4%, 26.7%, and 20.7%, respectively

TAA cancer vaccine clinical development

Meta-analysis

Breast CA

- 46 studies, 1698 patients: ORR* only 9%

Ovarian CA

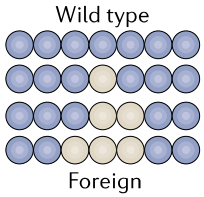
- 32 studies, 426 patients: ORR* only 4%

*ORR = overall response rate (incl. stable disease, partial response, complete response)

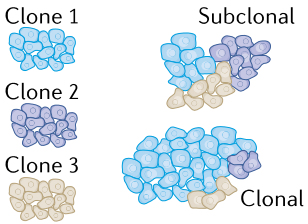
Neoantigens

Qualities of neoantigens

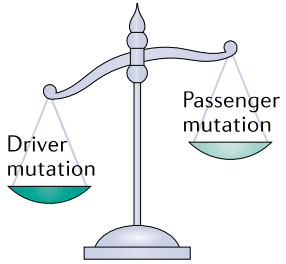
Foreignness
The greater the similarity to the wild-type amino acid sequence, the higher the probability of the responding T cells to be deleted during thymic selection



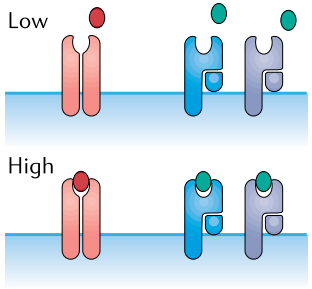
Clonal distribution
Subclonal mutations are present in a small percentage of tumour cells and have high chance of losing expression either spontaneously or after ICI



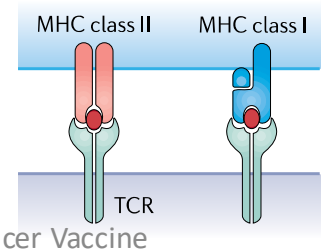
Driver vs passenger mutation
Passenger mutations are subject to loss of expression through tumour evolution or immune resistance. Driver mutations are more conserved as these serve critical survival functions



MHC presentation
Neoantigen presentation on MHC class I and/or MHC class II molecules and expression in tumours with higher HLA heterozygosity in HLA class I loci is more likely to induce T cell infiltration and increase survival in response to ICI

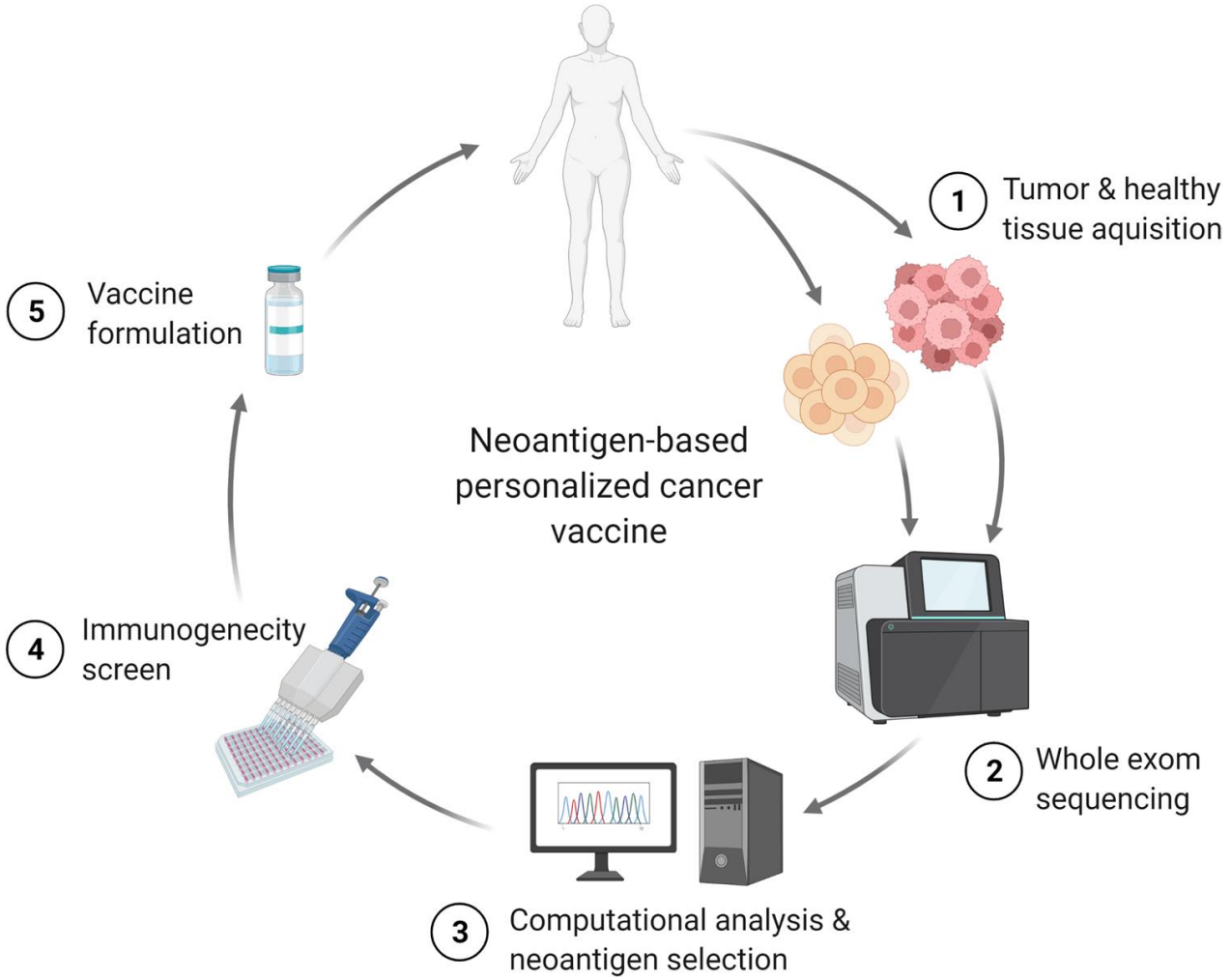


TCR avidity
- High TCR avidity of neoantigens induces a strong CTL-driven response to treatment
- Hard to predict



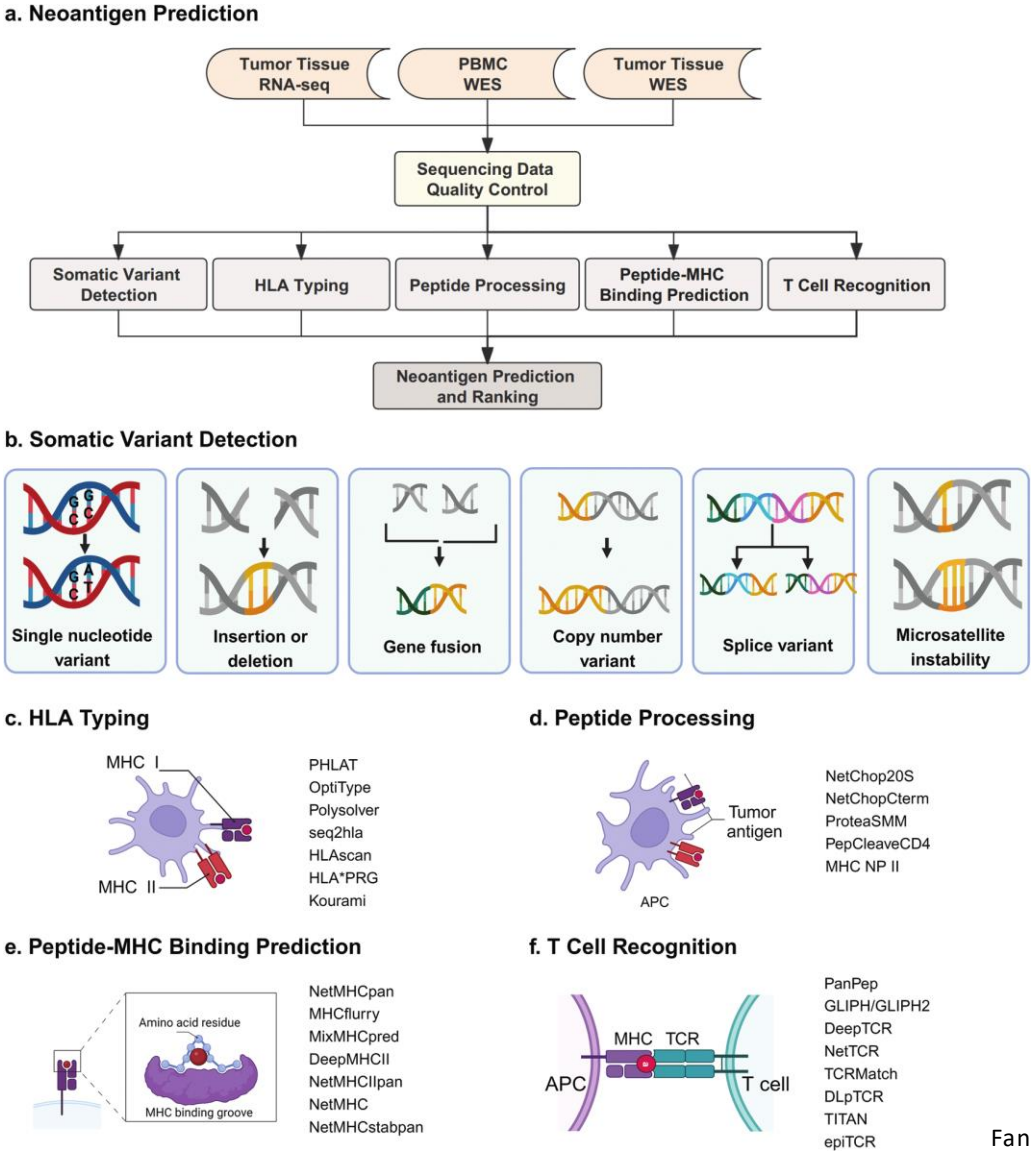
Saxena et al., Nature Rev Cancer, 2021

Personalized neoantigen vaccine – the simplified view



Grimmett et al., 2022,Discover Oncology

Personalized neoantigen vaccine – the complex view



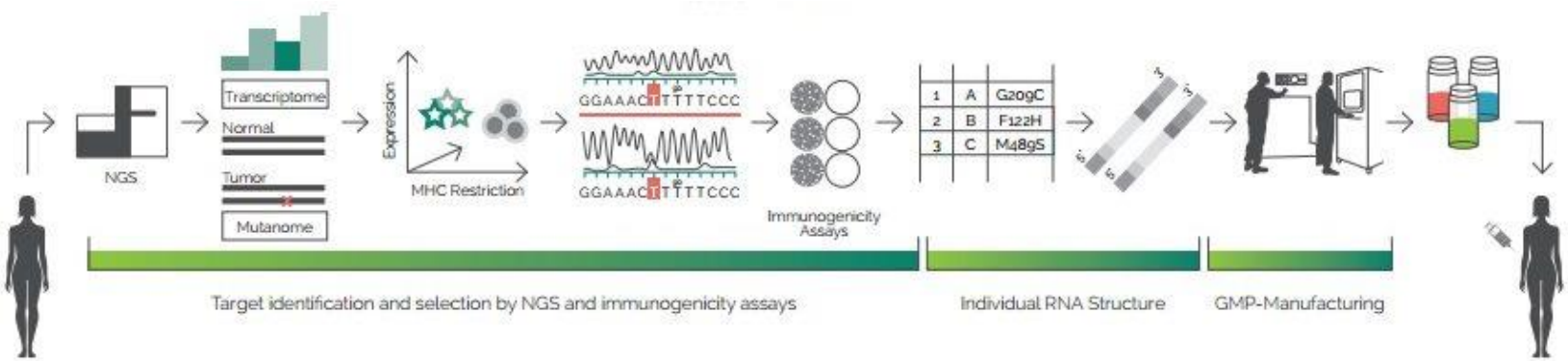
Fan et al. 2023, *Sig Transduct Target Ther*

Personalized neoantigen vaccine – CHALLENGES

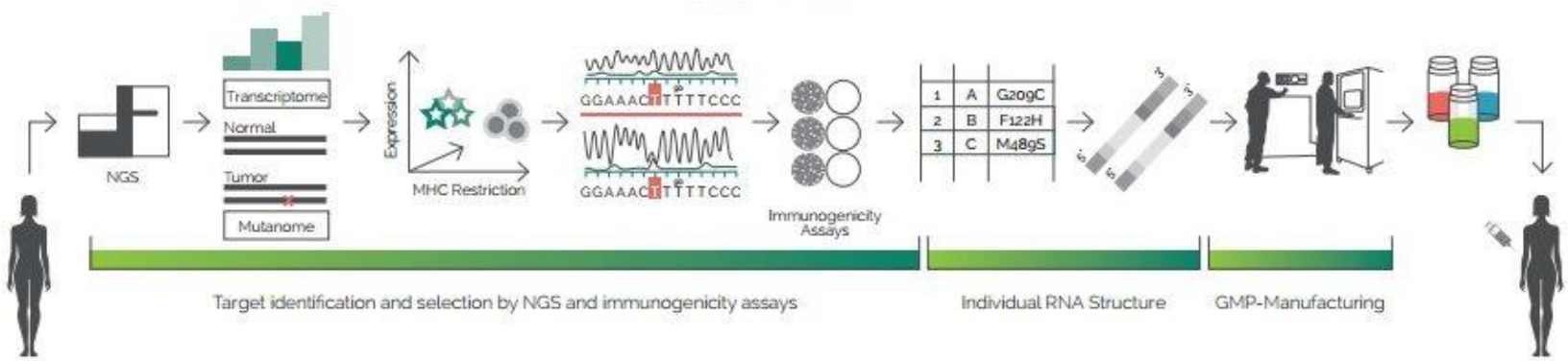
Challenges with personalized neoantigen vaccines:

- Speed
- Metastatic heterogeneity
- TMB (tumor mutational burden)
- Prediction
- HLA dependence

Challenge I - speed



Challenge I - speed



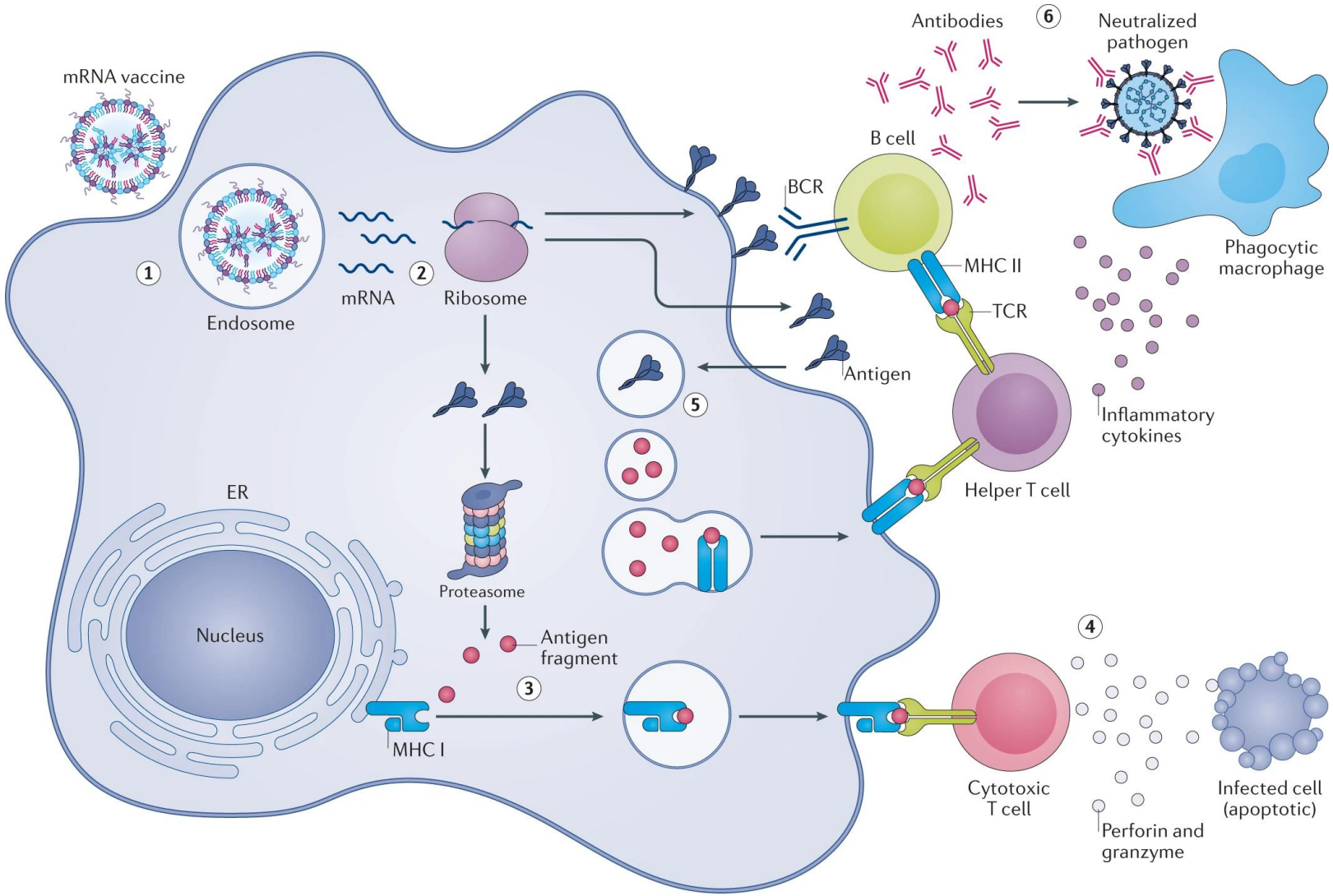
Turn around time from tumor biopsy to GMP-grade production and treatment*:

< 1 month!!!

* "needle-to-needle"

mRNA vaccine platform

Mode of action



Chaudhary et al., 2021, Nature Rev Drug Discovery

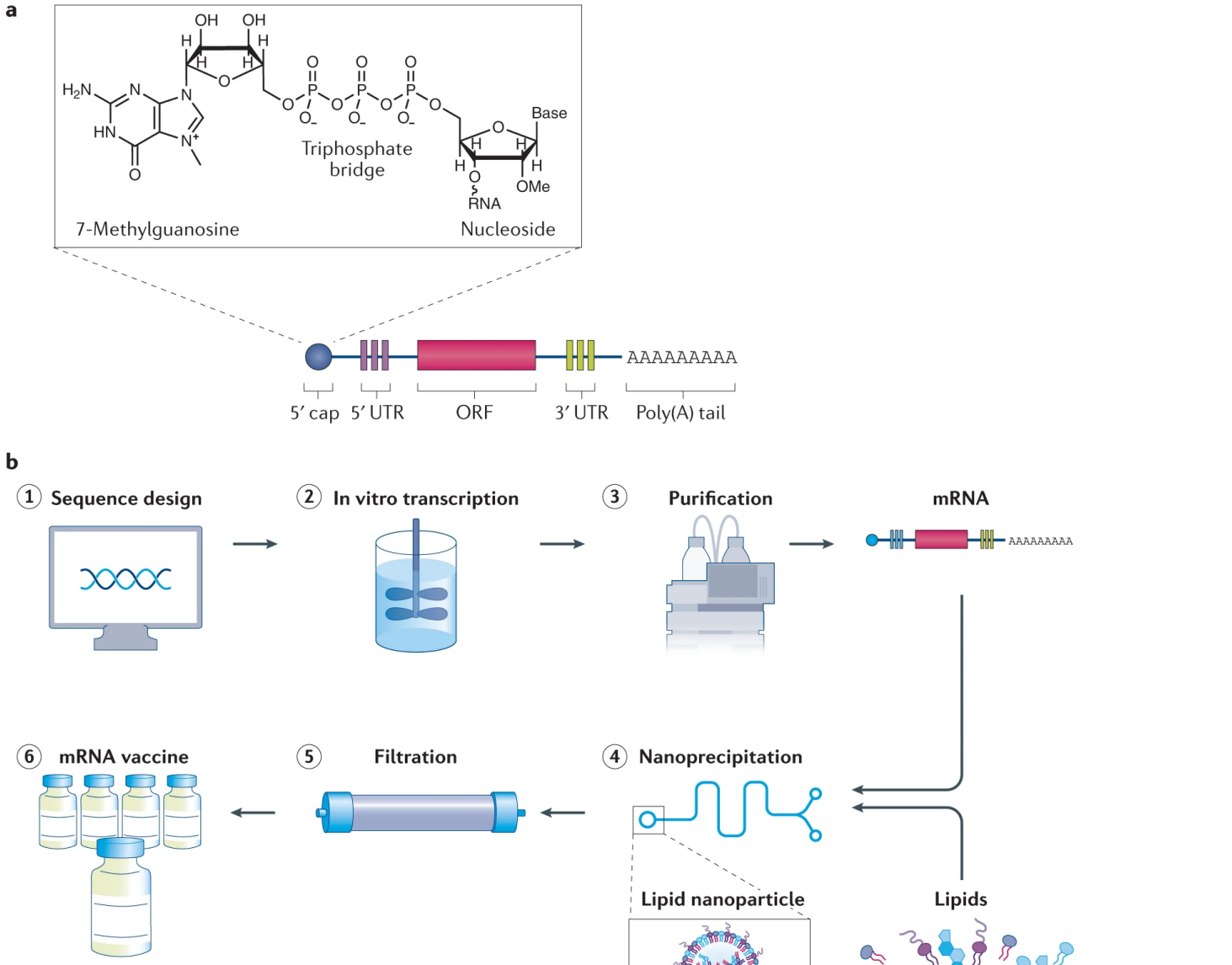
mRNA vaccine platform

Challenge of using mRNA vectors

1. **mRNA stability**
2. **mRNA delivery**
3. **mRNA reactogenicity**

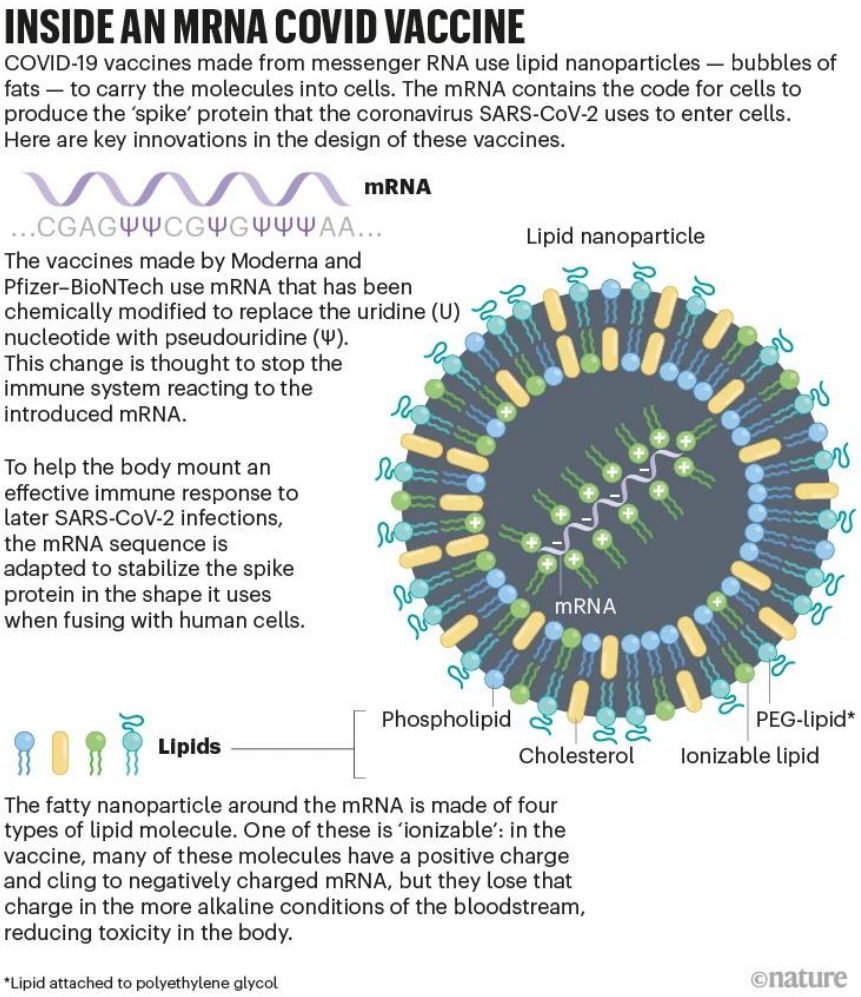
mRNA vaccine platform

Manufacturing mRNA - LNP vaccines



Chaudhary et al., 2021, Nature Rev Drug Discovery

mRNA vaccine platform



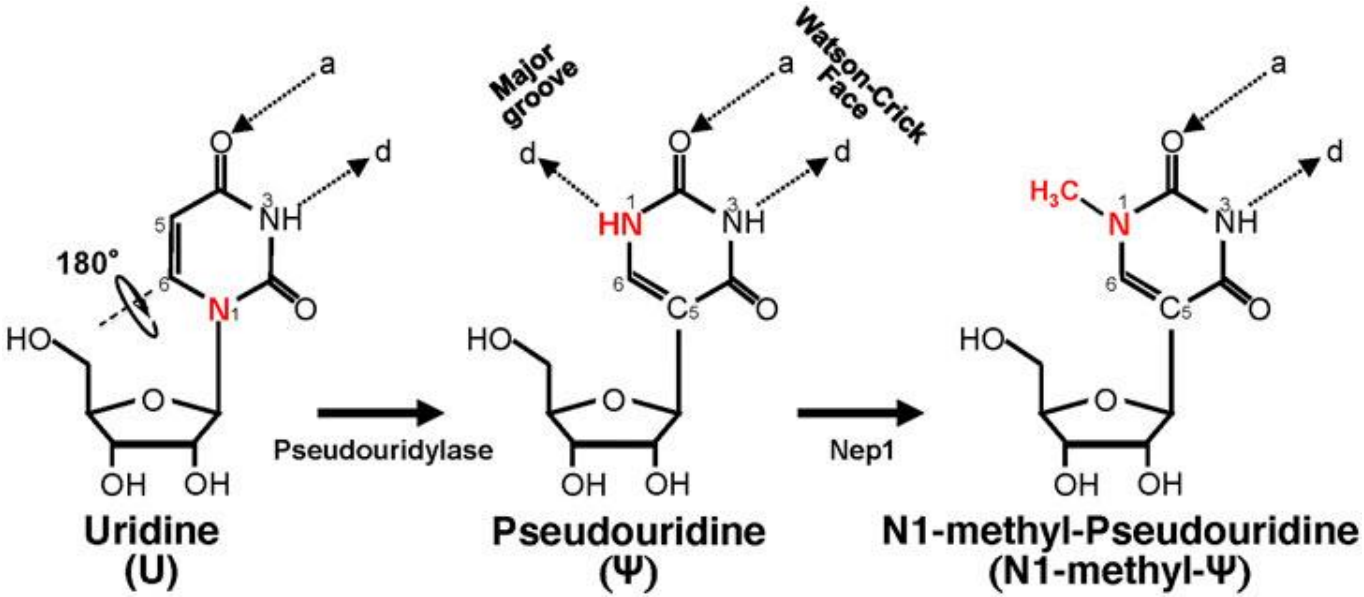
mRNA vaccines allow for a rapid turnover from design to clinical grade production:

- information input does not change biology/chemistry of compound
- stable pharmacokinetics (PK) and pharmacodynamics (PD)

Dolgin , 2021 Nature

mRNA vaccine platform

mRNA modification



mRNA modifications reduce the cellular defense mechanisms against exogenous mRNA:

- much higher antigen production inside the cell
- superior antibody responses
- role of mRNA modification on T cell immunity unclear

mRNA vaccine platform

mRNA vaccines allow for a rapid turnover from design to clinical grade production:

- information input does not change biology/chemistry of compound
- stable pharmacokinetics (PK) and pharmacodynamics (PD)
- ”needle-to-needle” time down to 28 days!

Personalized neoantigen vaccination via peptide vaccine platform

nature

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Article | Open access | Published: 05 February 2025

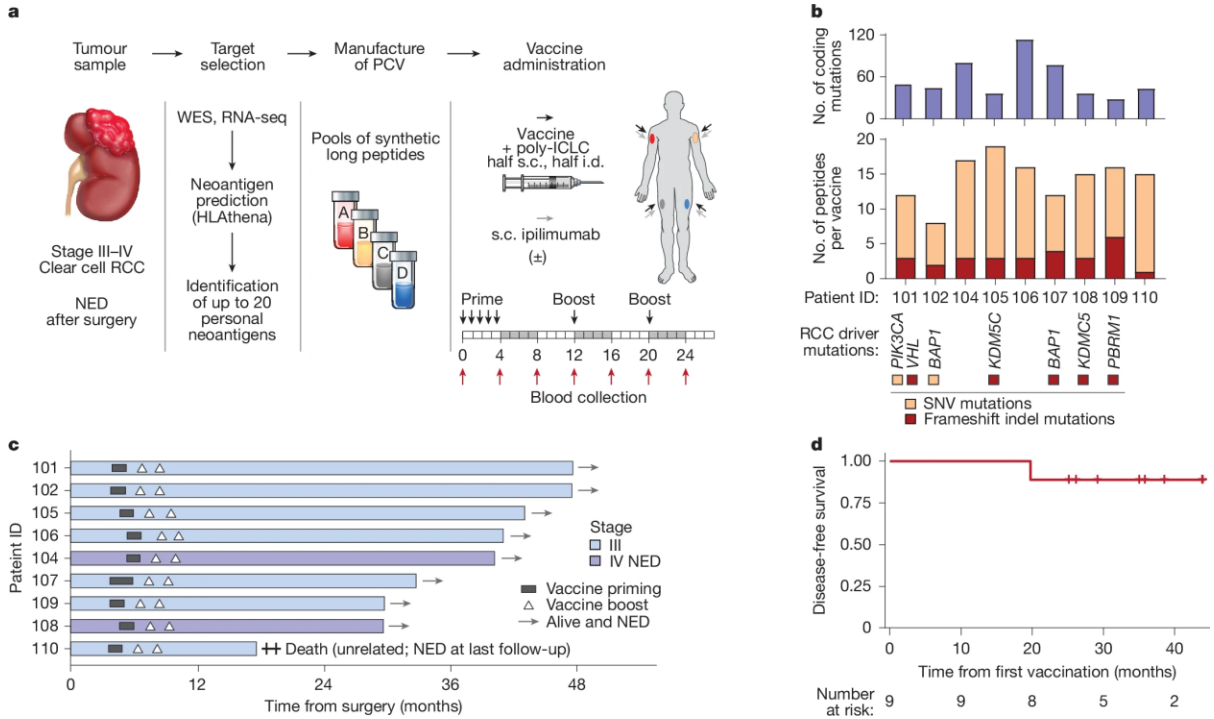
A neoantigen vaccine generates antitumour immunity in renal cell carcinoma

David A. Braun ✉, Giorgia Moranzoni, Vipheaviny Chea, Bradley A. McGregor, Eryn Blass, Chloe R. Tu, Allison P. Vanasse, Cleo Forman, Juliet Forman, Alexander B. Afeyan, Nicholas R. Schindler, Yiwen Liu, Shuqiang Li, Jackson Southard, Steven L. Chang, Michelle S. Hirsch, Nicole R. LeBoeuf, Oriol Olive, Ambica Mehndiratta, Haley Greenslade, Keerthi Shetty, Susan Klaeger, Siranush Sarkizova, Christina B. Pedersen, ... Toni K. Choueiri ✉ + Show authors

Nature **639**, 474–482 (2025) | Cite this article

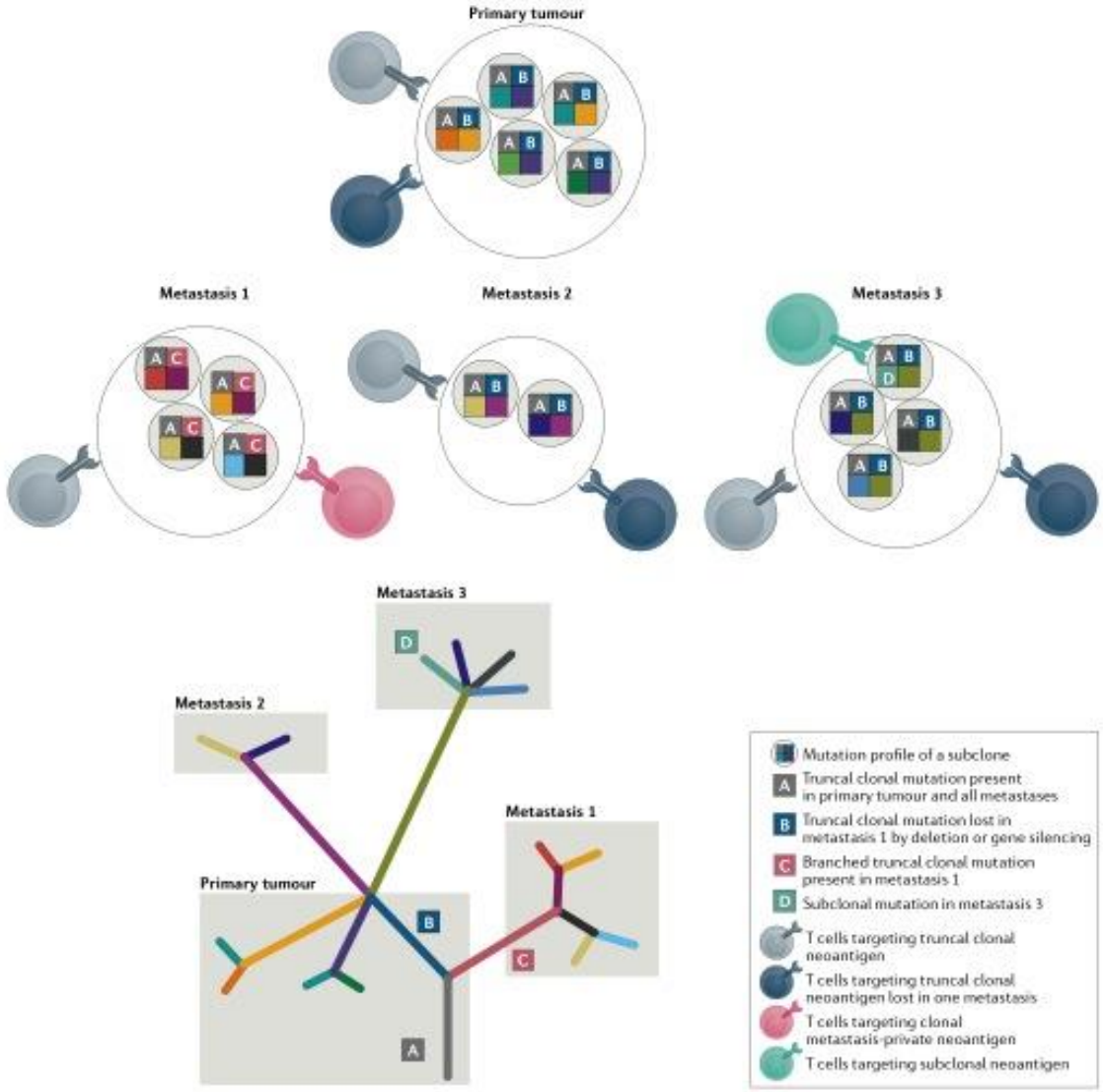
85k Accesses | **2** Citations | **1644** Altmetric | Metrics

Personalized neoantigen vaccine are NOT an exclusivity for mRNA platforms



Challenge II – heterogeneity of neoantigen landscape

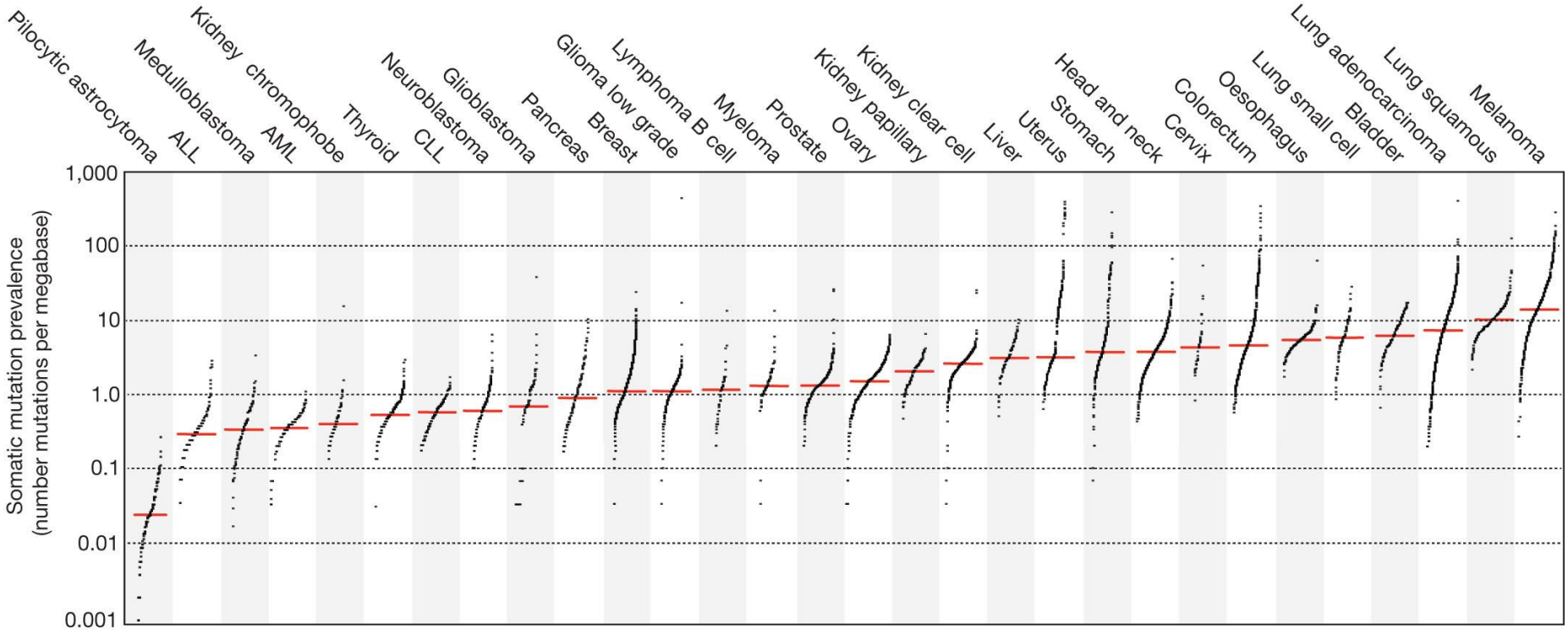
Neoantigens often differ between primary and secondary tumor sites!



Lang et al., Nature Reviews Drug Discovery, 2022

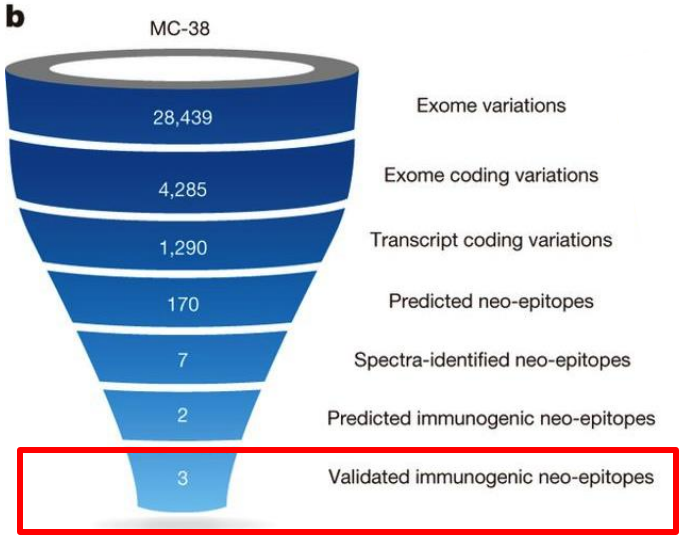
Challenge III – dependence on tumor mutational burden (TMB)

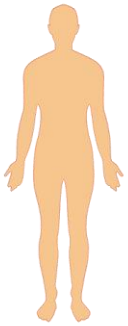
mutation frequency varies between tumor types

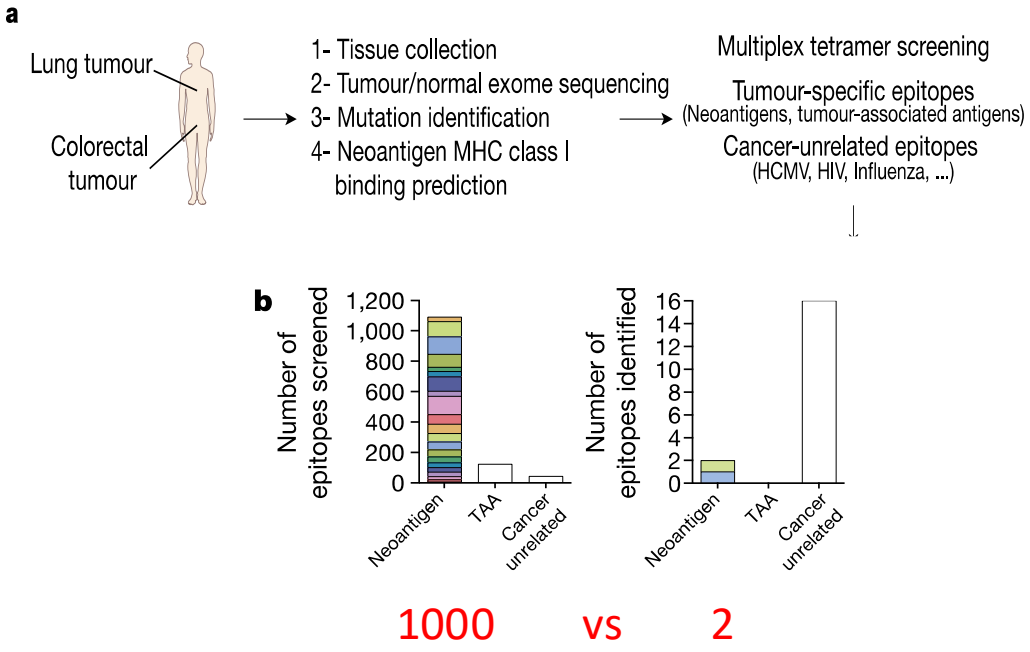


Alexandrov et al. Nature, 2013

Challenge IV – computational prediction







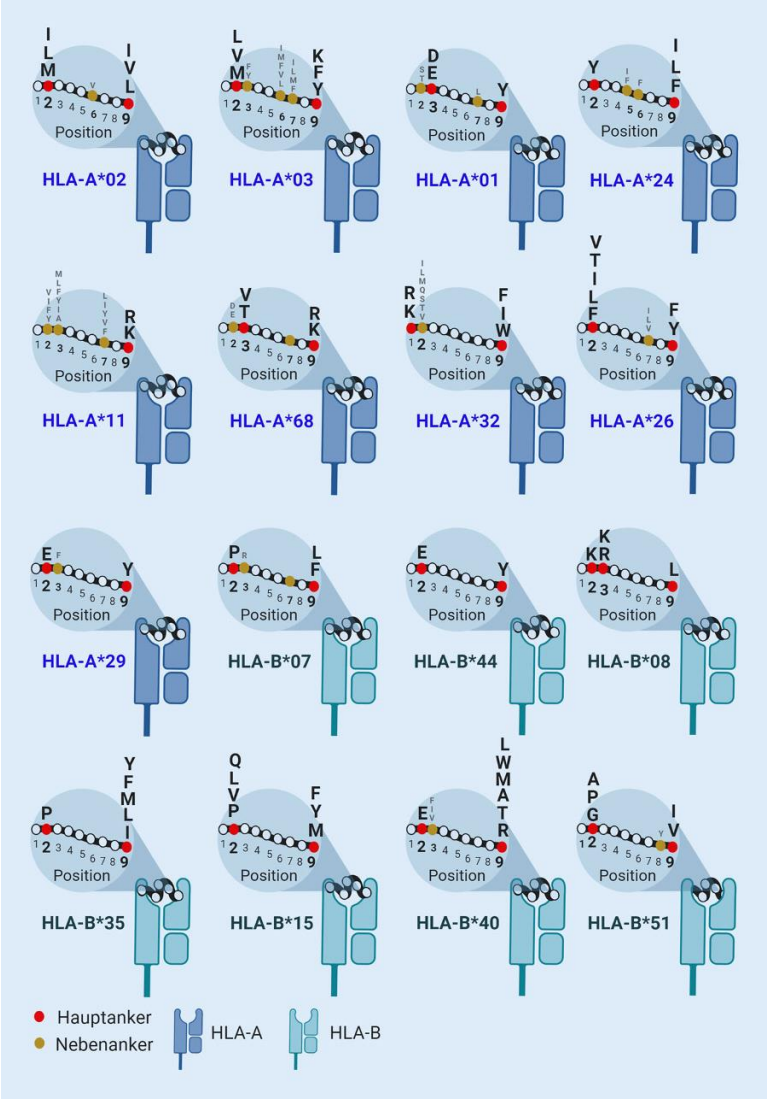
1000 vs 2

Yadav et al., Nature 2014

Simoni et al., Nature 2018

Challenge V – HLA dependency

HLA Variability



Epitope prediction depends on **common** HLA types

Rammensee and Löffler, 2020, Bundesgesundheitsblatt

Personalized neoantigen vaccine – clinical trials

Table 2 | Published clinical trials utilizing neoantigens as targets

Year of publication	Investigator /sponsor	Clinicaltrials.gov identifier, phase	Indication	Platform /treatment	Key results	Ref.
2014	NIH	NCT01174121, 1	Metastatic cholangiocarcinoma	Adoptive transfer of neoantigen-specific (ERBB2IP E805G) $CD4^+$ T cells isolated from tumor	Decrease in target lesions with stabilization of disease, reinjection led to tumor regression, single patient report	9
2015	Washington University	NCT00683670, 1	Stage III or IV melanoma	Intravenous application of neoepitope peptide-loaded DC vaccine	$CD8^+$ T cell responses and broadened antigenic breadth as well as clonal diversity	188,189
2016	NIH	NCT01174121, 2	Metastatic colorectal cancer	Adoptive transfer of neoantigen-specific (KRAS G12D) $CD8^+$ T cells isolated from tumor	Regression of multiple lung metastases upon infusion of four different T cell clonotypes	8
2017	BioNTech	NCT02035956, 1	Stage III or IV melanoma	Intranodal application of naked mRNA vaccine encoding for multiple neoepitopes	$CD8^+$ and especially $CD4^+$ T cell responses against multiple neoantigens, significant reduction of cumulative rate of metastatic events after vaccination	173
2017	Dana-Farber Cancer Institute	NCT01970358, 1	Stage III or IV melanoma	Subcutaneous application of peptide vaccine consisting of pooled mutated epitopes	Polyfunctional $CD8^+$ and especially $CD4^+$ T cell responses with durable memory response, recognition of autologous tumor, combination with anti-PD-1 therapy beneficial for clinical outcome	172,190
2019	Immatics	NCT02149225, 1	Glioblastoma	Intradermal application of peptide vaccine consisting of shared and mutated epitopes	$CD8^+$ and $CD4^+$ T cell responses against multiple shared and mutated epitopes	191
2019	Dana-Farber Cancer Institute	NCT02287428, 1/1b	Glioblastoma	Subcutaneous application of peptide vaccine consisting of pooled mutated epitopes	Polyfunctional $CD8^+$ and $CD4^+$ T cell responses with enriched memory phenotype and augmented T cell infiltration to the tumor	192
2020	Dana-Farber Cancer Institute /Neon Therapeutics / BioNTech US	NCT02897765, 1	Advanced melanoma, NSCLC, bladder cancer	Subcutaneous application of peptide vaccine consisting of pooled mutated epitopes combined with PD-1 blockade	Durable $CD8^+$ and especially $CD4^+$ T cell responses with cytotoxic potential, observation of epitope spreading upon vaccination	193
2020	NIH/Moderna	NCT03480152, 1	Metastatic gastrointestinal cancer	Intramuscular application of LNP-formulated mRNA vaccine encoding for multiple neoepitopes	$CD8^+$ and $CD4^+$ T cell responses against multiple mutated epitopes, small patient group ($n=4$), no objective clinical response	194
2021	NCT/ University of Heidelberg	NCT02454634, 1	Newly diagnosed glioma	Subcutaneous application of a single IDH1 (R132H) peptide vaccine	Vaccine-induced $CD4^+$ T cell responses across multiple MHC alleles in over 90% of the patients	174

= vector based gene transfer

Peri et al., Nature Cancer, 2023

Personalized neoantigen vaccine – clinical trials

Example 1

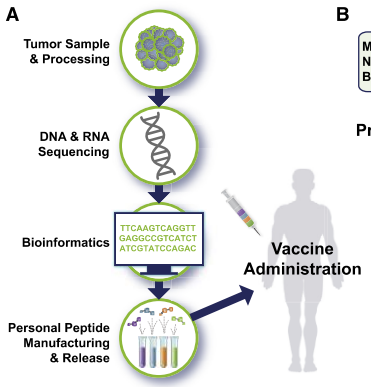
Cell

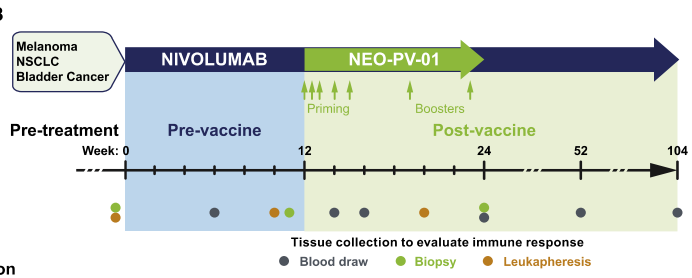
Volume 183, Issue 2, 15 October 2020, Pages 347-362.e24

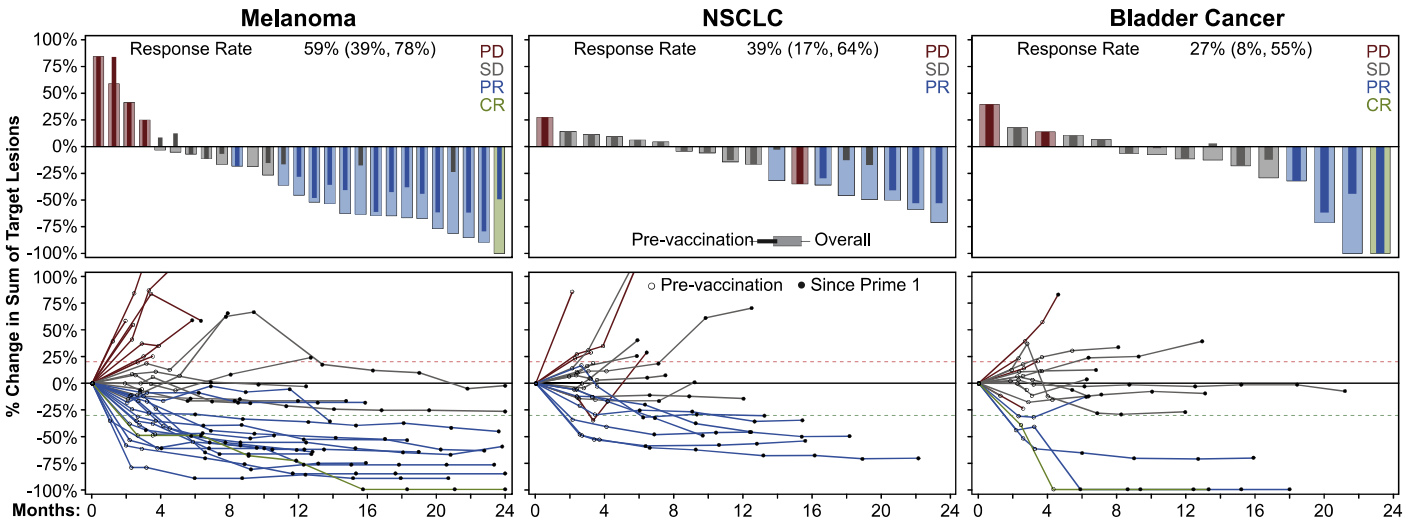
Article

A Phase Ib Trial of Personalized Neoantigen Therapy Plus Anti-PD-1 in Patients with Advanced Melanoma, Non-small Cell Lung Cancer, or Bladder Cancer

Patrick A. Ott [1], Siwen Hu-Lieskovan [2], Bartosz Chmielowski [2], Ramaswamy Govindan [3], Aung Naing [4], Nina Bhardwaj [5], Kim Margolin [6], Mark M. Awad [1], Matthew D. Hellmann [7], Jessica J. Lin [8], Terence Friedlander [9], Meghan E. Bushway [10], Kristen N. Balogh [10], Tracey E. Sciuto [10], Victoria Kohler [10], Samantha J. Turnbull [10], Rana Besada [10], Riley R. Curran [10] ... Lakshmi Srinivasan [10, 11]







Personalized neoantigen vaccine – clinical trials

Example **2**

Article

Personalized RNA neoantigen vaccines stimulate T cells in pancreatic cancer

https://doi.org/10.1038/s41586-023-06063-y

Received: 10 January 2023

Accepted: 6 April 2023

Published online: 10 May 2023

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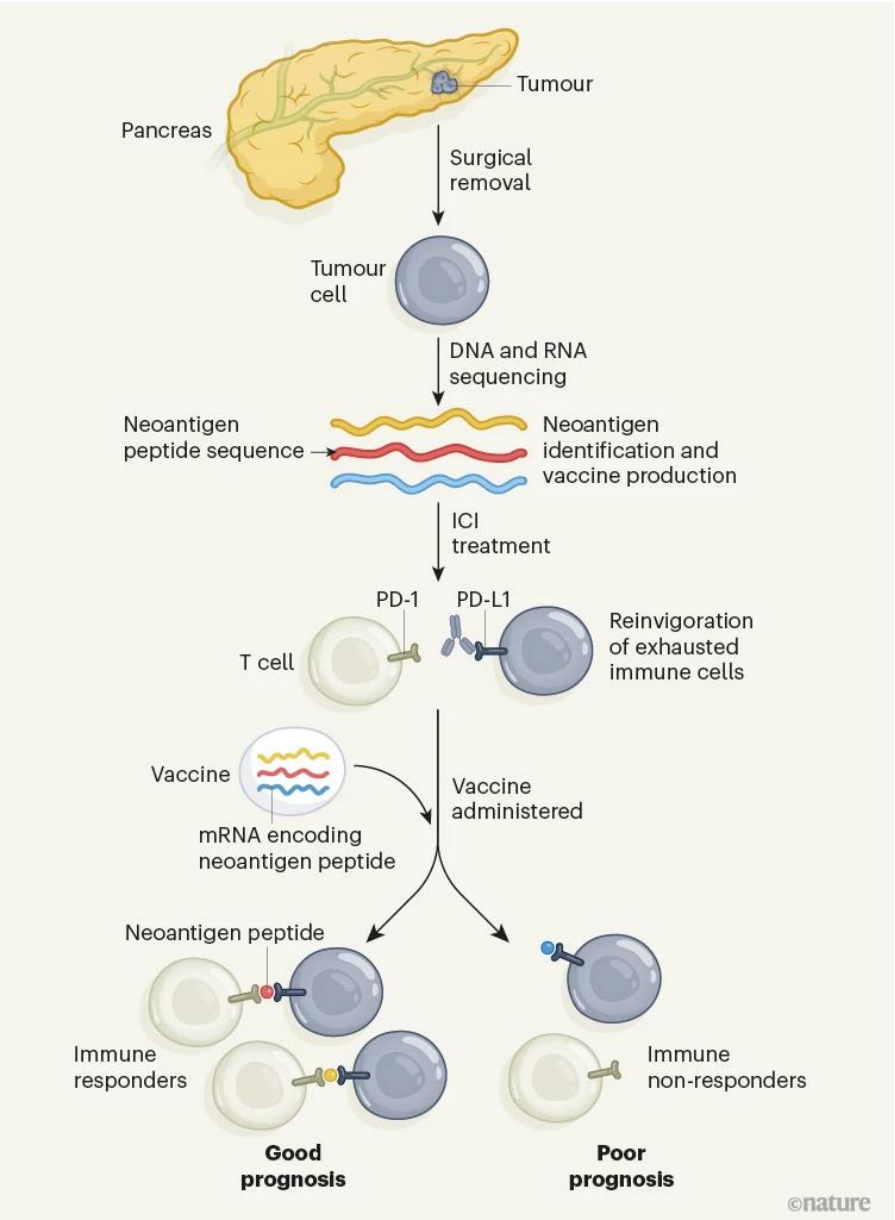

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- 16 pancreas cancer patients
- **up to 20 neoantigens** per vaccine compound
- **co-treatment with checkpoint inhibitor** anti-PD-L1 (atezolizumab)
- co-treatment with four-drug chemotherapy
- Study endpoints:
  - Neoantigen-specific T cell immunogenicity assay
  - 18 month recurrence-free survival

Personalized neoantigen vaccine – clinical trials

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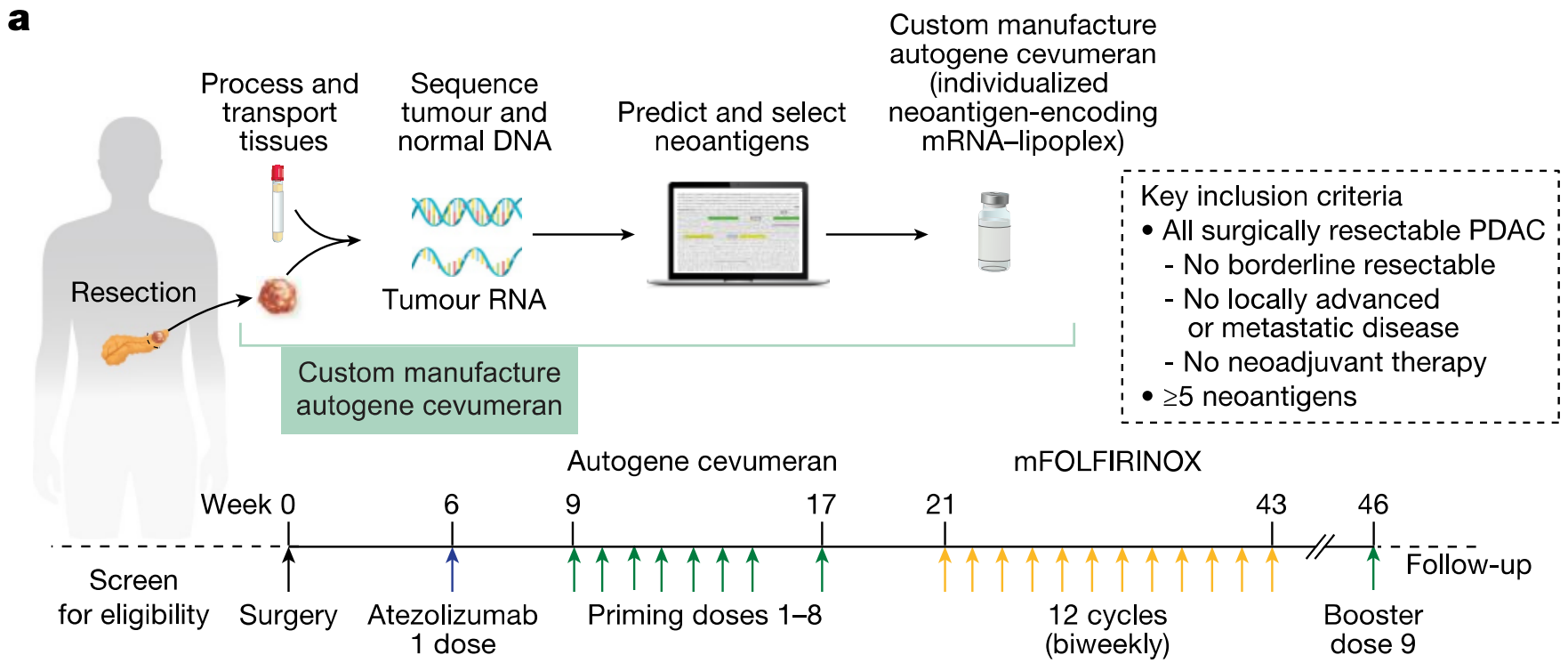

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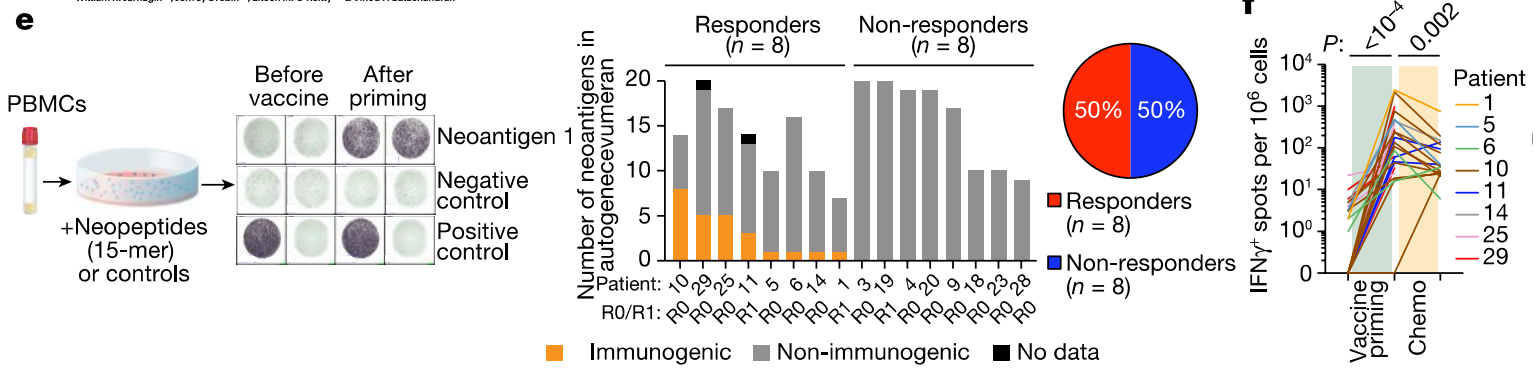


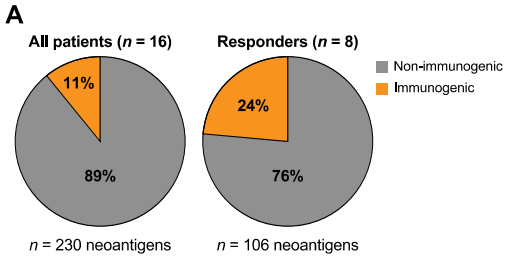
Exemplary ELISpot

CAVE: Only minority of included neoantigens are immunogenic

de novo response

50% of patients showed measurable immune responses against neoantigens

But only minority of all neoantigens responded to!



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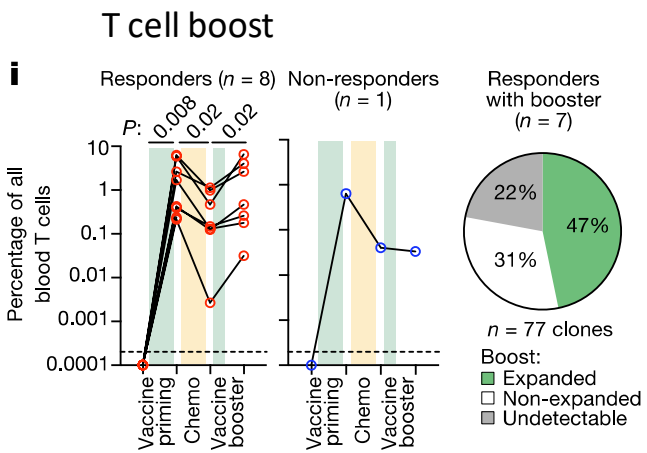
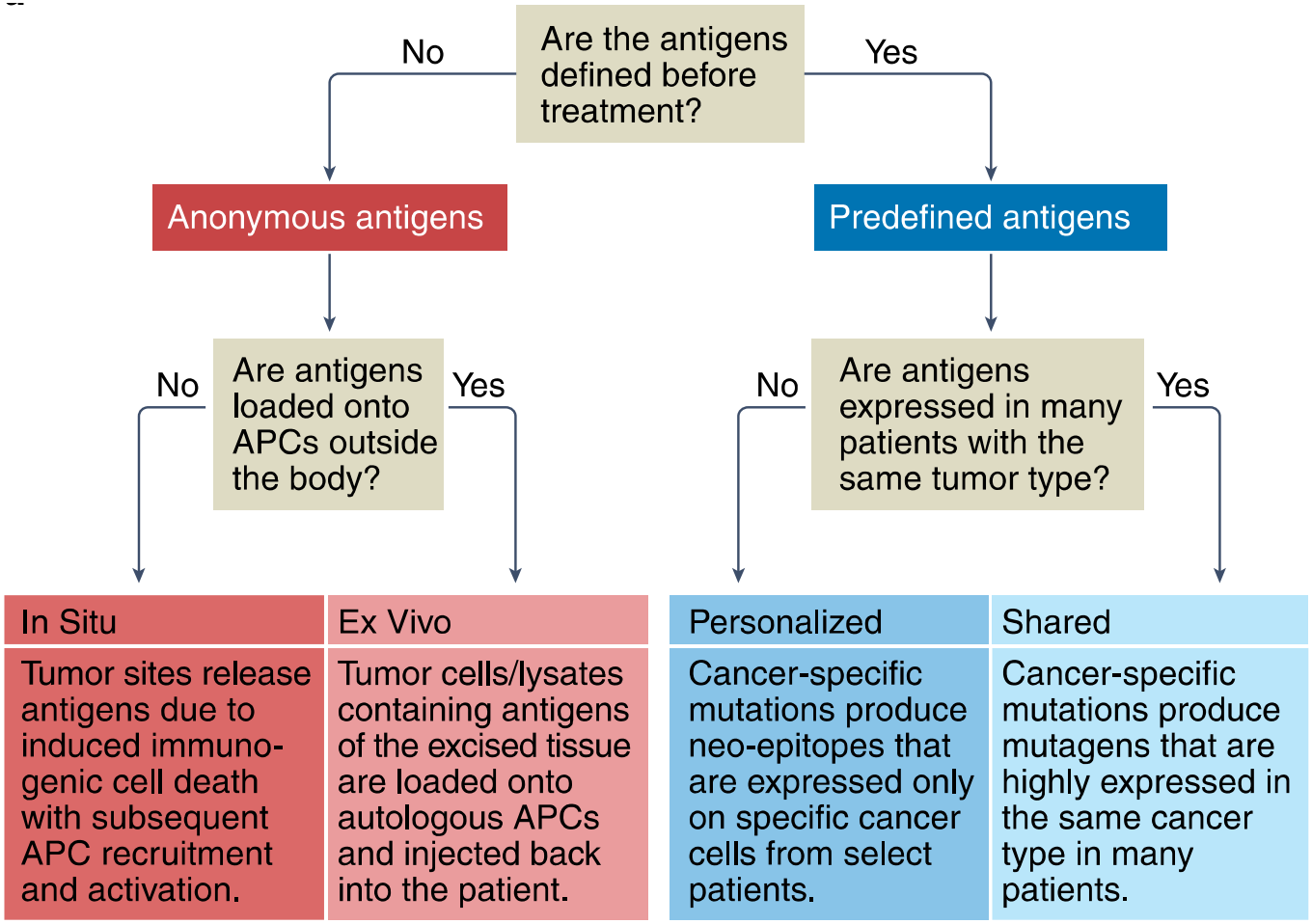
Boost effect of mRNA vaccines after chemotherapy



Important: maintained T cell functionality under chemotherapy (up to 2 years)!

Tumor antigens – quo vadis?



Lin et al., Nature Cancer 2022

Tumor antigens – anything else?

Private neoantigens

Shared tumor-associated antigens

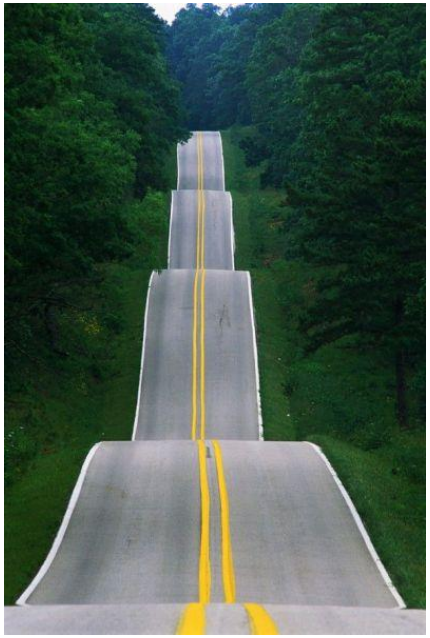
Black box

Tumor antigens – anything else?

Private neoantigens

Shared tumor-associated antigens

The road ahead



Shared neoantigens

1. driver mutations (e.g. KRAS, p53)
2. NON-coding regions
3. splicing variants
4. cryptic peptides

Shared neoantigen vaccine – clinical trials

Example **3**

nature medicine

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Article | Open access | Published: 09 January 2024

Lymph-node-targeted, mKRAS-specific amphiphile vaccine in pancreatic and colorectal cancer: the phase 1 AMPLIFY-201 trial

Shubham Pant ✉, Zev A. Wainberg, Colin D. Weekes, Muhammad Furqan, Pashtoon M. Kasi, Craig E. Devoe, Alexis D. Leal, Vincent Chung, Olca Basturk, Haley VanWyk, Amy M. Tavares, Lochana M. Seenappa, James R. Perry, Thian Kheoh, Lisa K. McNeil, Esther Welkowsky, Peter C. DeMuth, Christopher M. Haqq ✉ & Eileen M. O'Reilly ✉

Nature Medicine **30**, 531–542 (2024) | Cite this article

Shared neoantigen vaccine – clinical trials

Example **3**

nature medicine

Article https://doi.org/10.1038/s41591-023-02760-3

Lymph-node-targeted, mKRAS-specific amphiphile vaccine in pancreatic and colorectal cancer: the phase 1 AMPLIFY-201 trial

AMPLIFY-201 Study Overview

Phase 1 dose-ranging study to assess safety and efficacy of ELI-002 2P as adjuvant treatment in patients who completed standard therapy and have molecular disease

CLINICAL PROGRAM OVERVIEW: NCT04853017

Key Criteria

- ✓ mKRAS G12D / R – aligned to 2 peptide formulation
- ✓ No metastatic disease after locoregional treatment
- ✓ No radiographic evidence of disease (NED)
- ✓ High risk of relapse (MRD+ ctDNA/serum biomarkers)

Baseline Characteristics

25 patients enrolled across 5 dose cohorts, 23 evaluable at database cutoff (4/25/2023)

- **Advanced:** 68% had stage III or oligometastatic resected stage IV disease
- **Pre-treated:** All received prior chemo and surgery, 28% had prior radiation

Local Therapy
(e.g., Surgery, Chemo)

1-2 months

Prime
(6 doses over 8 weeks)

3-month

Boost
(4 doses over 4 weeks)

2 months

20-Months Follow-up

Basket Trial Enrollment

Pancreatic Ductal Adenocarcinoma (PDAC)	n=20
Colorectal Cancer (CRC)	n=5

Endpoints

- Safety
- Maximum Tolerated Dose (MTD) or RP2D
- ctDNA/serum biomarker change from baseline
- Immunological Responses
- Relapse Free Survival (RFS)

Shared neoantigen vaccine – clinical trials

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nature medicine

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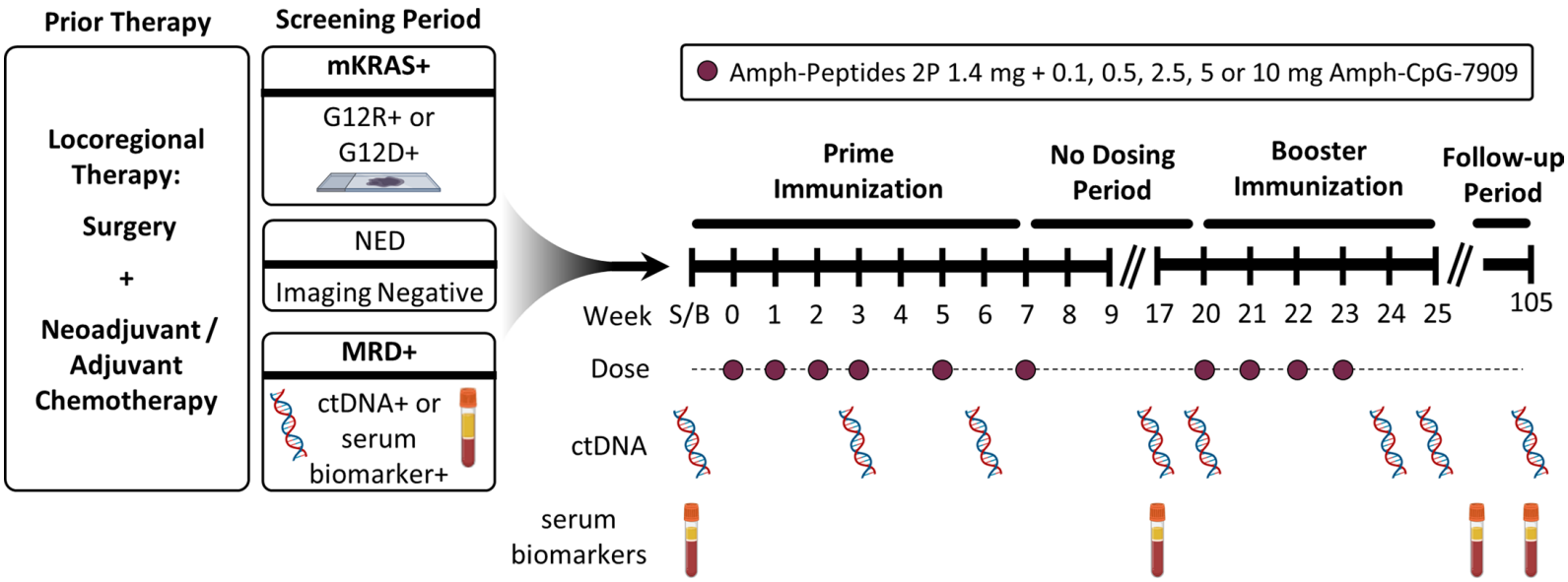

Shared neoantigen vaccine – clinical trials

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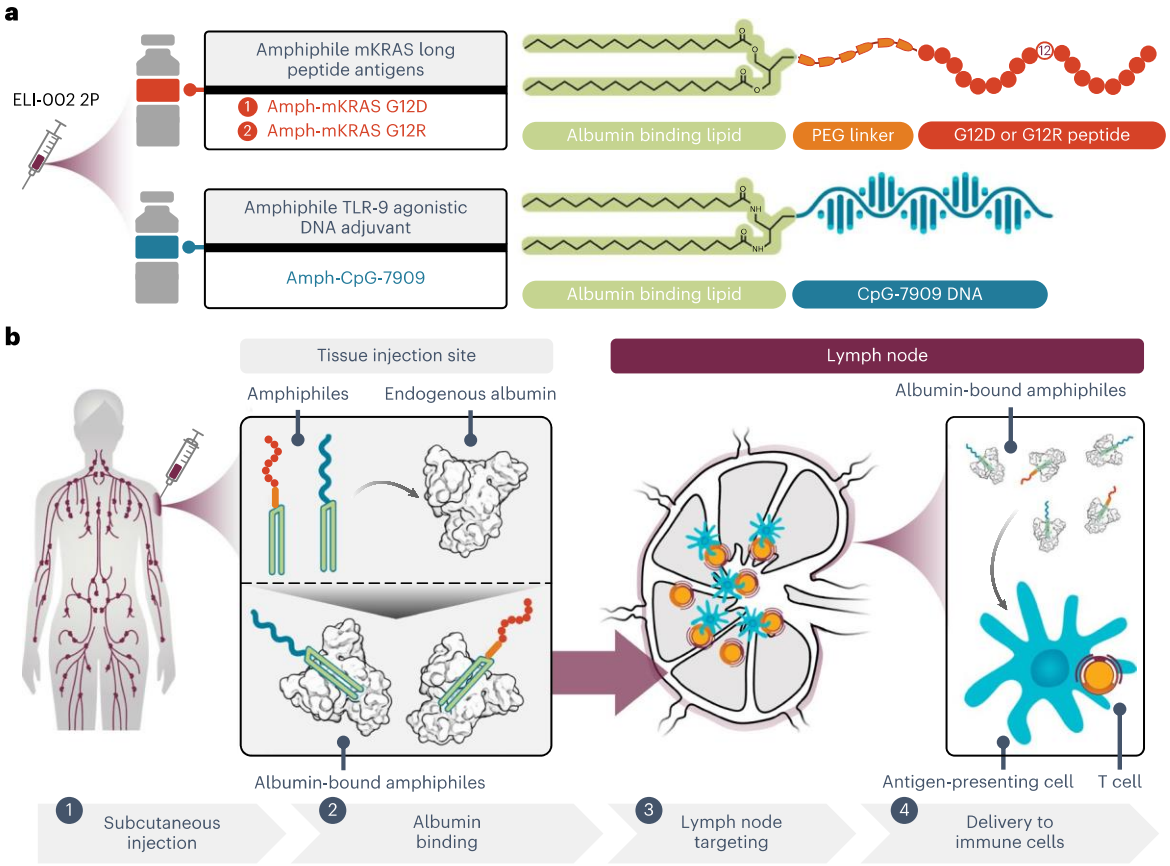

Shared neoantigen vaccine – clinical trials

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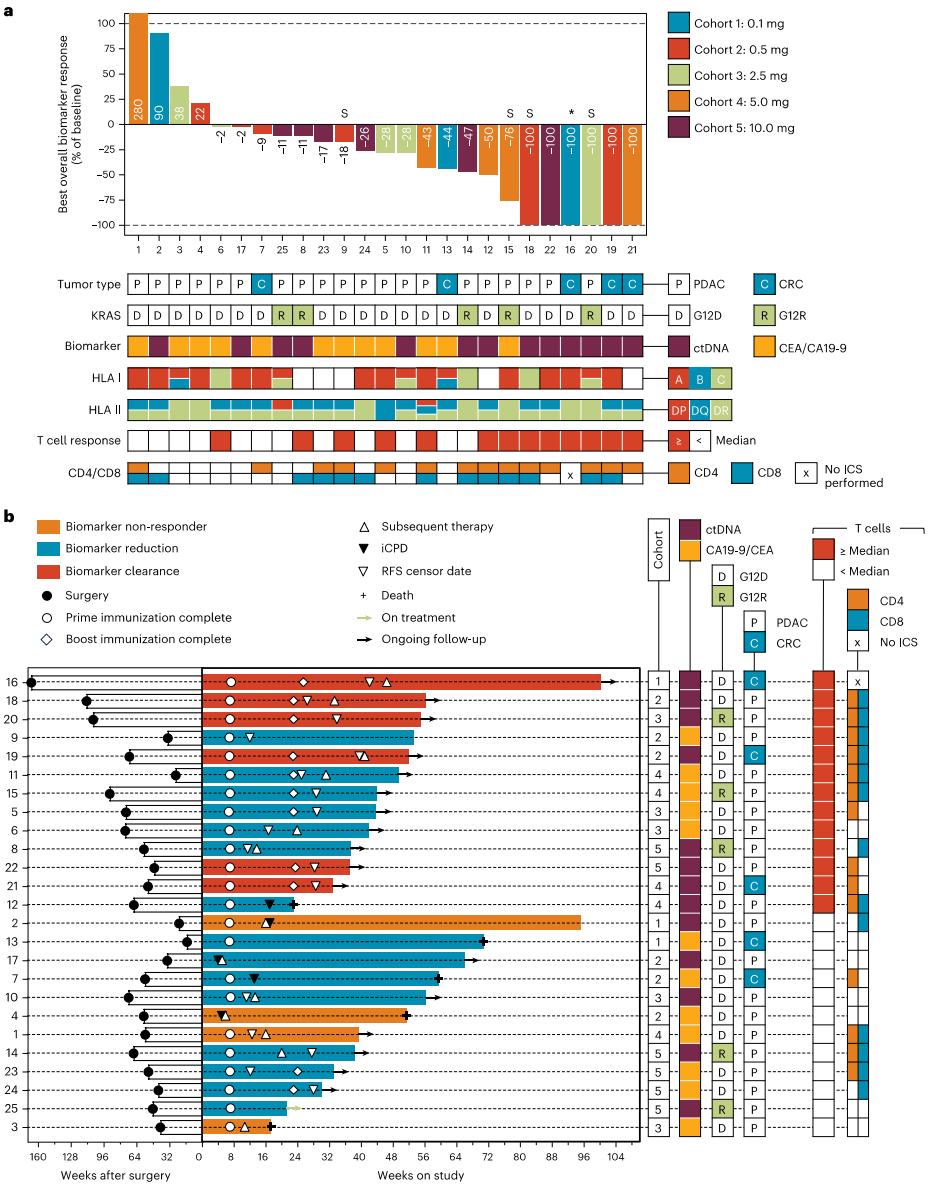

MCBO II – Cancer Vaccine

Shared neoantigen vaccine – clinical trials

Example **3**

nature medicine

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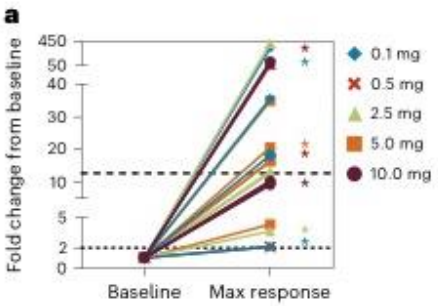

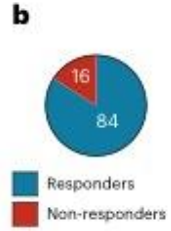

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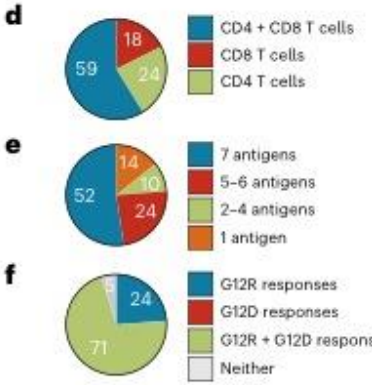
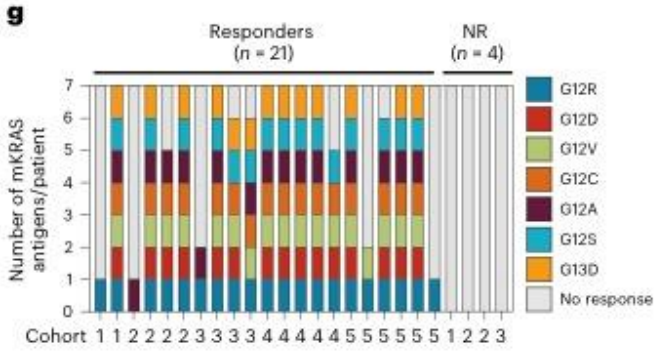
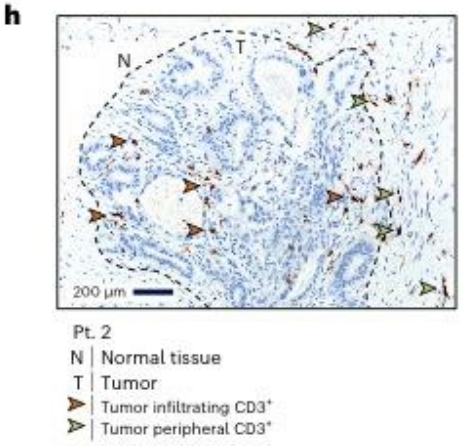
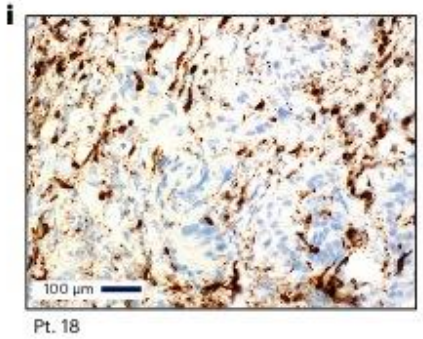
Amph-CpG dose level	Ex vivo T cell response (n, %)	Average fold change
0.1 mg	2/3 (67%)	30
0.5 mg	4/6 (67%)	101
2.5 mg	4/5 (80%)	113
5.0 mg	5/5 (100%)	19
10.0 mg	6/6 (100%)	36
Total	21/25 (84%)	58









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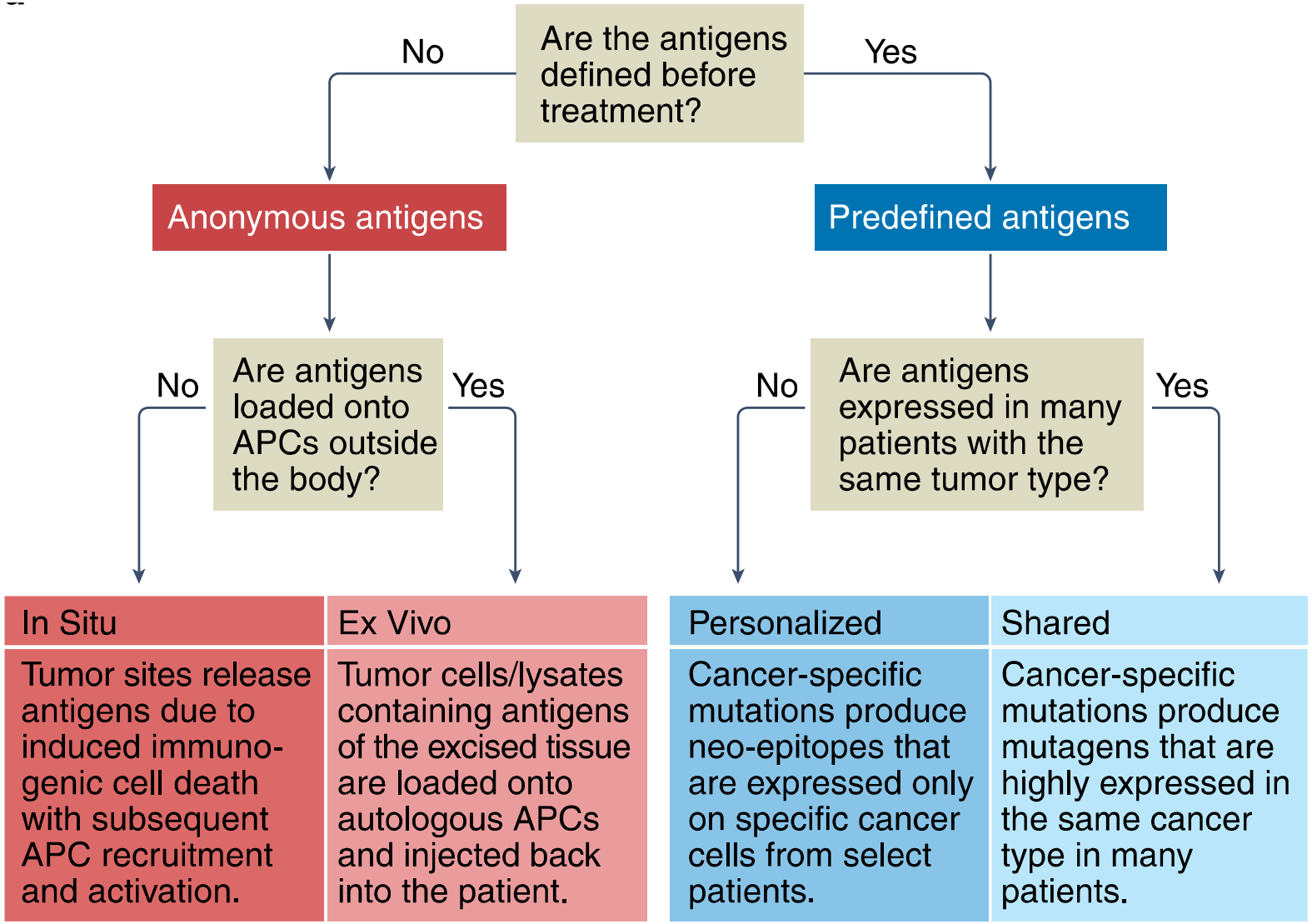
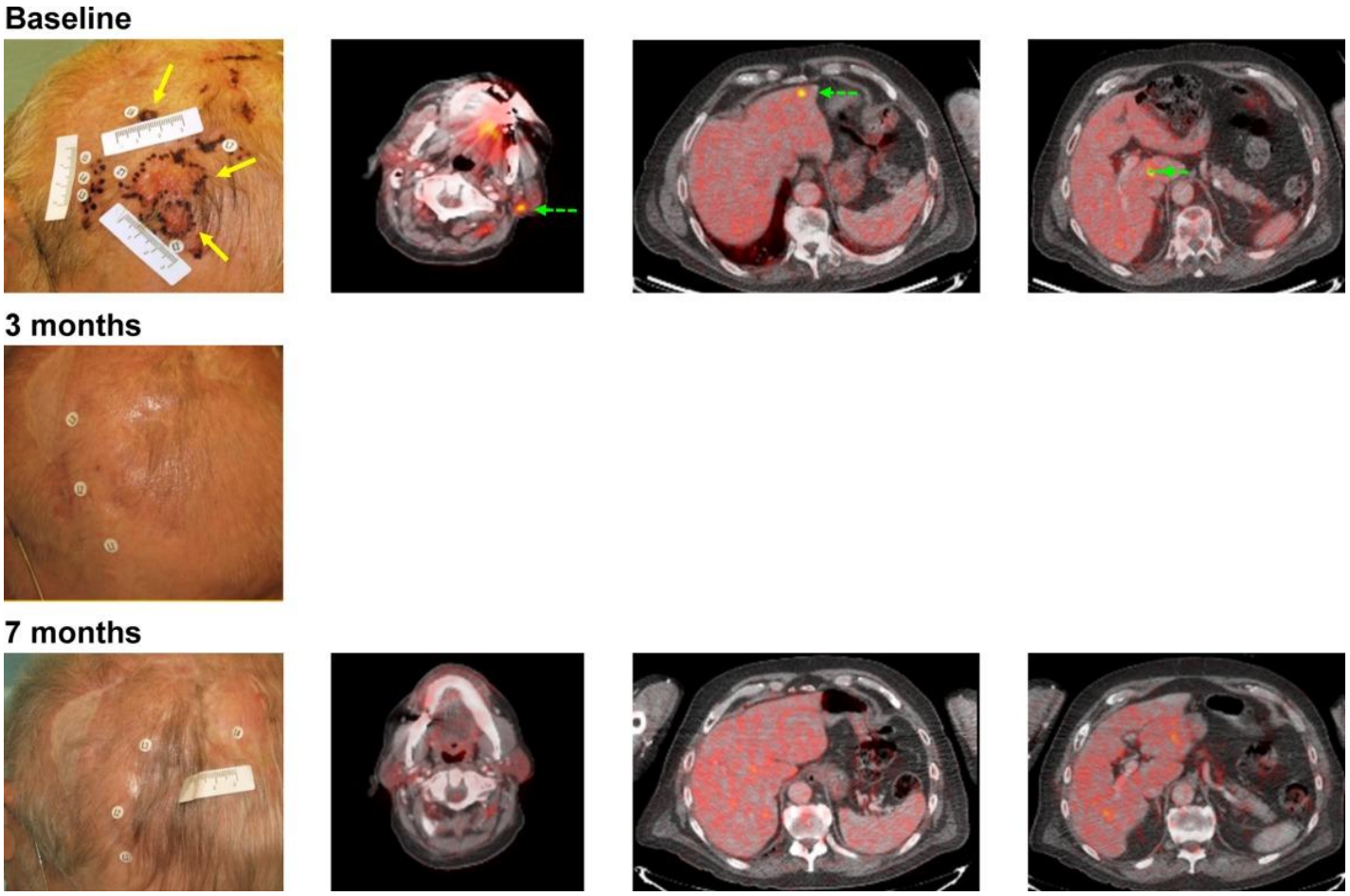


Lin et al., Nature Cancer 2022

Vaccination THROUGH Therapy

local therapy of melanoma skin cancer with **oncolytic virotherapy**



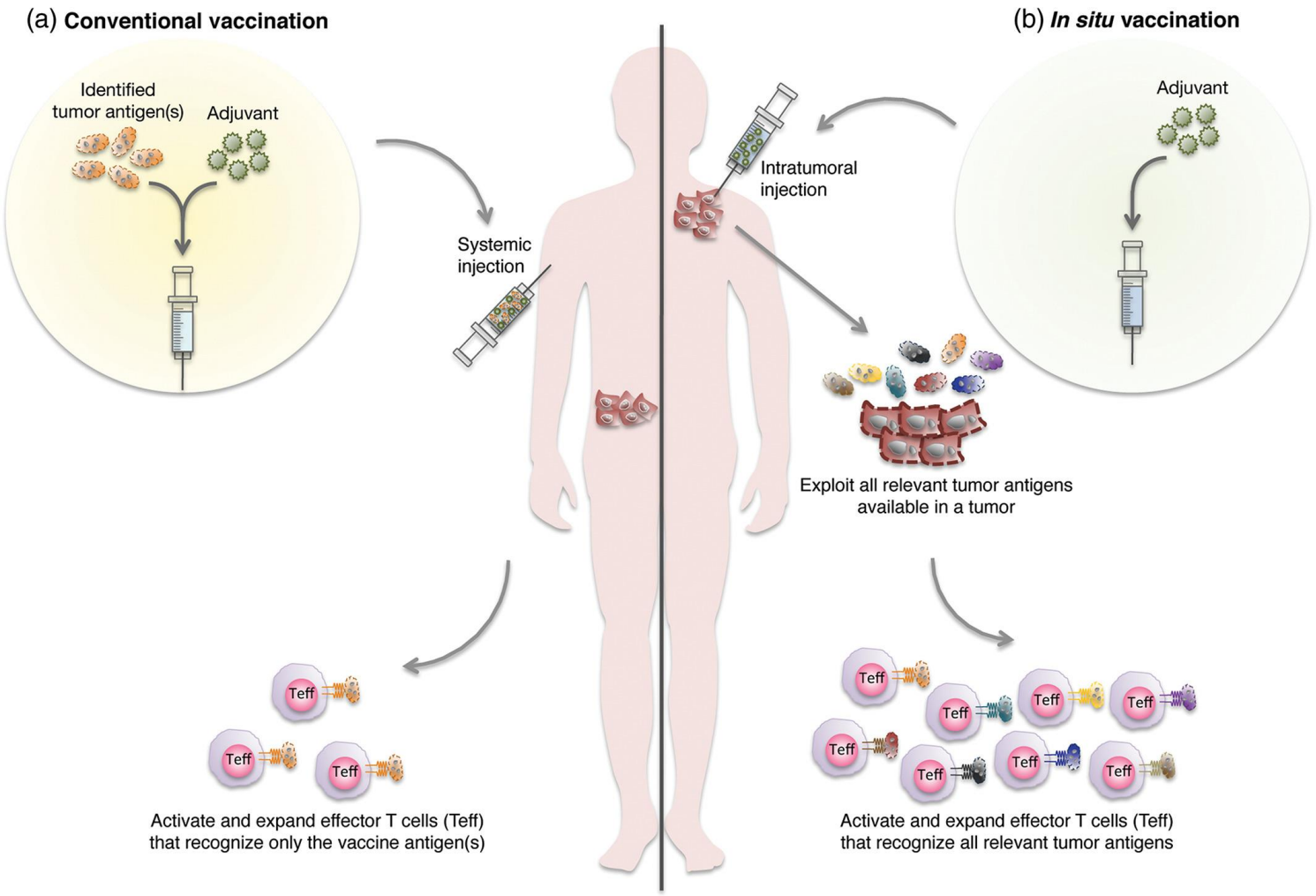
=> Effect on remote metastases by virus induced immune activation

Andtbacka et al., Head and Neck 2016

Cancer *in situ* vaccination

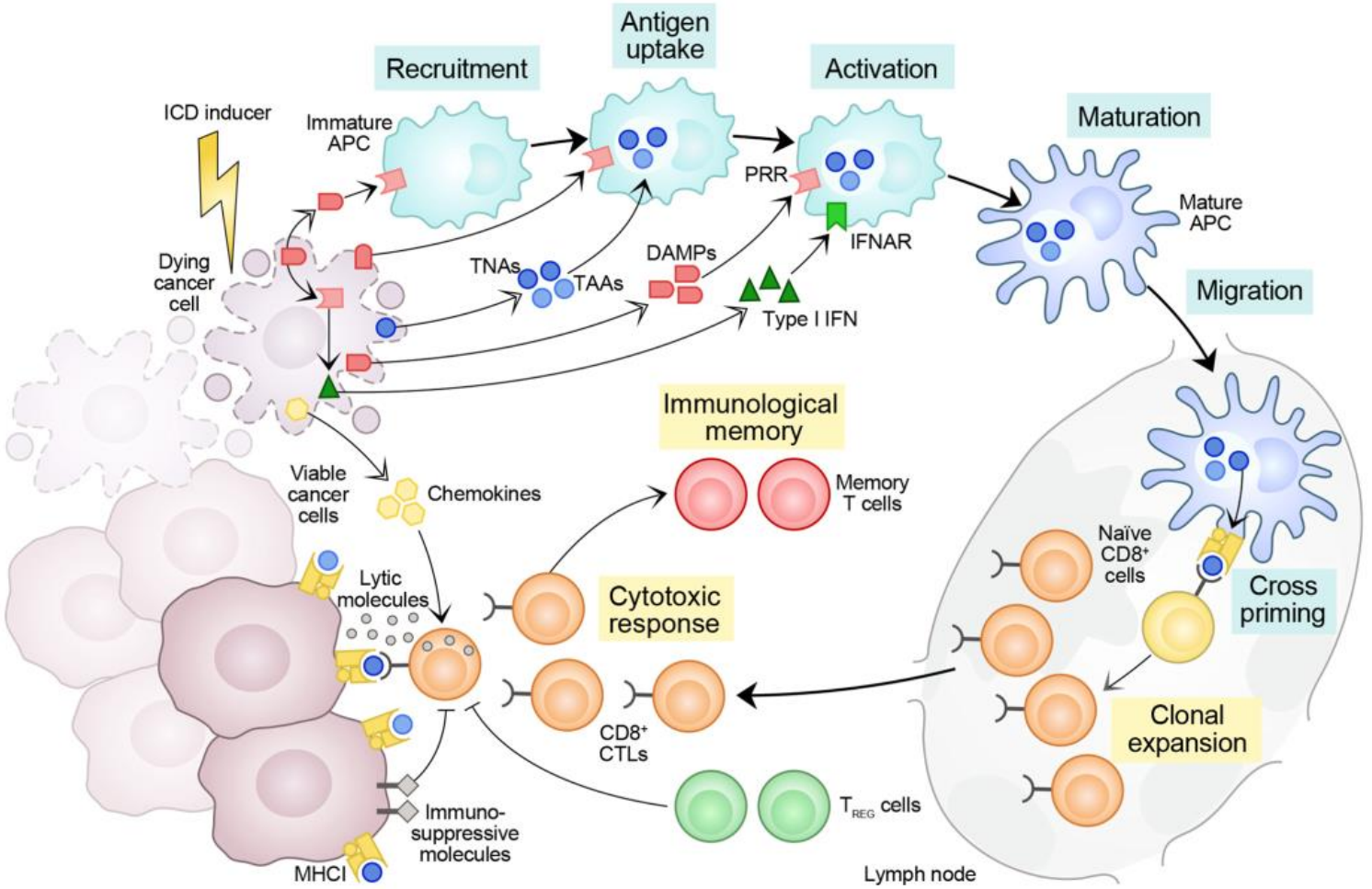
antigens known/predicted

antigen "agnostic"



WIREs Nanomed Nanobiotechnol. 2018;e1524.

Cell death modality impacts immunogenictiy recognition



Galuzzi (2020) J Immunother Cancer

Questions???