Cancer Bio Course 2025

Session 3: Introduction to cancer biology

Bridge and Engage Scholars

August 20th, 2025

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Course structure

In-person activities:

- Session 1 – Introduction to course and basic techniques applied in basic cancer research
  - **Explanation of the question under research** - *why on earth did they decide to do this?*
  - **Discussion figure by figure –** *is this paper not as good as authors think?:*
    - What is the point of each figure/panel?
    - Are there any missing experimental conditions?
    - Are results interpretable?
    - Do the results support the conclusions by the authors?
    - Would you have done anything differently?
    - Are there any missing experiments?
    - What are the limitations of the work?
    - What experiments could be done as a follow-up to the paper?
- Session 2 – Paper discussion
- Session 3 – Paper discussion
- Session 4 – Paper discussion

+ Presentations!!

- Session 5 – Guided live research activity


Cancer Cell
Article

The Genomic Landscape of Endocrine-Resistant Advanced Breast Cancers

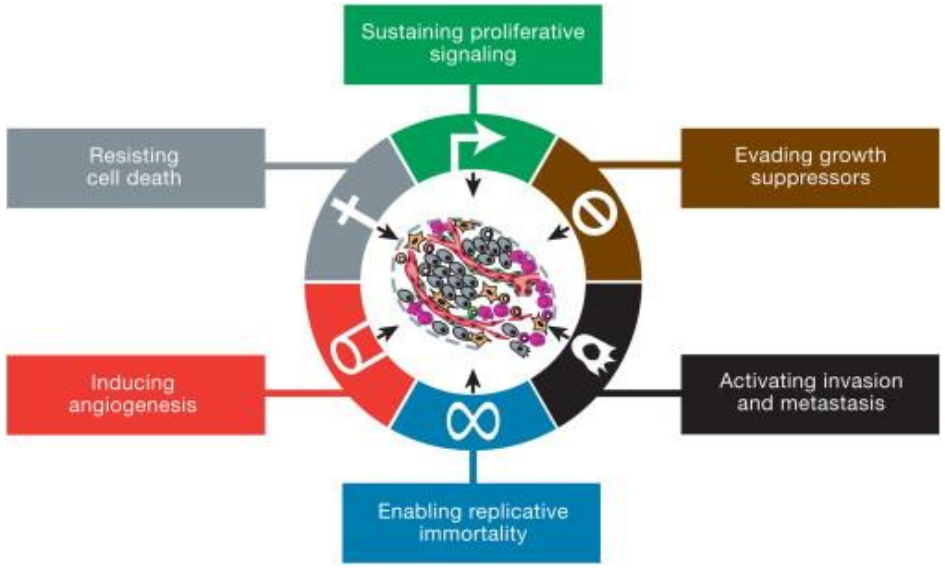

Article

Lung adenocarcinoma promotion by air pollutants

Molecular basis of cancer

Cancer 101: What is a cancer cell?

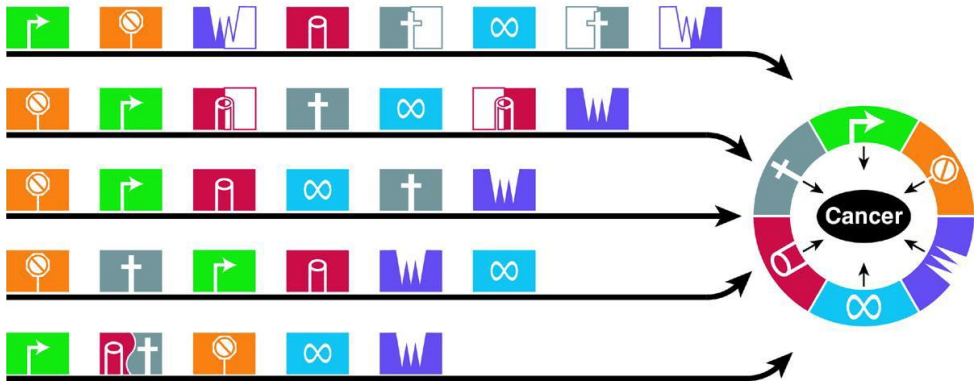
"Cells": Basic unit of life



A

Component	Acquired Capability	Example of Mechanism
	Self-sufficiency in growth signals	Activate H-Ras oncogene
	Insensitivity to anti-growth signals	Lose retinoblastoma suppressor
	Evading apoptosis	Produce IGF survival factors
	Limitless replicative potential	Turn on telomerase
	Sustained angiogenesis	Produce VEGF inducer
	Tissue invasion & metastasis	Inactivate E-cadherin

B

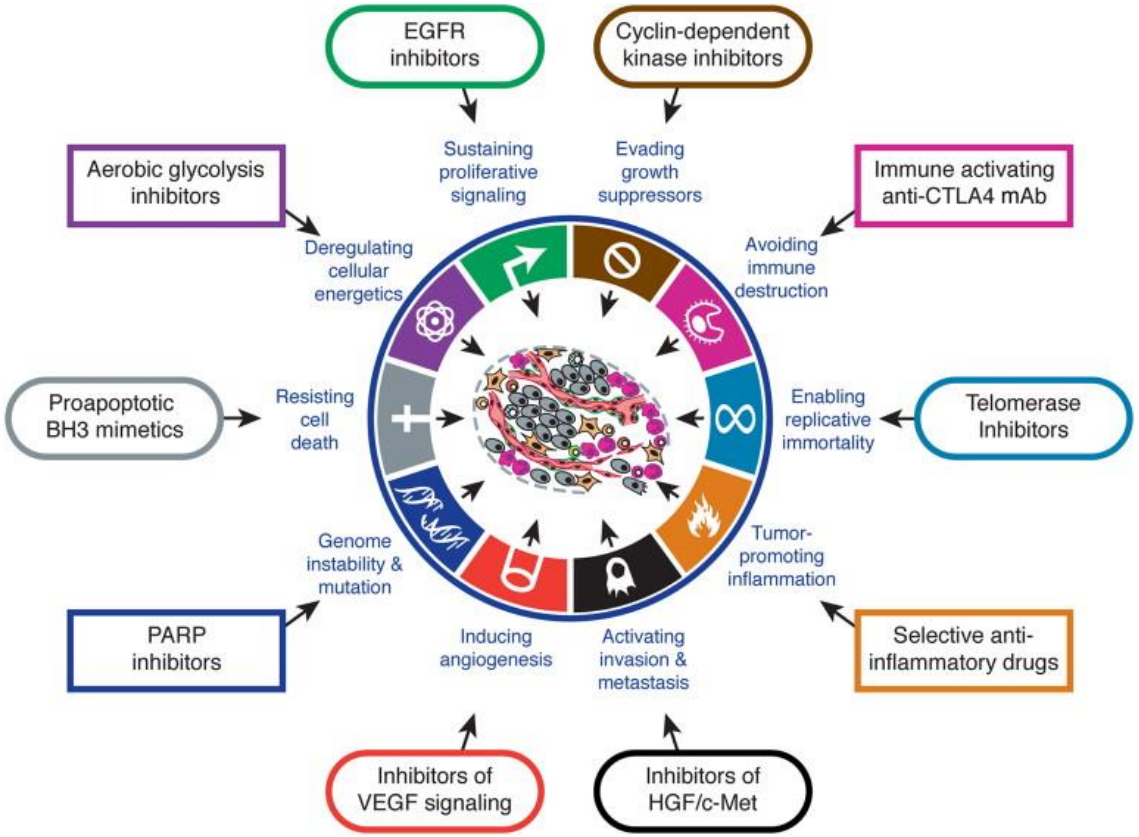


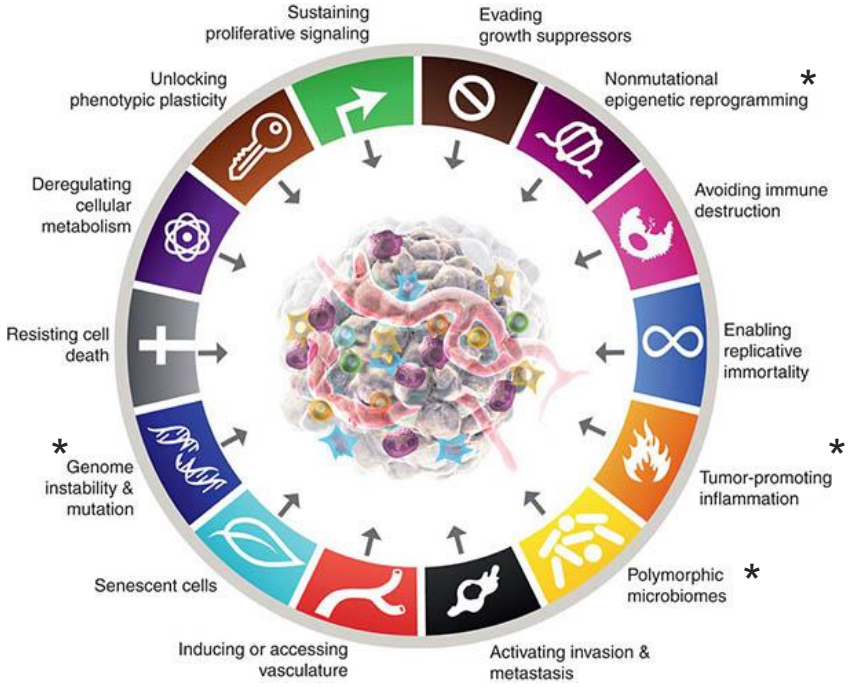
Hallmarks of Cancer. 2000 (Cell), 2011 (Cell), 2020 (Cancer Discovery)

Cancer 101: What is a cancer cell?

"Cells": Basic unit of life

Cancer Hallmarks and Enabling Characteristics*

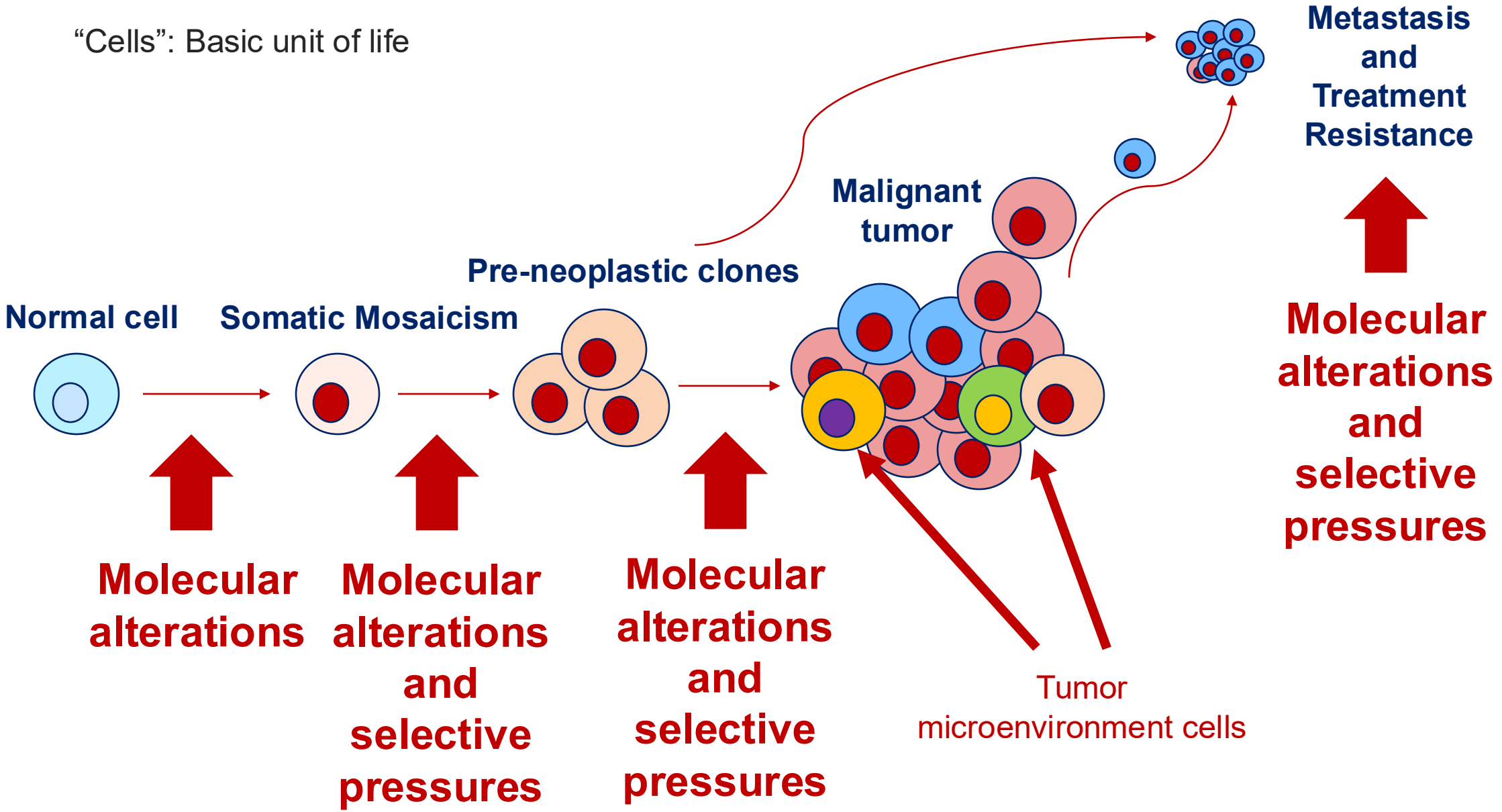




Hallmarks of Cancer. 2000 (Cell), 2011 (Cell), 2020 (Cancer Discovery)

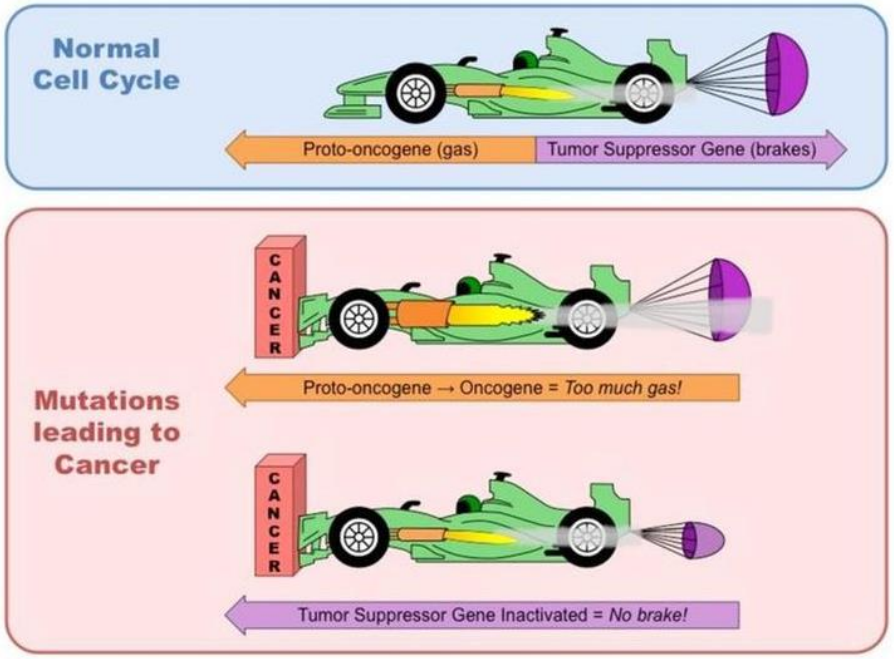
Cancer 101: Tumor evolution

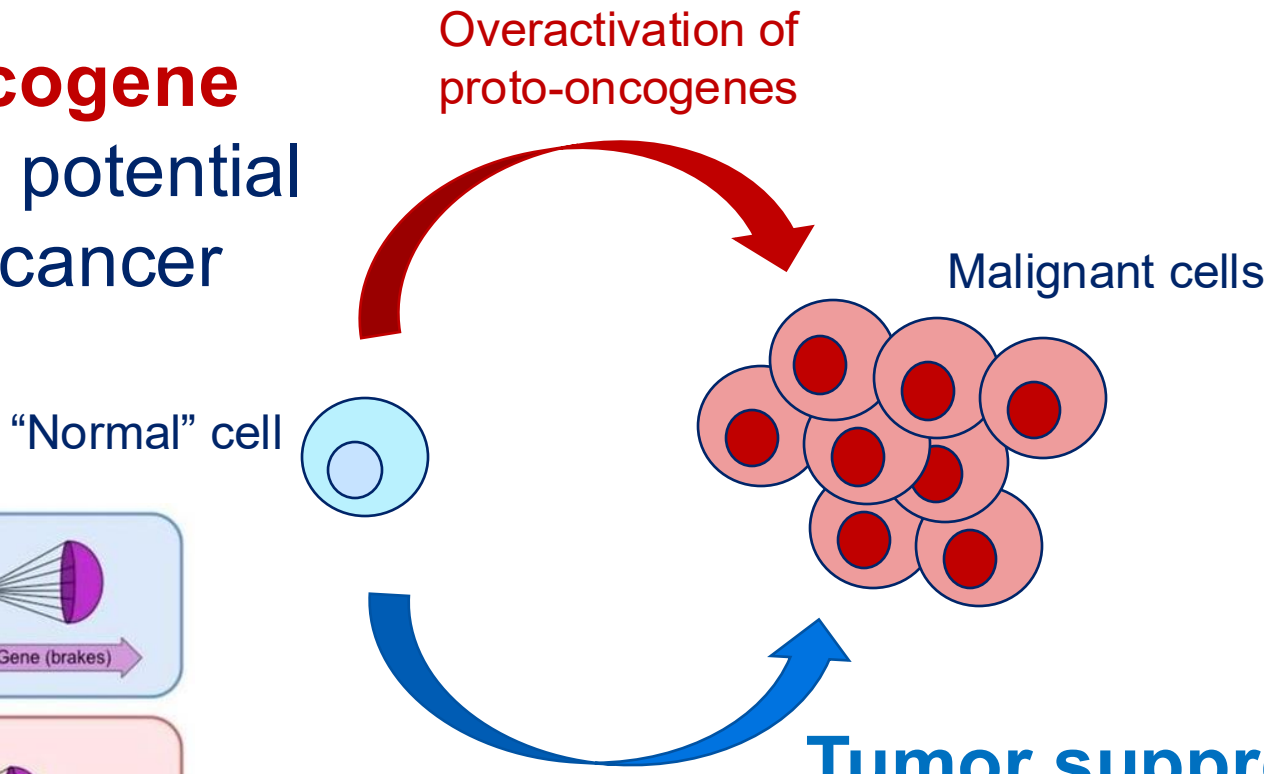
"Cells": Basic unit of life



Cancer 101: Cancer is a genetic disease

(Proto-)Oncogene
Gene with the potential to promote cancer

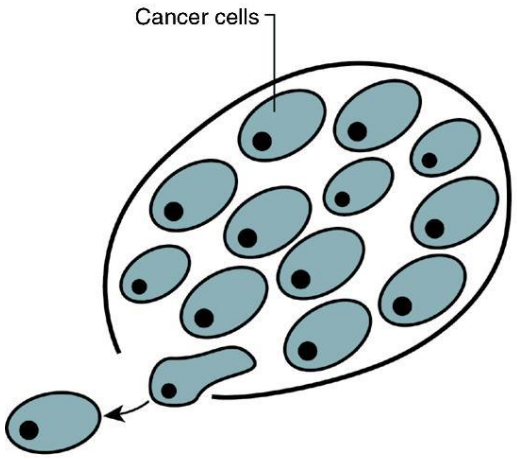




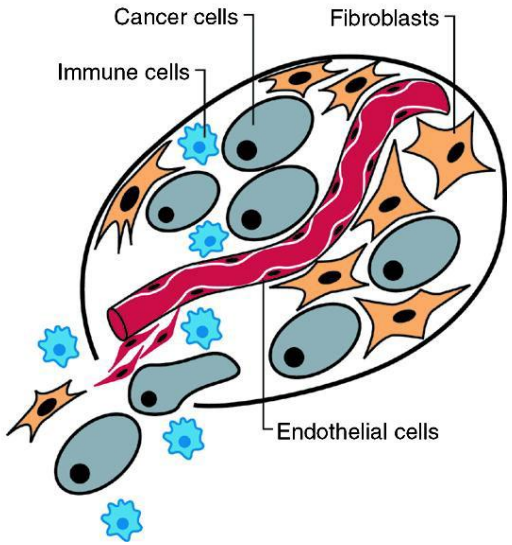
Tumor suppressor gene
Gene whose loss/dysfunction contributes to cancer

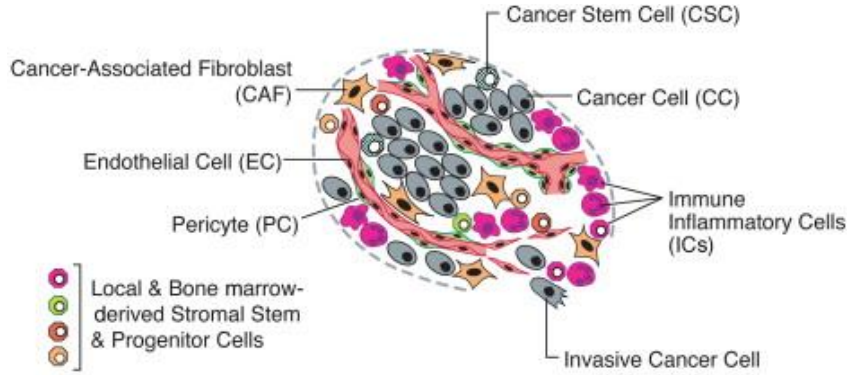
The importance of context

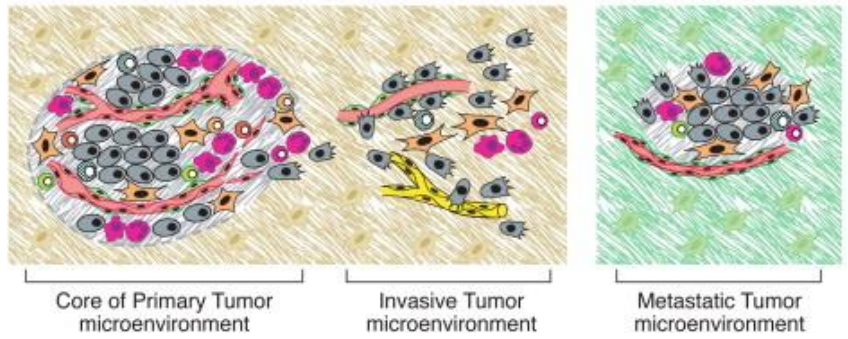
The Reductionist View

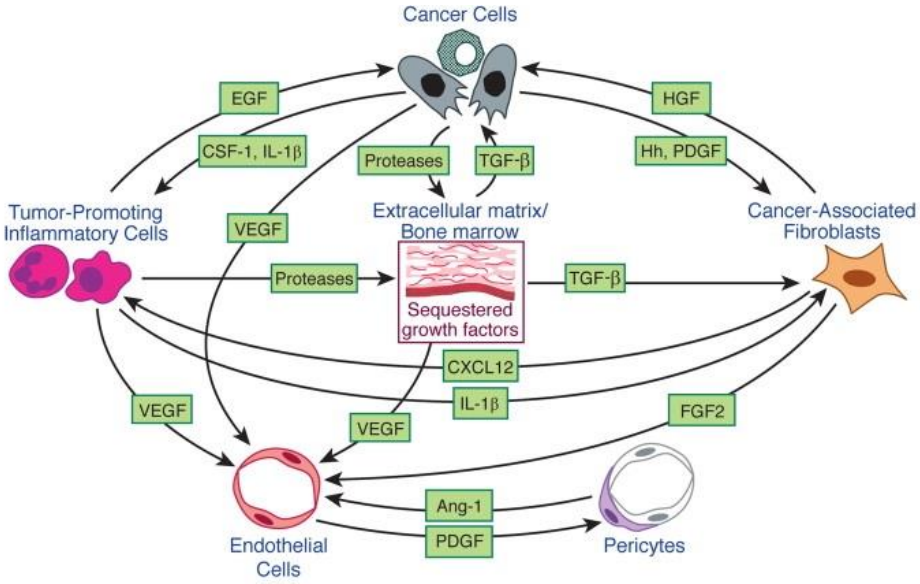


A Heterotypic Cell Biology



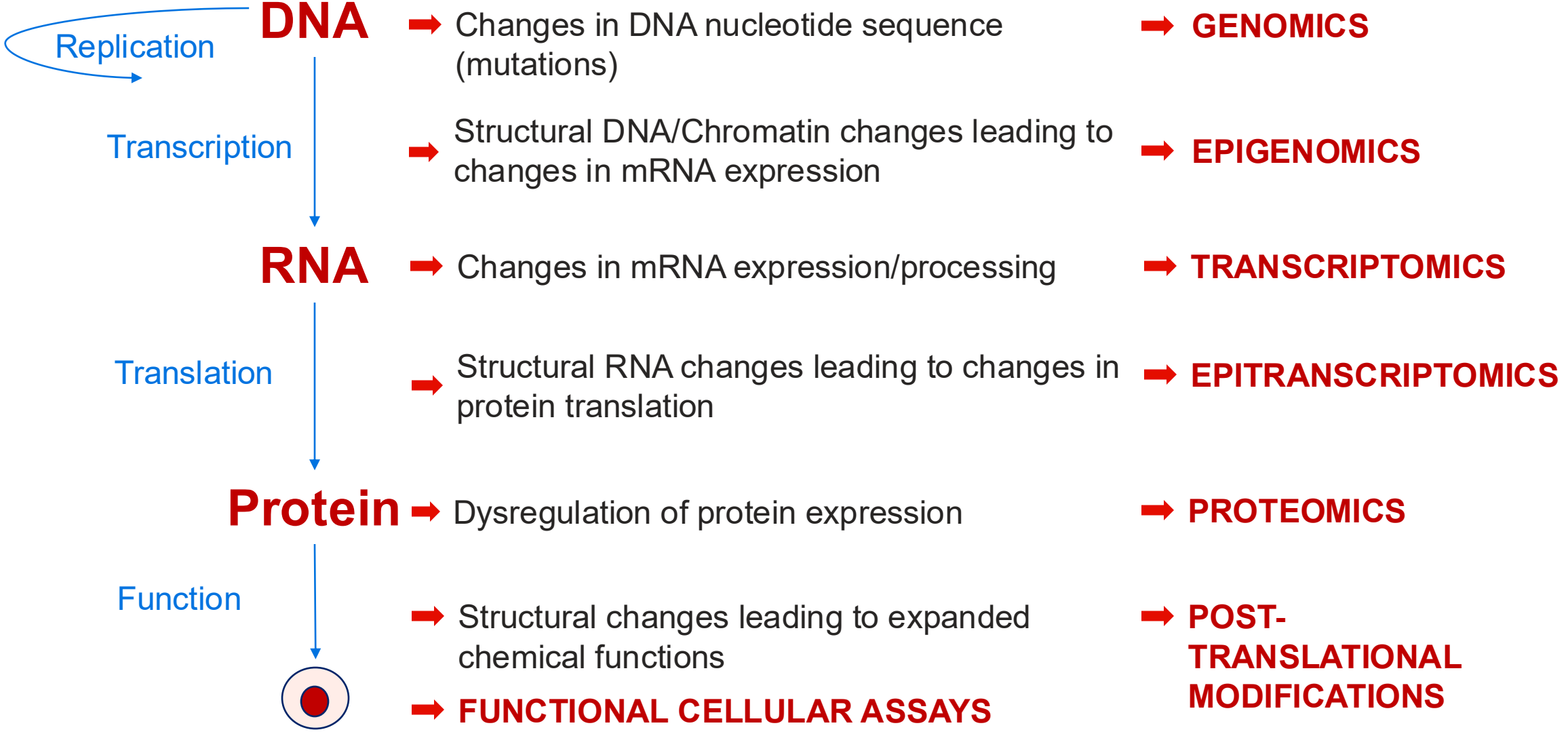




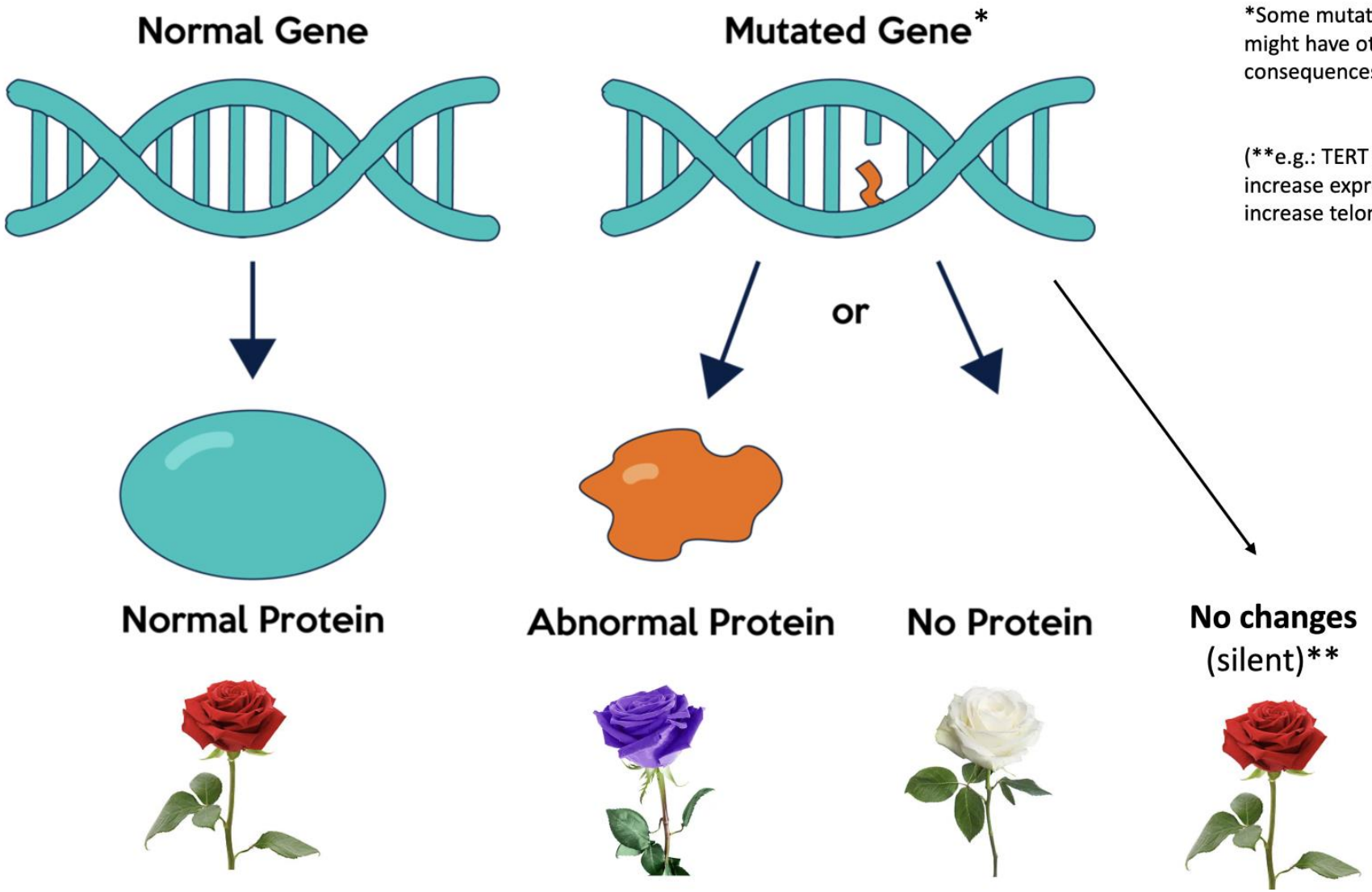


Cancer 101: Main Molecular alterations

"Genes": Basic units of heredity



Mutations in the DNA have functional consequences (or not)



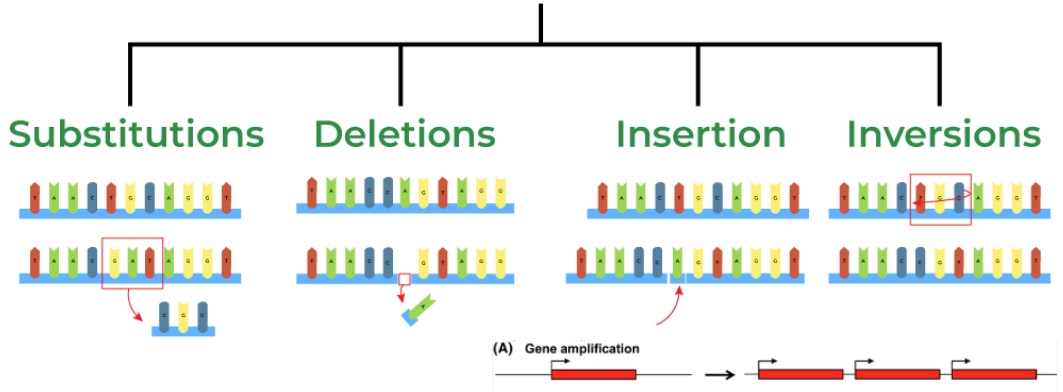
*Some mutations (variants) outside genes might have other non-direct protein coding consequences like altering gene expression.

(**e.g.: TERT promoter mutations lead to increase expression of TERT and ultimately increase telomerase complex function)

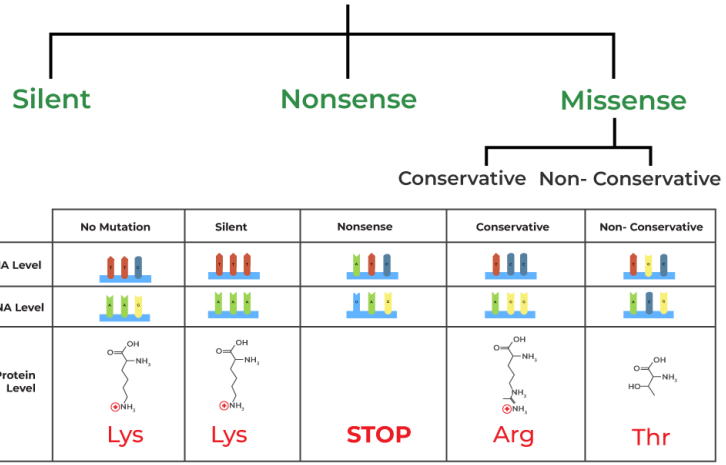
Intro to Cancer Bio 2025 PSV

Cancer 101: Mutations glossary

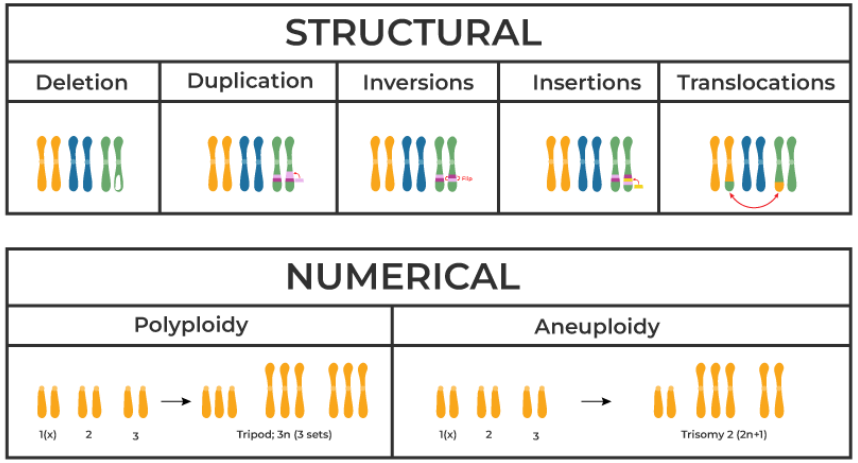
Types of Mutations
(At the DNA level)

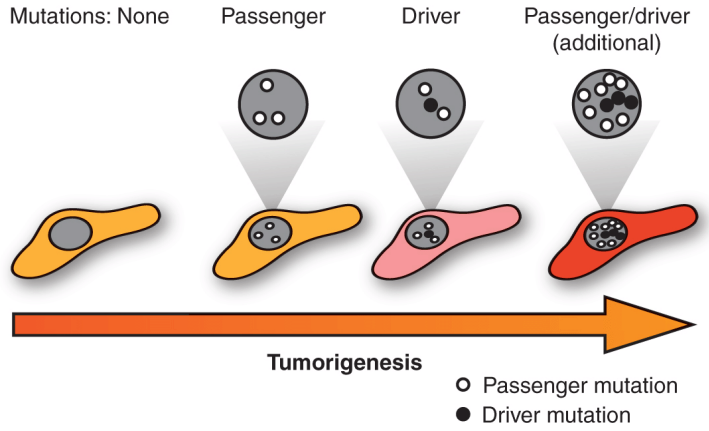


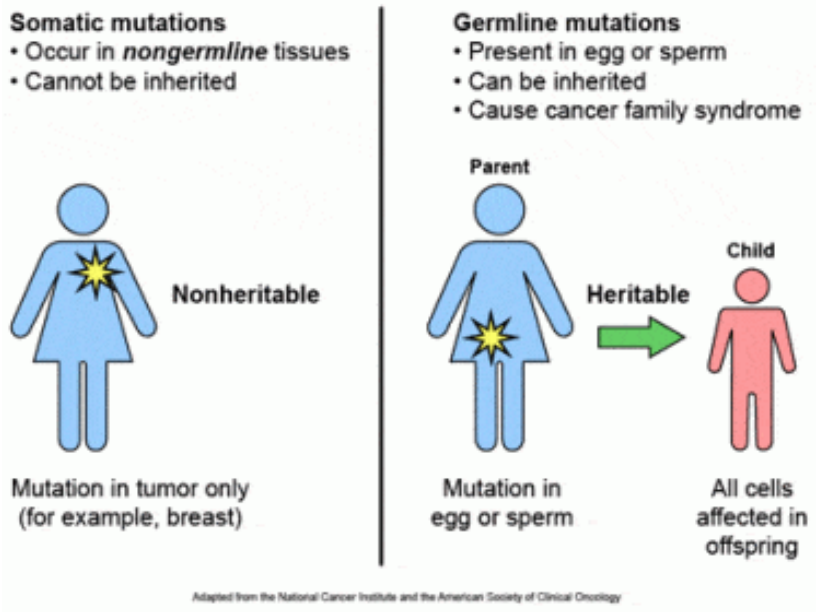
Types of Mutations
(At the Protein level)



Types of Mutations
(At the Chromosomal level)



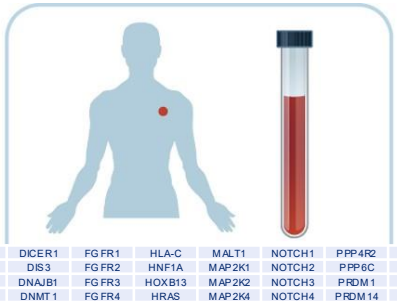


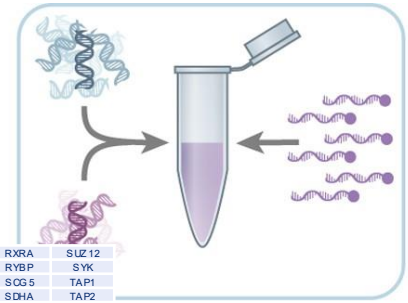


MSK-IMPACT

(Integrated Mutation Profiling of Actionable Cancer Targets

1. Patient consen





Sample preparation

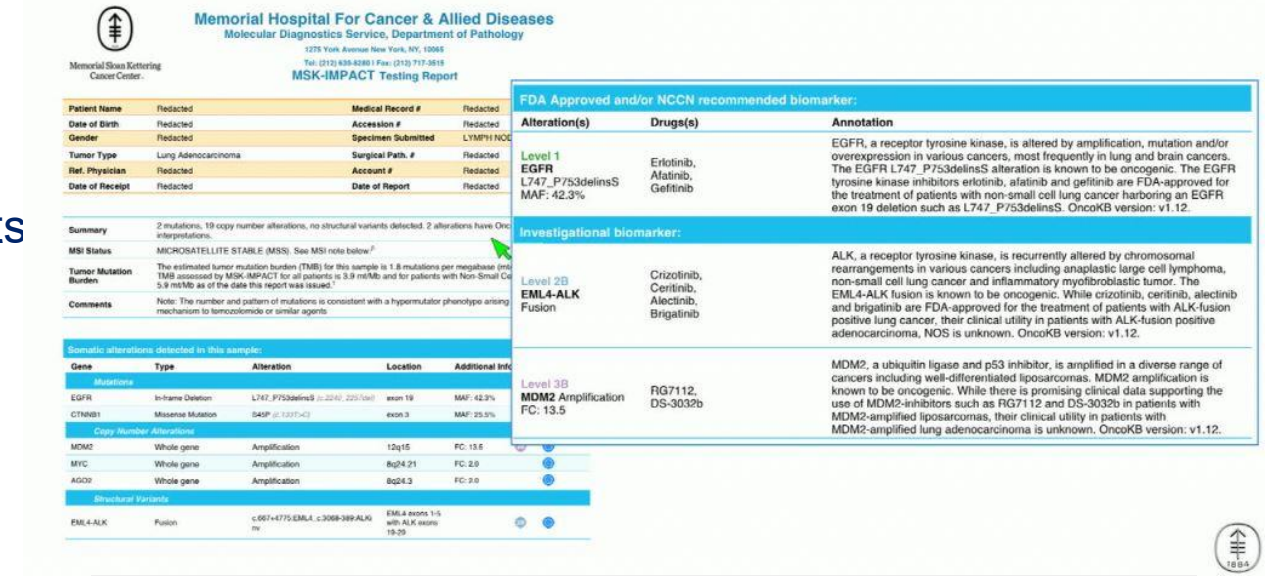
4. Sequencing

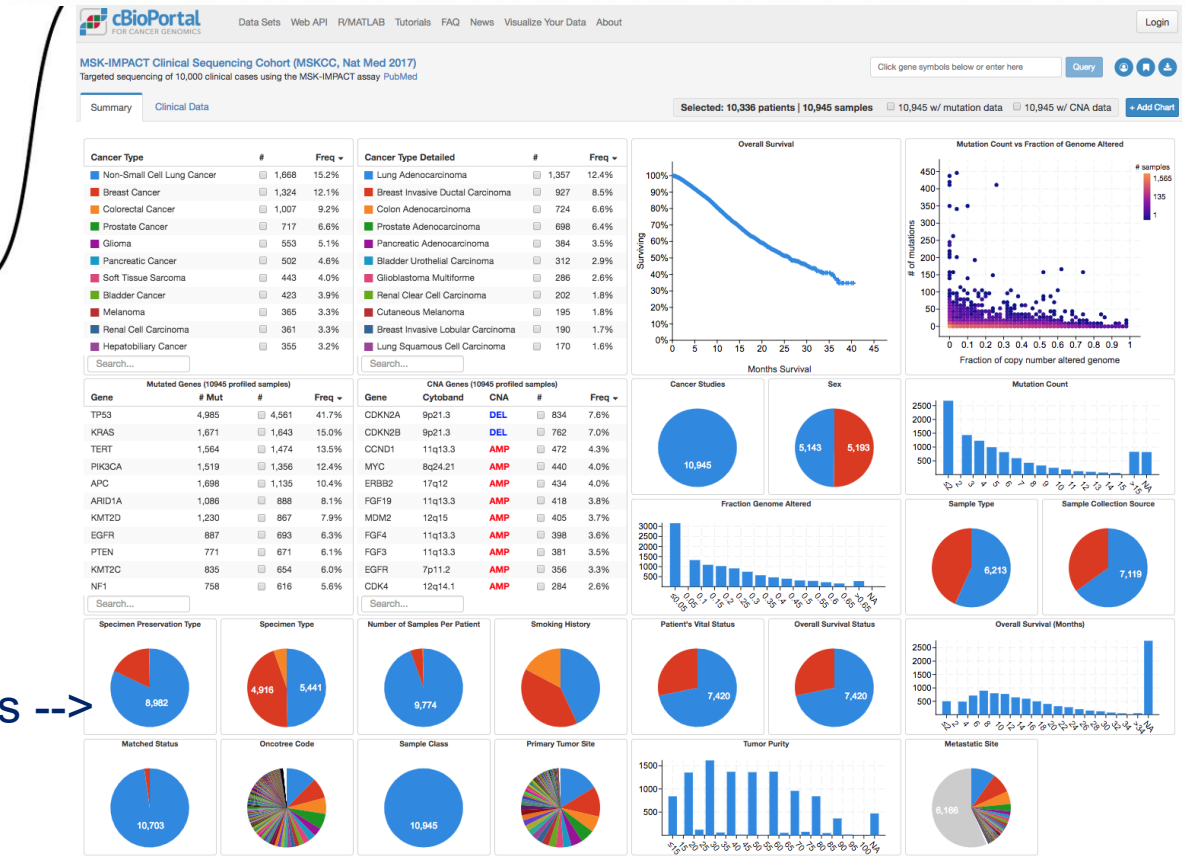
. Case review and sign out

ABL1	CALR	DICER1	FGFR1	HLA-C	MALT1	NOTCH1	PPP4R2	RXRA	SUZ12
ACVR1	CARD11	DIS3	FGFR2	HNF1A	MAP2K1	NOTCH2	PPP6C	RYBP	SYK
AGO1	CARM1	DNAJB1	FGFR3	HOXB13	MAP2K2	NOTCH3	PRDM1	SOG5	TAP1
AGO2	CASP8	DNMT1	FGFR4	HRAS	MAP2K4	NOTCH4	PRDM14	SDHA	TAP2
AKT1	CBFB	DNMT3A	FH	ICOSLG	MAP3K1	NPM1	PREX2	SDHAF2	TBX3
AKT2	CBL	DNMT3B	FLCN	ID3	MAP3K13	NRAS	PRKAR1A	SDHB	TCEB1
AKT3	CCND1	DOT1L	FLT1	IDH1	MAP3K14	NSD1	PRKCI	SDHC	TCF3
ALB	CCND2	DROSHA	FLT3	IDH2	MAPK1	NTHL1	PRKD1	SDHD	TCF7L2
ALK	CCND3	DUSP4	FLT4	IFNGR1	MAPK3	NTRK1	PTCH1	SERPINB3	TEK
ALOX12B	CCNE1	E2F3	FOXA1	IGF1	MAPKAP1	NTRK2	PTEN	SERPINB4	TERT
ANKRD11	CD274	EED	FOXF1	IGF1R	MAX	NTRK3	PTP4A1	SESN1	TET1
APC	CD276	EGFL7	FOXL2	IGF2	MCL1	NUF2	PTPN11	SESN2	TET2
APLNR	CD79A	EGFR	FOXO1	IKBKE	MDC1	NUP93	PTPRD	SESN3	TGFBR1
AR	CD79B	EIF1AX	FOXP1	IKZF1	MDM2	PAK1	PTPRS	SETD2	TGFBR2
ARAF	CDC42	EIF4A2	FUBP1	IL10	MDM4	PAK7	PTPRT	SETDB1	TMEM127
ARHGAP35	CDC73	EIF4E	FYN	IL7R	MED12	PALB2	RAB35	SF3B1	TMPRSS2
ARID1A	CDH1	ELF3	GAB1	INHA	MEF2B	PARK2	RAC1	SH2B3	TNFAIP3
ARID1B	CDK12	EP300	GAB2	INHBA	MEN1	PARP1	RAC2	SH2D1A	TNFRSF14
ARID2	CDK4	EPAS1	GATA1	INPP4A	MET	PAX5	RAD21	SHOC2	TOP1
ARID5B	CDK6	EPCAM	GATA2	INPP4B	MGA	PBRM1	RAD50	SHQ1	TP53
ASXL1	CDK8	EPHA3	GATA3	INPPL1	MITF	PDCD1	RAD51	SLFN11	TP53BP1
ASXL2	CDKN1A	EPHA5	GLI1	INSR	MLH1	PDCD1LG2	RAD51C	SLX4	TP63
ATM	CDKN1B	EPHA7	GNA11	IRF4	MLLT1	PDGFRA	RAD51L1	SMAD2	TRAF2
ATR	CDKN2A	EPHB1	GNAQ	IRS1	MPL	PDGFRB	RAD51L3	SMAD3	TRAF7
ATRX	CDKN2B	ERBB2	GNAS	IRS2	MRE11A	PDPK1	RAD52	SMAD4	TRIP13
ATXN7	CDKN2C	ERBB3	GNB1	JAK1	MSH2	PGBD5	RAD54L	SMARCA2	TSC1
AURKA	CEBPA	ERBB4	GPS2	JAK2	MSH3	PGR	RAF1	SMARCA4	TSC2
AURKB	CENPA	ERCC2	GREM1	JAK3	MSH6	PHF6	RARA	SMARCB1	TSHR
AXIN1	CHEK1	ERCC3	GRIN2A	JUN	MSI1	PHOX2B	RASA1	SMARCD1	U2AF1
AXIN2	CHEK2	ERCC4	GSK3B	KBTBD4	MSI2	PIK3C2G	RB1	SMARCE1	UPF1
AXL	CIC	ERCC5	H3F3A	KDM5A	MST1	PIK3C3	RBM10	SMO	USP8
B2M	CMTR2	ERF	H3F3B	KDM5C	MST1R	PIK3CA	RECQL	SMYD3	VEGFA
BABAM1	CREBBP	ERG	H3F3C	KDM6A	MTAP	PIK3CB	RECQL4	SOCS1	VHL
BAP1	CRKL	ERRFI1	HGF	KDR	MTOR	PIK3CD	REL	SOS1	VTCN1
BARD1	CRLF2	ESR1	HIST1H1C	KEAP1	MUTYH	PIK3CG	REST	SOX17	WHSC1
BBC3	CSDE1	ETAA1	HIST1H2BD	KIT	MYC	PIK3R1	RET	SOX2	WHSC1L1
BCL10	CSF1R	ETV1	HIST1H3A	KLF4	MYCL1	PIK3R2	RFWD2	SOX9	WT1
BCL2	CSF3R	ETV6	HIST1H3B	KLF5	MYCN	PIK3R3	RHEB	SPEN	WWTR1
BCL2L1	CTCF	EZH1	HIST1H3C	KMT2A	MYD88	PIM1	RHOA	SPOP	XIAP
BCL2L11	CTLA4	EZH2	HIST1H3D	KMT2B	MYOD1	PLCG2	RICTOR	SPRED1	XPO1
BCL6	CTNNB1	FAM123B	HIST1H3E	KMT2C	NADK	PLK2	RIT1	SPRTN	XRCC2
BCOR	CTR9	FAM175A	HIST1H3F	KMT2D	NBN	PMAIP1	RNF43	SRC	YAP1
BIRC3	CUL3	FAM46C	HIST1H3G	KMT5A	NCOA3	PMS1	ROS1	SRSF2	YES1
BLM	CXCR4	FAM58A	HIST1H3H	KNSTRN	NCOR1	PMS2	RPS6KA4	STAG2	ZFHX3
BMPR1A	CXORF67	FANCA	HIST1H3I	KRAS	NEGR1	PNRC1	RPS6KB2	STAT3	ZNRF3
BRAF	CYLD	FANCC	HIST1H3J	LATS1	NF1	POLD1	RPTOR	STAT5A	ZRSR2
BRCA1	CYP19A1	FAT1	HIST2H3C	LATS2	NF2	POLE	RRAGC	STAT5B	
BRCA2	CYSLTR2	FBXW7	HIST2H3D	LMO1	NFE2L2	POT1	RRAS	STK11	
BRD4	DAXX	FGF19	HIST3H3	LYN	NFKBIA	PPARG	RRAS2	STK19	
BRIP1	DCUN1D1	FGF3	HLA-A	LZTR1	NKX2-1	PPM1D	RTEL1	STK40	
BTK	DDR2	FGF4	HLA-B	MAD2L2	NKX3-1	PPP2R1A	RUNX1	SUFU	

cBioPortal for Cancer Genomics -->

https://www.cbioportal.org





Paper discussion

Article

Respiratory viral infections awaken metastatic breast cancer cells in lungs

https://doi.org/10.1038/s41586-025-09332-0

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Open access

Check for updates

Shi B. Chia[1,24], Bryan J. Johnson[1,24], Junxiao Hu[2,3], Felipe Valença-Pereira[4], Marc Chadeau-Hyam[5,6,7], Fernando Guntoro[6,7,8], Hugh Montgomery[9], Meher P. Boorgula[3,10], Varsha Sreekanth[3,11], Andrew Goodspeed[3,10], Bennett Davenport[4], Marco De Dominici[1], Vadym Zaberezhnyy[1], Wolfgang E. Schleicher[1], Dexiang Gao[2,3], Andreia N. Cadar[12,13], Lucia Petriz-Otaño[14], Michael Papanicolaou[14], Afshin Beheshti[15,16,17], Stephen B. Baylin[15,18,19], Joseph W. Guarnieri[20,23], Douglas C. Wallace[20,21], James C. Costello[3,11], Jenna M. Bartley[12,13], Thomas E. Morrison[4], Roel Vermeulen[5,6,22,25], Julio A. Aguirre-Ghiso[14,25], Mercedes Rincon[3,4,25] & James DeGregori[1,2,3,4,25] ✉

Paper discussion

- **Explanation of the question under research** - *why did they decide to do this?*
- **Discussion figure by figure –** *is this paper not as good as authors think?:*
  - What is the point of each figure/panel?
  - Are there any missing experimental conditions?
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  - What experiments could be done as a follow-up to the paper?

Research Question

- **Explanation of the question under research** - *why did they decide to do this?*

"The observation that death rates from cancer rose in the first two years of the COVID-19 pandemic[12], which is not fully accounted for by COVID-19 deaths or delayed screening and treatment, prompts an important hypothesis: that pulmonary viral infections increase cancer deaths by triggering the development of metastases from dormant DCCs. We sought to test this hypothesis through a dual approach: examining the effects of viral respiratory infections (influenza virus and SARS-CoV-2) on breast cancer dormancy in mouse models and correlating SARS-CoV-2 infection among cancer survivors to metastatic progression and cancer mortality."

Figure 1

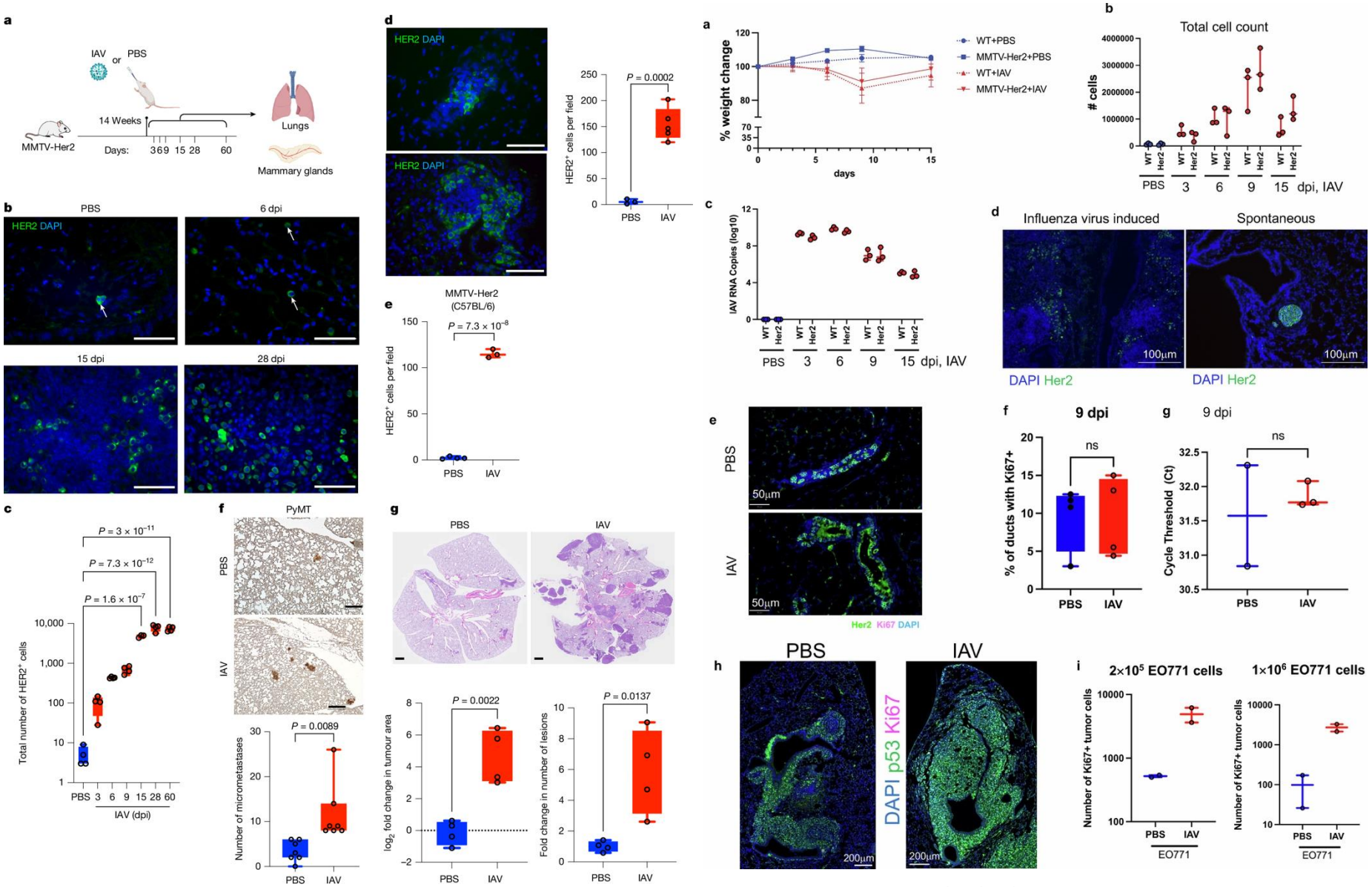
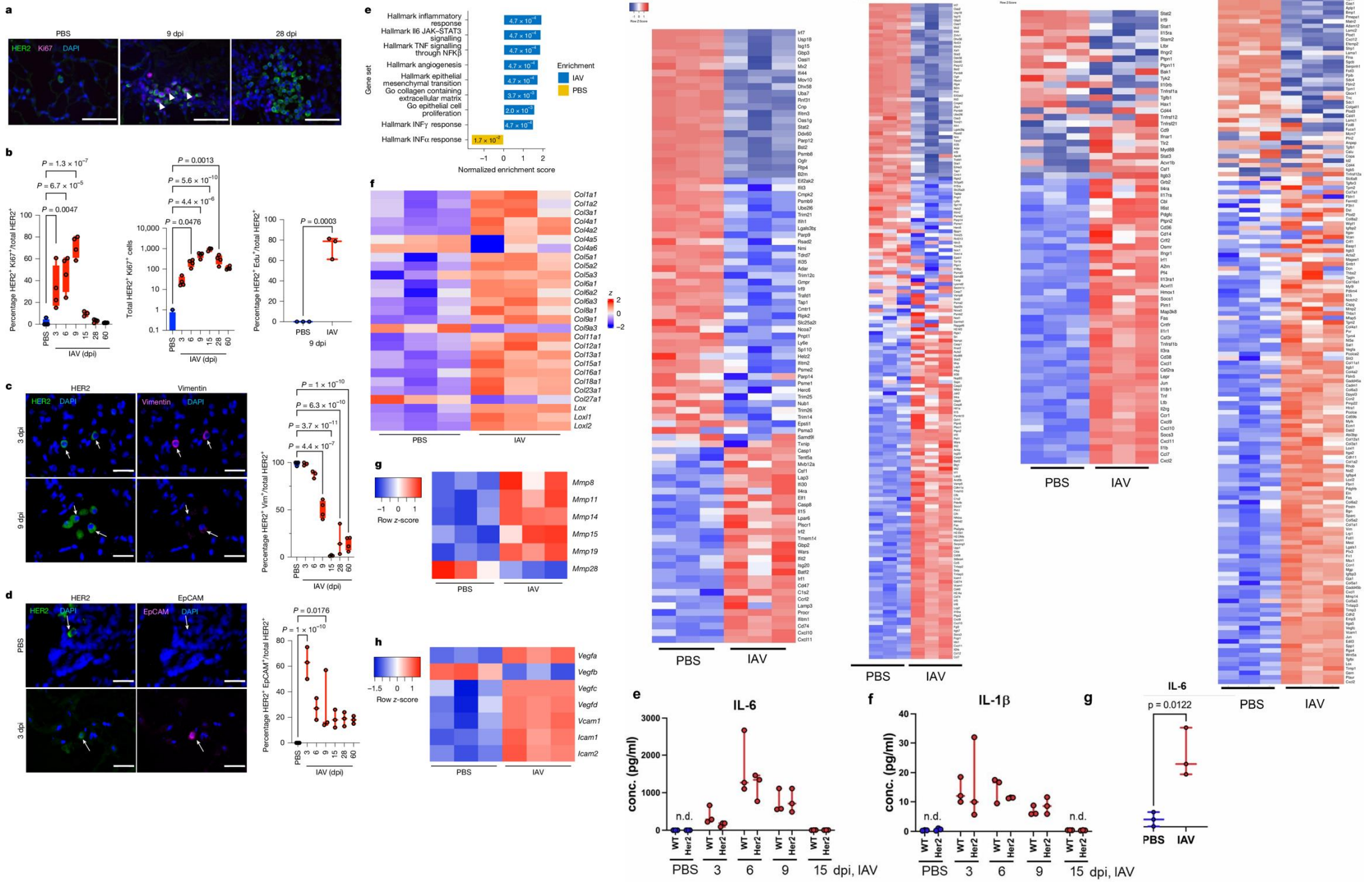
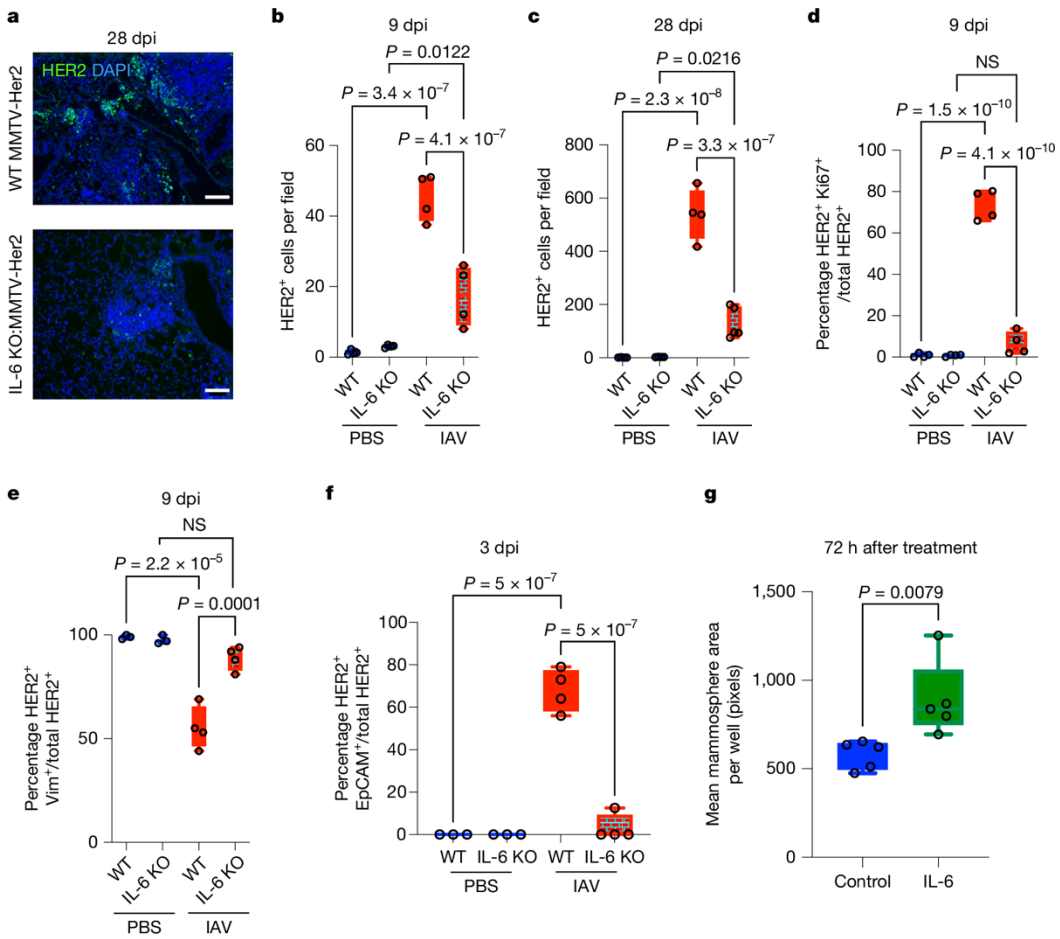

a
IAV or PBS
14 Weeks
MMTV-Her2
Days: 3 6 9 15 28 60
Lungs
Mammary glands
b
PBS
6 dpi
15 dpi
28 dpi
HER2 DAPI
c
P = 3 × 10−11
P = 7.3 × 10−12
P = 1.6 × 10−7
Total number of HER2+ cells
PBS 3 6 9 15 28 60
IAV (dpi)
d
HER2 DAPI
HER2+ cells per field
P = 0.0002
PBS IAV
e
MMTV-Her2 (C57BL/6)
P = 7.3 × 10−8
HER2+ cells per field
f
PyMT
PBS
IAV
Number of micrometastases
P = 0.0089
g
PBS IAV
log2 fold change in tumour area
P = 0.0022
Fold change in number of lesions
P = 0.0137
a
% weight change
days
WT+PBS
MMTV-Her2+PBS
WT+IAV
MMTV-Her2+IAV
b
Total cell count
cells
PBS 3 6 9 15 dpi, IAV
c
IAV RNA Copies (log10)
PBS 3 6 9 15 dpi, IAV
d
Influenza virus induced
Spontaneous
100μm
DAPI Her2
e
PBS
IAV
50μm
Her2 Ki67 DAPI
f
9 dpi
% of ducts with Ki67+
ns
PBS IAV
g
9 dpi
Cycle Threshold (Ct)
ns
PBS IAV
h
PBS
IAV
DAPI p53 Ki67
200μm
i
2×10^5 EO771 cells
1×10^6 EO771 cells
Number of Ki67+ tumor cells
PBS IAV
EO771

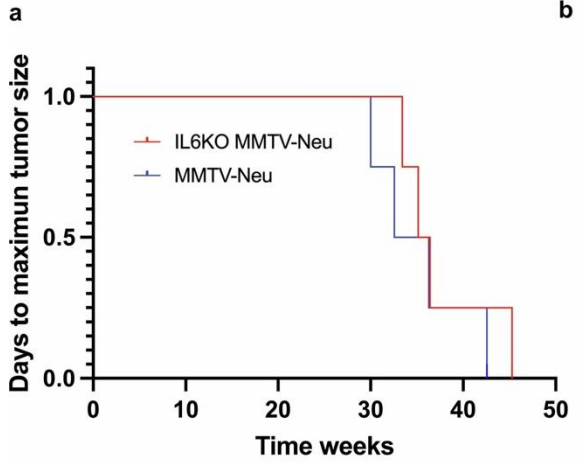
Figure 2

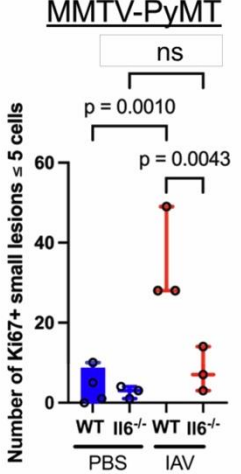

a
PBS
9 dpi
28 dpi
HER2 Ki67 DAPI
b
Percentage HER2+ Ki67+/total HER2+
Total HER2+ Ki67+ cells
Percentage HER2+ EdU+/total HER2+
IAV (dpi)
9 dpi
c
HER2
Vimentin
HER2 DAPI
Vimentin DAPI
3 dpi
9 dpi
Percentage HER2+ Vim+/total HER2+
d
HER2
EpCAM
EpCAM DAPI
Percentage HER2+ EpCAM+/total HER2+
e
Hallmark inflammatory response
Hallmark Il6 JAK–STAT3 signalling
Hallmark TNF signalling through NFKβ
Hallmark angiogenesis
Hallmark epithelial mesenchymal transition
Go collagen containing extracellular matrix
Go epithelial cell proliferation
Hallmark INFγ response
Hallmark INFα response
Gene set
Enrichment
IAV
PBS
Normalized enrichment score
f
Col1a1
Col1a2
Col3a1
Col4a1
Col4a2
Col4a5
Col4a6
Col5a1
Col5a2
Col5a3
Col6a1
Col6a2
Col6a3
Col8a1
Col9a1
Col9a3
Col11a1
Col12a1
Col13a1
Col15a1
Col16a1
Col18a1
Col23a1
Col27a1
Lox
Loxl1
Loxl2
g
Row z-score
Mmp8
Mmp11
Mmp14
Mmp15
Mmp19
Mmp28
h
Vegfa
Vegfb
Vegfc
Vegfd
Vcam1
Icam1
Icam2

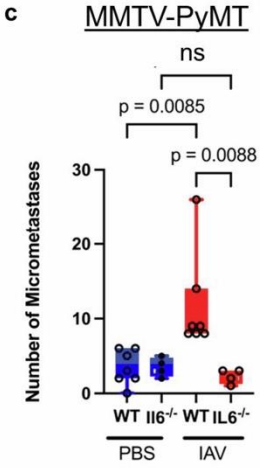
a
HALLMARK_INTERFERON_ALPHA_RESPONSE
b
HALLMARK_INTERFERON_GAMMA_RESPONSE
c
HALLMARK_IL6_JAK_STAT3_SIGNALING
d
HALLMARK_EPITHELIAL_MESENCHYMAL_TRANSITION
PBS
IAV
e
IL-6
conc. (pg/ml)
n.d.
WT
Her2
PBS 3 6 9 15 dpi, IAV
f
IL-1β
g
IL-6
p = 0.0122

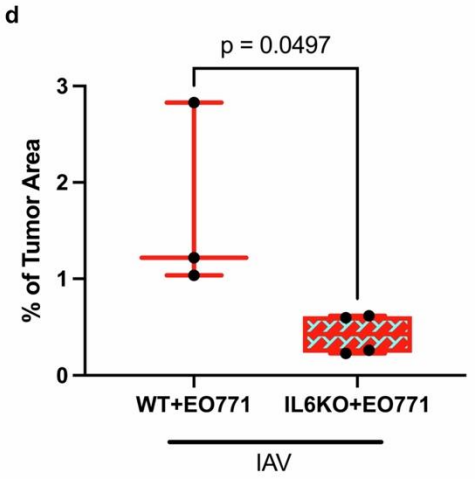
Figure 3

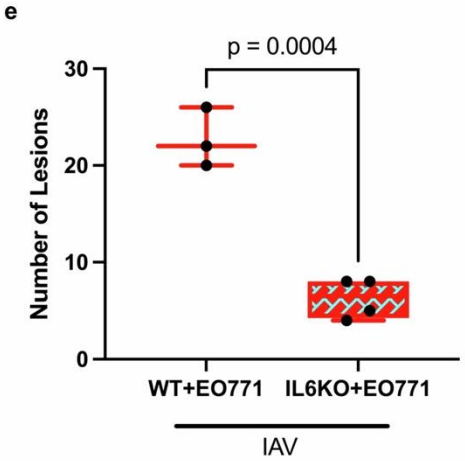

a
28 dpi
HER2 DAPI
WT MMTV-Her2
IL-6 KO:MMTV-Her2
b
9 dpi
P = 0.0122
P = 3.4 × 10−7
P = 4.1 × 10−7
HER2+ cells per field
WT
IL-6 KO
WT
IL-6 KO
PBS
IAV
c
28 dpi
P = 0.0216
P = 2.3 × 10−8
P = 3.3 × 10−7
HER2+ cells per field
d
9 dpi
NS
P = 1.5 × 10−10
P = 4.1 × 10−10
Percentage HER2+ Ki67+ /total HER2+
e
9 dpi
NS
P = 2.2 × 10−5
P = 0.0001
Percentage HER2+ Vim+/total HER2+
f
3 dpi
P = 5 × 10−7
P = 5 × 10−7
Percentage HER2+ EpCAM+/total HER2+
g
72 h after treatment
P = 0.0079
Mean mammosphere area per well (pixels)
Control
IL-6

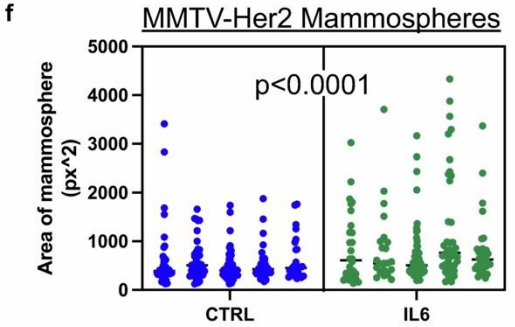

a
Days to maximun tumor size
IL6KO MMTV-Neu
MMTV-Neu
Time weeks


b
MMTV-PyMT
ns
p = 0.0010
p = 0.0043
Number of Ki67+ small lesions ≤ 5 cells
WT
Il6-/-
WT
Il6-/-
PBS
IAV


c
MMTV-PyMT
ns
p = 0.0085
p = 0.0088
Number of Micrometastases
WT
Il6-/-
WT
IL6-/-
PBS
IAV


d
p = 0.0497
% of Tumor Area
WT+EO771
IL6KO+EO771
IAV


e
p = 0.0004
Number of Lesions
WT+EO771
IL6KO+EO771
IAV


f
MMTV-Her2 Mammospheres
p<0.0001
Area of mammosphere (px^2)
CTRL
IL6

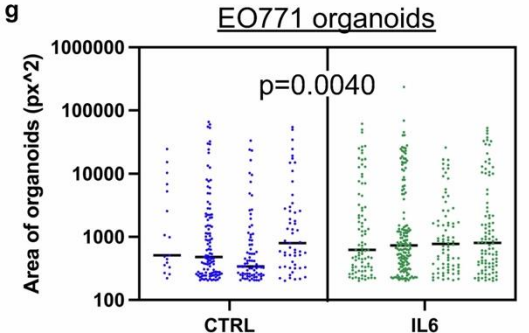

g
EO771 organoids
p=0.0040
Area of organoids (px^2)
CTRL
IL6

Figure 4

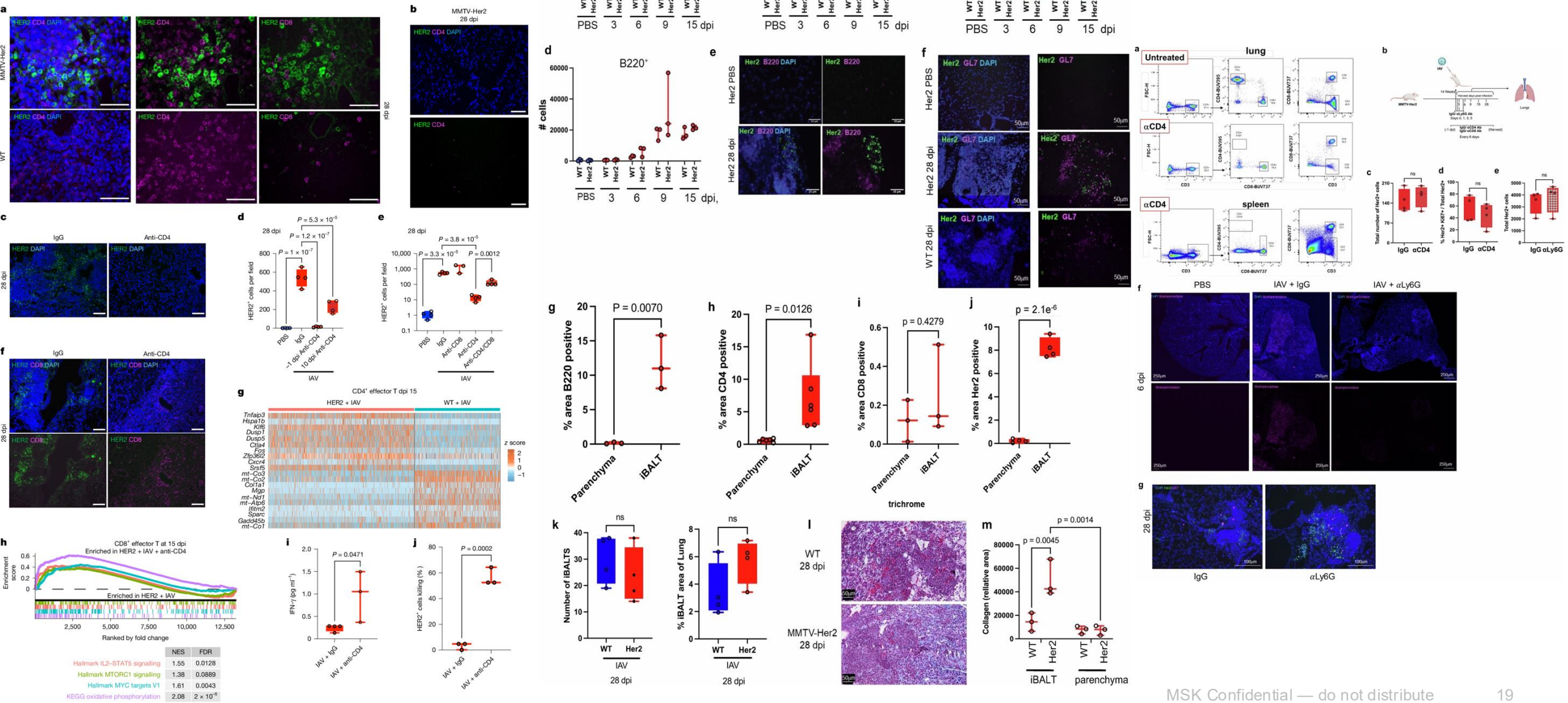
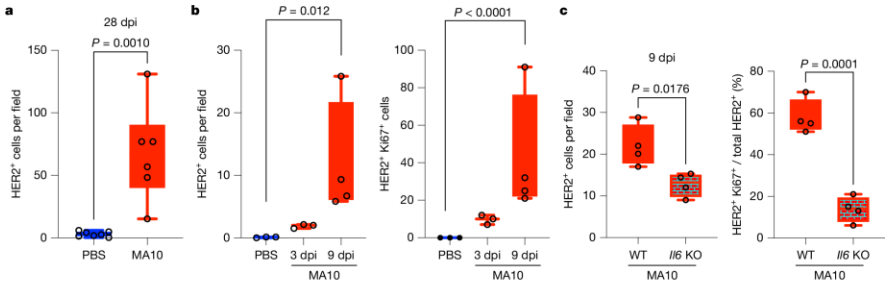
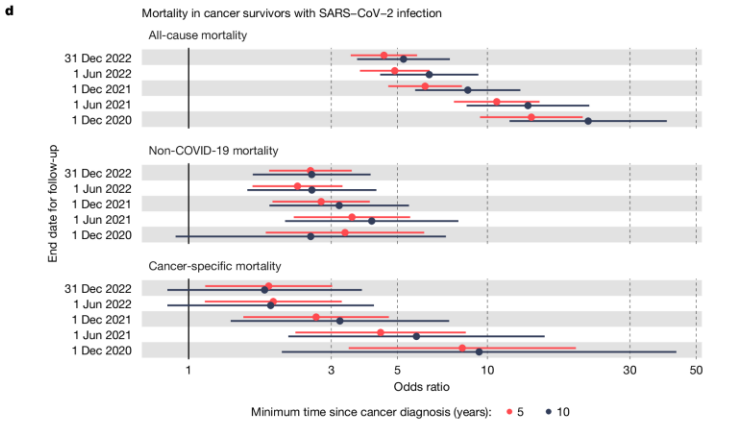
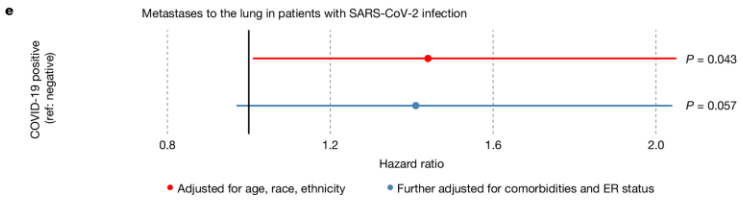
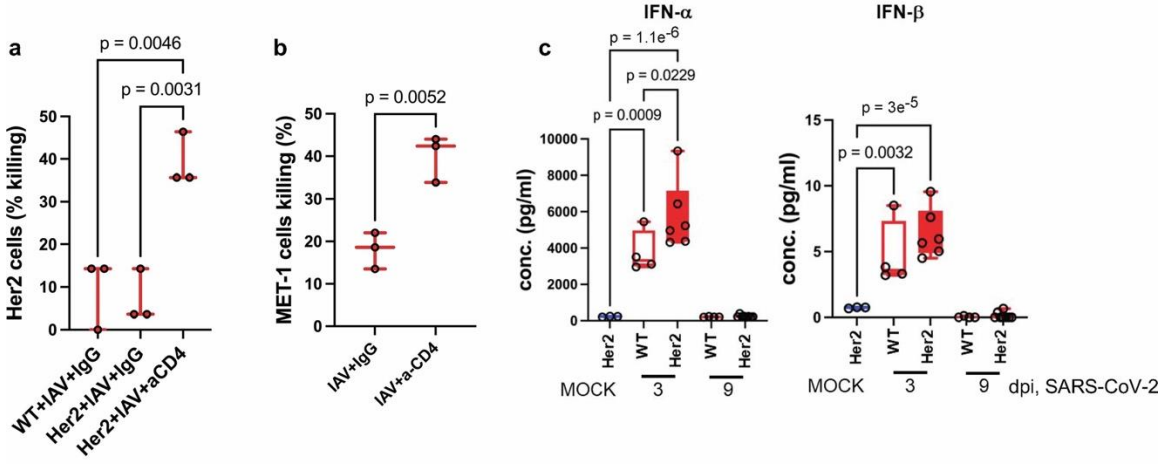

a
HER2 CD4 DAPI
HER2 CD4
HER2 CD8
MMTV-Her2
WT
28 dpi
b
MMTV-Her2
28 dpi
HER2 CD4 DAPI
HER2 CD4
c
IgG
Anti-CD4
HER2 DAPI
28 dpi
d
28 dpi
HER2+ cells per field
PBS
IgG
−1 dpi Anti-CD4
10 dpi Anti-CD4
IAV
e
28 dpi
HER2+ cells per field
PBS
IgG
Anti-CD8
Anti-CD4
Anti-CD4/CD8
IAV
f
IgG
Anti-CD4
HER2 CD8 DAPI
HER2 CD8
28 dpi
g
CD4+ effector T dpi 15
HER2 + IAV
WT + IAV
Tnfaip3
Hspa1b
Klf6
Dusp1
Dusp5
Ctla4
Fos
Zfp36l2
Cxcr4
Srsf5
mt−Co3
mt−Co2
Col1a1
Mgp
mt−Nd1
mt−Atp6
Ifitm2
Sparc
Gadd45b
mt−Co1
z score
h
CD8+ effector T at 15 dpi
Enriched in HER2 + IAV + anti-CD4
Enriched in HER2 + IAV
Enrichment score
Ranked by fold change
NES
FDR
Hallmark IL2–STAT5 signalling
1.55
0.0128
Hallmark MTORC1 signalling
1.38
0.0889
Hallmark MYC targets V1
1.61
0.0043
KEGG oxidative phosphorylation
2.08
2 × 10−6
i
IFN-γ (pg ml−1)
IAV + IgG
IAV + anti-CD4
j
HER2+ cells killing (%)
IAV + IgG
IAV + anti-CD4
a
Neutrophils
cells
PBS
3
6
9
15 dpi
b
CD4+
cells
c
CD8+
cells
d
B220+
cells
e
Her2 PBS
Her2 28 dpi
Her2 B220 DAPI
Her2 B220
f
Her2 PBS
Her2 28 dpi
WT 28 dpi
Her2 GL7 DAPI
Her2 GL7
50μm
a
Untreated
lung
αCD4
spleen
b
c
Total number of Her2+ cells
IgG
αCD4
d
% Her2+ Ki67+ / Total Her2+
IgG
αCD4
e
Total Her2+ cells
IgG
αLy6G
f
PBS
IAV + IgG
IAV + αLy6G
6 dpi
g
28 dpi
IgG
αLy6G
g
% area B220 positive
P = 0.0070
Parenchyma
iBALT
h
% area CD4 positive
P = 0.0126
Parenchyma
iBALT
i
% area CD8 positive
p = 0.4279
Parenchyma
iBALT
trichrome
j
% area Her2 positive
p = 2.1e−6
Parenchyma
iBALT
k
Number of iBALTS
ns
WT
Her2
IAV
28 dpi
% iBALT area of Lung
ns
WT
Her2
IAV
28 dpi
l
WT
28 dpi
MMTV-Her2
28 dpi
m
Collagen (relative area)
p = 0.0014
p = 0.0045
WT
Her2
iBALT
parenchyma

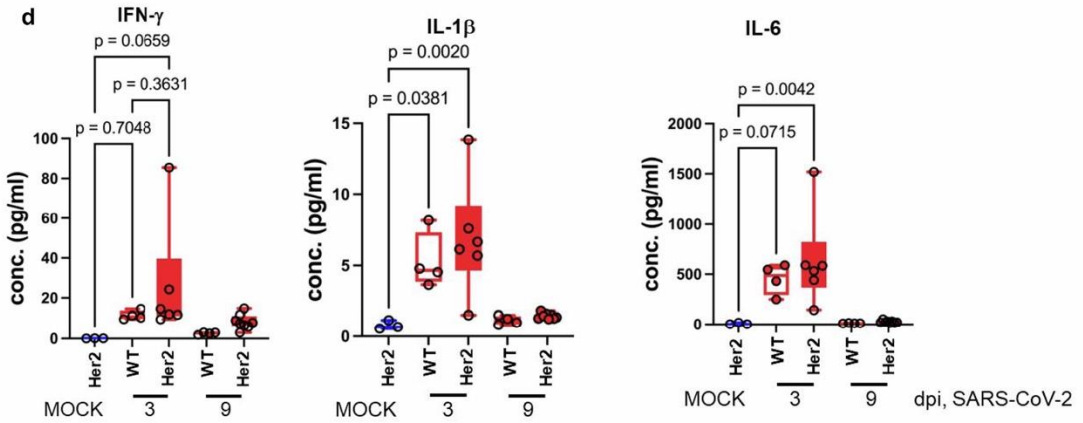
Figure 5

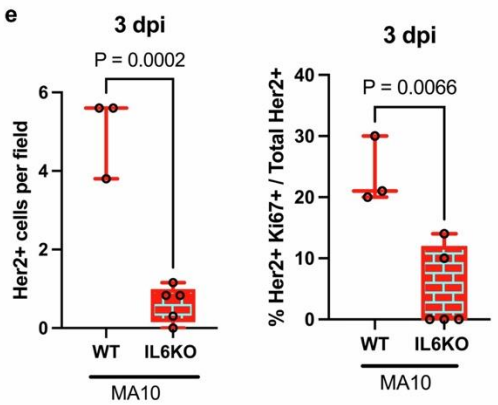

a
28 dpi
P = 0.0010
HER2+ cells per field
PBS
MA10
b
P = 0.012
HER2+ cells per field
PBS
3 dpi
9 dpi
MA10
P < 0.0001
HER2+ Ki67+ cells
c
9 dpi
P = 0.0176
HER2+ cells per field
WT
Il6 KO
MA10
P = 0.0001
HER2+ Ki67+ / total HER2+ (%)

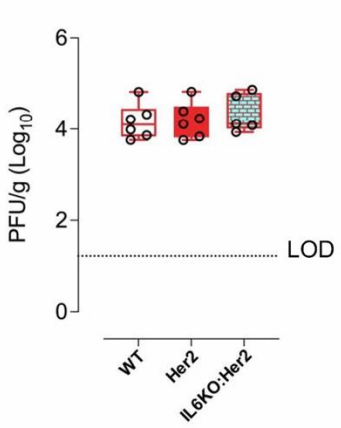

d
Mortality in cancer survivors with SARS–CoV–2 infection
All-cause mortality
Non-COVID-19 mortality
Cancer-specific mortality
End date for follow-up
31 Dec 2022
1 Jun 2022
1 Dec 2021
1 Jun 2021
1 Dec 2020
Odds ratio
Minimum time since cancer diagnosis (years): 5 10


e
Metastases to the lung in patients with SARS-CoV-2 infection
COVID-19 positive (ref: negative)
P = 0.043
P = 0.057
Hazard ratio
Adjusted for age, race, ethnicity
Further adjusted for comorbidities and ER status

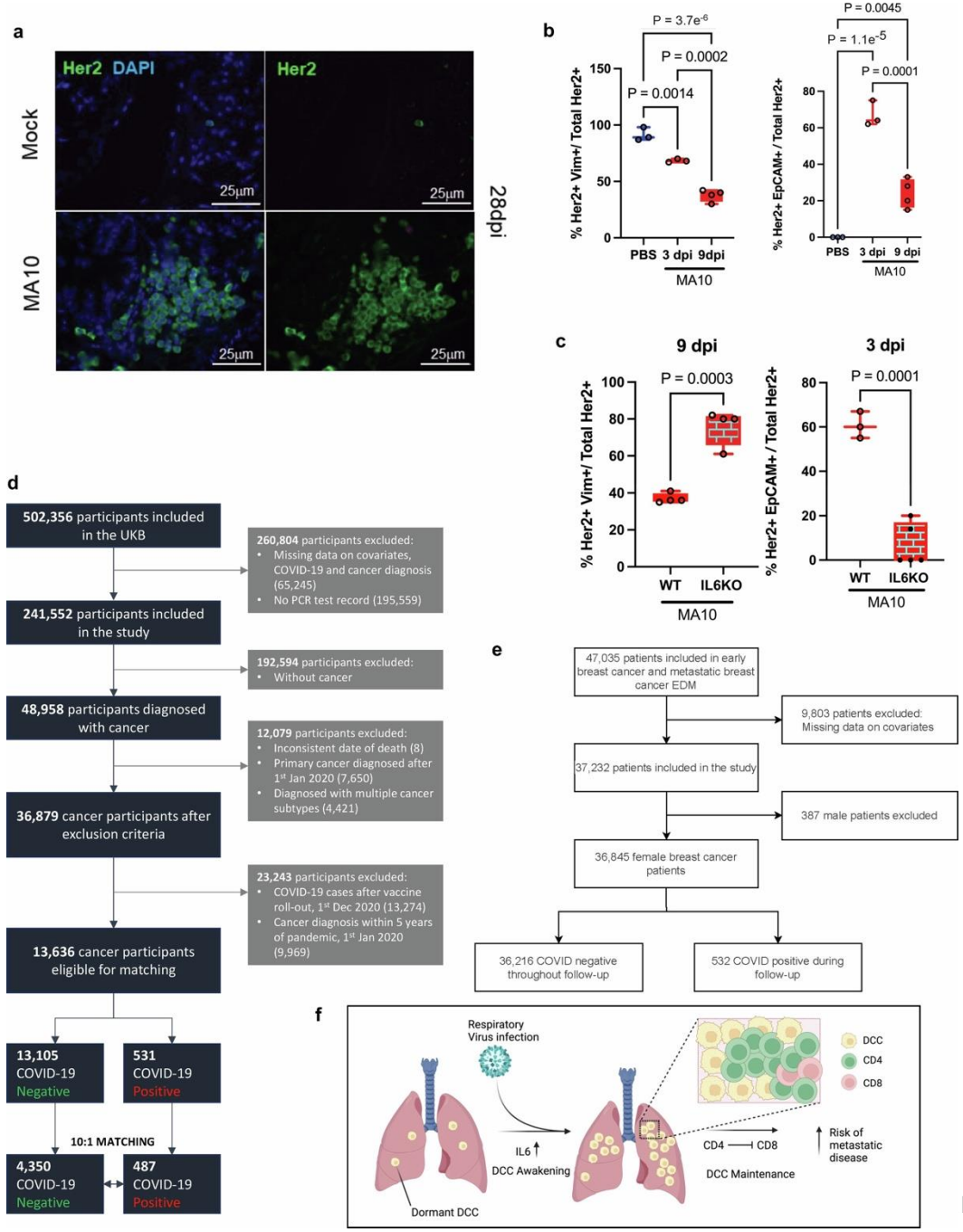

a
p = 0.0046
p = 0.0031
Her2 cells (% killing)
WT+IAV+IgG
Her2+IAV+IgG
Her2+IAV+aCD4
b
p = 0.0052
MET-1 cells killing (%)
IAV+IgG
IAV+a-CD4
c
IFN-α
p = 1.1e-6
p = 0.0229
p = 0.0009
conc. (pg/ml)
IFN-β
p = 3e-5
p = 0.0032
MOCK
3
9
dpi, SARS-CoV-2


d
IFN-γ
p = 0.0659
p = 0.3631
p = 0.7048
IL-1β
p = 0.0020
p = 0.0381
IL-6
p = 0.0042
p = 0.0715
conc. (pg/ml)
Her2
WT
MOCK
3
9
dpi, SARS-CoV-2


e
3 dpi
P = 0.0002
Her2+ cells per field
WT
IL6KO
MA10
3 dpi
P = 0.0066
% Her2+ Ki67+ / Total Her2+


f
PFU/g (Log10)
LOD
WT
Her2
IL6KO:Her2

Conclusion/Model



Thanks for your attention!

Any questions?


Memorial Sloan Kettering
Cancer Center