
Supplementary information

Innovation in the Chinese pharmaceutical industry

In the format provided by the authors

Data and analysis

The top 20 multinational and Chinese pharmaceutical companies were selected from *The Pharma 1000 - Top Global Pharmaceutical Company Report*¹ published by Torrey research (a globally active investment bank focused on the pharmaceutical sector) on November 2021. In the report, public and private companies were both covered, and ranked by the estimated value, with a common set of standards. Specifically, the publicly traded companies were valued using their enterprise value, and the estimated values of private companies were imputed using its specific approach. The 1,000 pharmaceutical companies were distinguished as Big Pharma, Branded Pharma, Generics, Biotechnology, Biosimilars, Animal Health, and Royalty Company. Generally, any company classified to the sector “Animal Health” were not included in this study.

The data for the 40 companies’ R&D pipelines were retrieved from the Cortellis Database of Clarivate Analytics, as of 13 December 2021. The profiles of drugs launched and registered in the past 10 years were retrieved by defining the company name and the date in the advanced search. The number of active drugs by highest status (for example, phase 2) was displayed by retrieving the company names. We downloaded the list of all drugs for further analysis. Basic characteristics included drug name, active company, therapy area, active indication, highest status, and target-based actions. Notably, because the ninth ranked Chinese company Imeik Technology Development focuses on the R&D, production and sales of medical soft tissue repair materials, no drug development pipeline was found and so it was not included in the detailed analysis.

Data were manually verified and analyzed with respect to clinical-stage products, therapeutic areas and novel drug targets of the R&D pipelines of the 40 companies. All indications were divided into several broad therapeutic areas (cancer, infection, neurology/psychiatric, endocrine/metabolic, immune, gastrointestinal, genitourinary /sexual function, dermatologic, musculoskeletal, respiratory, hematologic, ocular, cardiovascular, inflammatory, and so on) as defined in the Cortellis database. Based on the data generated from the database, we selected the top 5 therapeutic areas by the number of drugs for each company to illustrate. Moreover, the clinical landscapes of products were only based on the highest clinical phase. The clinical-stage products’ targets disclosed were artificially divided into new targets or mechanisms of action (MOAs) and mature targets, according to whether drugs that are considered to act by modulating the target have been approved or not, as of 13 December 2021.

References

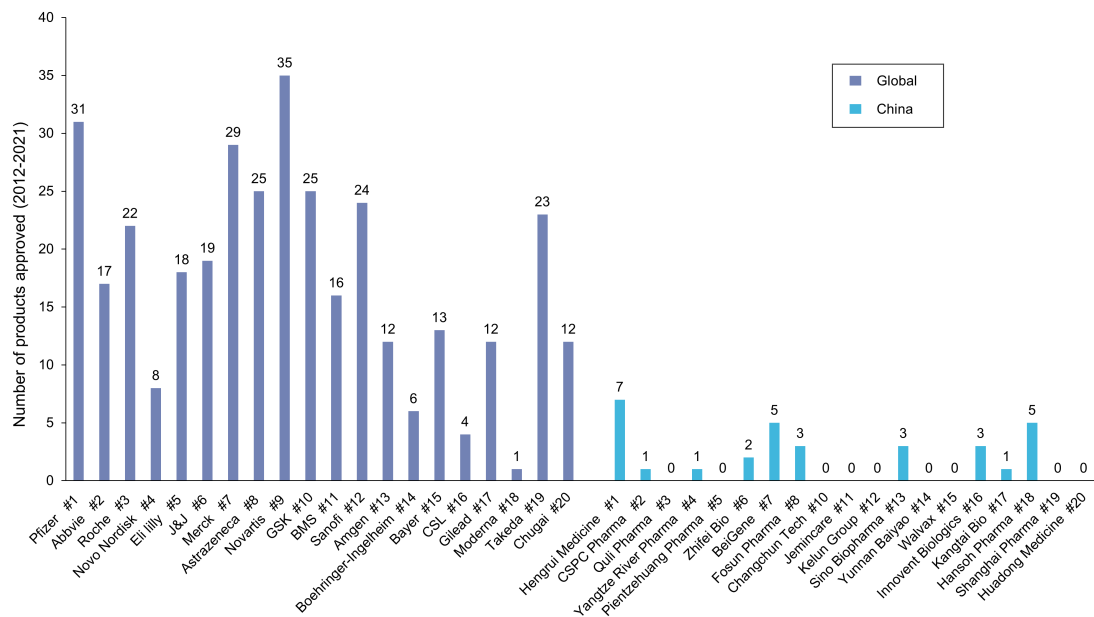
1. Torrey. *The Pharma 1000 - Top Global Pharmaceutical Company Report*. <https://torreya.com/publications/pharma-1000-report-update-torreya-2021-11-18.pdf> (2021).

Supplementary Table 1 | Top 20 pharmaceutical companies in the world in 2021 by value¹

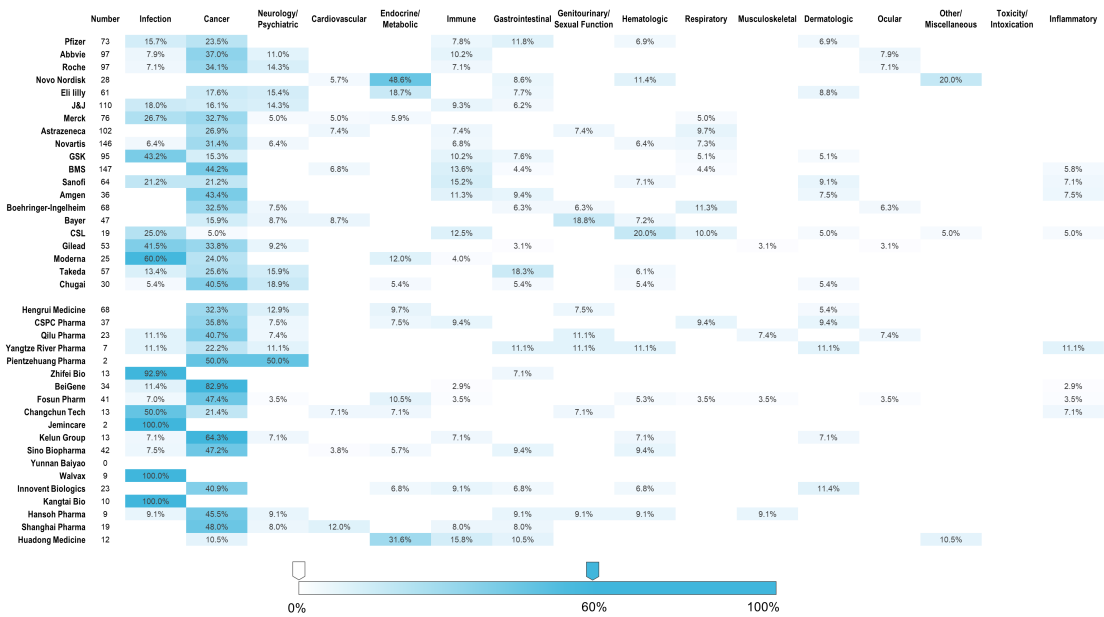
Rank	Global rank	Name	Value (billion)	Location	Company type	Sector
1	1	Pfizer	\$289	New York Area, US	Public Company	Big Pharma
2	2	AbbVie	\$276	Chicago Area, US	Public Company	Big Pharma
3	3	Roche Pharma Segment	\$264	Basel, Switzerland	Public Company Segment	Big Pharma
4	4	Novo Nordisk	\$254	Copenhagen, Denmark	Public Company	Big Pharma
5	5	Eli Lilly	\$252	Indiana, US	Public Company	Big Pharma
6	6	Janssen (J&J Rx Segment)	\$241	New York Area, US	Public Company Segment	Big Pharma
7	7	Merck	\$224	New York Area, US	Public Company	Big Pharma
8	8	AstraZeneca	\$208	Cambridge and Oxford, UK	Public Company	Big Pharma
9	9	Novartis	\$192	Basel, Switzerland	Public Company	Big Pharma
10	10	GSK Pharma Segment	\$173	London, United Kingdom	Public Company Segment	Big Pharma
11	11	Bristol-Myers Squibb	\$161	New York Area, US	Public Company	Big Pharma
12	12	Sanofi	\$142	Paris, France	Public Company	Big Pharma
13	13	Amgen	\$139	Los Angeles, US	Public Company	Big Pharma
14	14	Boehringer Ingelheim	\$121	Rhine Area, Germany	Private Company	Big Pharma
15	15	Bayer Pharma Segment	\$112	Rhine Area, Germany	Public Company Segment	Big Pharma
16	16	CSL	\$110	Melbourne, Australia	Public Company	Big Pharma
17	18	Gilead	\$103	Bay Area, US	Public Company	Big Pharma
18	19	Moderna	\$88.0	Boston Area, US	Public Company	Big Pharma
19	20	Takeda	\$76.7	Tokyo, Japan	Public Company	Branded Pharma
20	21	Chugai	\$58.2	Tokyo, Japan	Public Company	Branded Pharma

Supplementary Table 2 | Top 20 pharmaceutical companies in China in 2021 by value¹

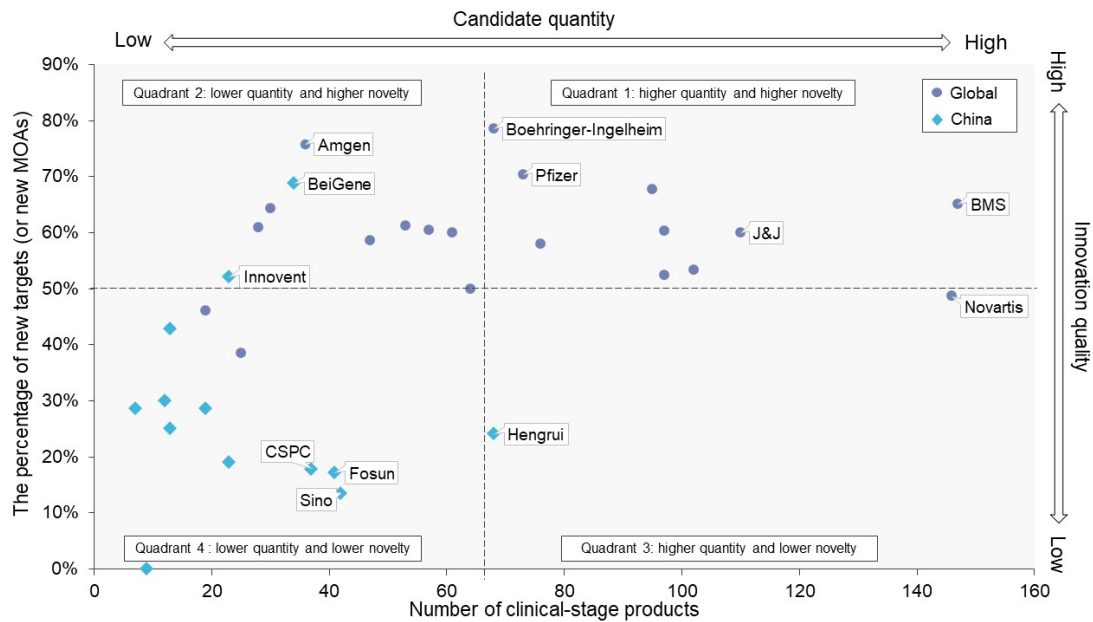
Rank	Global rank	Name	Value (billion)	Location	Company type	Sector
1	24	Hengrui Medicine	\$48.9	Jiangsu Province, China	Public Company	Branded Pharma
2	25	CSPC Pharma	\$47.0	Hebei Province, China	Private Company	Branded Pharma
3	27	Qilu Pharma	\$44.3	Shandong Province, China	Private Company	Branded Pharma
4	32	Yangtze River Pharma	\$42.9	Jiangsu Province, China	Private Company	Generics
5	33	Pientzhuang Pharma	\$38.7	Fujian Province, China	Public Company	Generics
6	34	Zhifei Bio	\$32.6	Sichuan Province, China	Public Company	Branded Pharma
7	38	BeiGene	\$31.0	Beijing, China	Public Company	Branded Pharma
8	50	Fosun Pharma	\$19.6	Shanghai, China	Public Company	Branded Pharma
9	51	Imeik Technology	\$18.5	Beijing, China	Public Company	Branded Pharma
10	56	Changchun Tech	\$17.9	Jilin Province, China	Public Company	Biosimilars
11	59	Jemincare	\$16.1	JianxiProvince, China	Private Company	Generics
12	60	Kelun Group	\$16.1	Sichuan Province, China	Private Company	Generics
13	61	Sino Biopharma	\$14.7	Hong Kong, China	Public Company	Generics
14	68	Yunnan Baiyao	\$14.0	Yunnan Province, China	Public Company	Generics
15	72	Walvax	\$12.7	Yunnan Province, China	Public Company	Biosimilars
16	76	Innovent Biologics	\$11.5	Jiangsu Province, China	Public Company	Branded Pharma
17	77	Kangtai Bio	\$11.4	Guangdong Province, China	Public Company	Branded Pharma
18	78	Hansoh Pharma	\$10.4	Jiangsu Province, China	Public Company	Branded Pharma
19	85	Shanghai Pharma - Mfg	\$9.7	Shanghai, China	Public Company Segment	Generics
20	87	Huadong Medicine	\$9.5	Zhejiang Province, China	Public Company	Generics



Supplementary Figure 1 | The landscape of products approved for companies (2012–2021). Bar plots showing the cumulative number of innovative agents (new molecular entities or biologics) that have been registered or launched for each company. The innovative agents were picked and calculated by performing a second-round manual processing to the data exported from the database. It should be noted that the sum of the numbers of drugs from the individual 20 multinational companies is 352, and 39 agents were co-developed by multiple companies. Thus, the total number of approved drugs in the text is 313, a result of subtracting 39 from 352.



Supplementary Figure 2 | The number of clinical-stage products and their indications.
 The number of clinical-stage products for each company is shown in the second column. The percentage value was obtained by dividing the cumulative number of products for each disease area by the number of clinical-stage products. A gradient two-tone colour scale was used to visualize the percentage value, with the color becoming deeper as the proportion get larger.



Supplementary Figure 3 | A quadrant chart assessing quantity and novelty of the clinical-stage pipelines for Chinese and multinational pharma companies. We excluded 6 Chinese companies for which drug targets were not available. The clinical-stage pipelines for total of 33 companies were plotted (Chinese pharma in blue dots and multinational pharma in purple dots). The vertical line and horizontal line were drawn at the X value as 66 (median of the products number of top 20 multinational companies) and the Y value as 50% novel mechanisms of action. This allows rough classification of the companies into four categories based on their drug candidates' quantity and the level of novelty in terms of mechanisms of action/targets.

Supplementary Table 3 | Target summary of clinical-stage products of the top 20 multinational pharma companies

New targets and new MOAs (multinational)							
17β-HSD13	1	CFD	3	IGF-2 IGF-1	1	PDE9	1
4-1BB	3	CH24H	2	IKZF1 CRBN IKZF3	1	PDE9A	1
A17	1	ChR2	1	IKZF2	1	PDR CRBN	1
A2aR A2bR	1	Chymase	1	IL-12 gene stimulator	1	PGRN	1
Abl Fyn Src	1	CK1α	1	IL-12 Muc16	1	PI3K mTOR	2
ACC	1	CNGA3	1	IL-12R	1	PI3Kα	1
ACC DGAT2	1	CNGB3	2	IL-13 OX40	1	PI3Kγ ATR	1
ACVR2A BMP 11	1	CRK7	1	IL-15	1	PI4K	1
ADGRL1	1	CSF-1	2	IL-15 PD-1	1	PIP5K2B	1
ADM	2	CSF-3R	1	IL-18	2	PMCA4	2
AhR	1	CTLA4 IL-12	1	IL-1α	1	PNPLA3	3
AKT	4	CX3CR1	2	IL-2 IL-2Rβ	1	PORCN	1
Akt-1 Akt- 2 Akt-3	1	CXCR2	2	IL-2 Tenascin	1	PP2C	2
AL	1	CXCR5	1	IL-21	1	PPP1R1A	1
ALK5	2	CXCR5 CXCR6	1	IL-21 PD-1	1	PRMT1	1
AMPK Ang1 2	1	Cysteine protease	1	IL-22	2	PRMT5	4
ANG2 AT-2	1	DAF ICAM-1	1	IL-23 OX-40	1	PSMA	1
ANG3	1	DARC KRAS Me k1/2	1	IL-2Rβ FcRn	1	PSMB5	1
ANGPTL3	2	DC-SIGN	1	IL-31	2	PTH1R	2
ANO1	1	DGAT2	2	IL-33	1	PTK7	2
Tau	11	DKK1	1	IL-36R	1	PTPs	1
APLN	2	DLL3	2	IL-7	1	PYY	3
APOA	2	DNMT1	1	ILDR2	1	RARγ antagonist	2
APOA1	2	DOT1L	1	IRAK4	5	relaxin	3
APOC3 antagonist	1	DPEP3	1	JAK1 TYK2	2	RIG-I	1
APOL1	1	DPP-1	1	JAK3/Tec	1	RIPK1	4
APPBP1	1	DprE1	1	JNK1	1	RLBP1	1
AR CXCR2	1	Dystrophin gene	1	KAAG1	1	ROR1	3
ASK1	1	EL	1	KAT6A	1	RPGR	1
AT(RNAi)	1	Elf2	1	KHK	2	RSPO3	1
ATOH1	1	ENPP-2	1	Kir3.1	1	RSV F	2
ATP7B	1	Eotaxin-1	1	KLK2	2	RZRγ	3
ATR	1	ERK1/2	2	KMO	1	SAM2	1
AURKA	1	ERK2	1	KTM2A	1	SAP	1
Aurora B	1	ERα	1	LAG3	7	SAP TGF-β	1
Aurora kinase	2	EthR	1	LAG3 PD-1	1	SEMA3A	1
Axl Mer	1	F1F0-ATPase	3	LAIR2	2	Serp1B1	1
Aβ GlyT1	1	FAAH	1	LDLR PCSK9	1	SEZ6	1
B1 receptors	1			LIF	1	SHP2	3
B7-H4	1	Factor XI	2	LIV-1	1	SIRPα	1
bacterial Topo IV	1	Factor XIa	8	LOX-1	1	SLFN12	1

BB2	1	FAK	1	LPA	1	SLIT2 ROBO2	1
BB3	1	FcγR	1	LPAR1	3	SORL1	2
BCL11A	2	FGF	1	LRRC15	1	SOS1	1
Bcl-xl Bcl-2	2	FGF21	2	MAA3/6	1	SRPK1	1
Bcl-xl CD276	1	FGF21 KLB FGFR1	2	MAGEA3	1	SSTR4	1
BET	5	FimH	2	MAGEC1 survivin MAGEC2	1	STING	5
BMP6	1	FLAP	1	MAPKAPK2	2	SUMO	1
BMPR2	1	Flt3	1	MAPT gene inhibitor	1	Syk ZAP70	1
BRD2/3/4	1	FOXP3	1	Mcl-1	6	TAAR1	2
BRD4	1	FPR1	1	MDM2 p53	3	TASK	1
BTK	1	FPR2	1	MECP2	1	TCPTP	2
BTLA	1	FRα	1	mGluR2	2	TCR	1
C1s	2	FXR Insulin	1	mGluR5	2	TFPI	2
C3 CFP	1	GAA gene	1	mini-dystrophin gene	1	TfR1 Aβ	1
CA6	1	GABRA5	1	MLL1 KTM2A	1	TG2	1
CACNG8	1	GAP1	1	MPO	1	TGF-β1	1
CAIX	1	GARP TGF-β1	1	MSLN	3	TGF-β1 TGF-β3	1
Cas9	1	GCGR GLP-1R	1	Mtb LeuRS	1	Tie-2 p38 MAPK	1
Cbl-b	1	GCGR GLP-1R OXM	1	mTOR	1	TIGIT	7
CCR	1	G-CSF	1	mTOR DNA-PK	1	TIM3	4
CCR2 CCR5	1	GDF15	4	mTOR1/2	1	TIM3 PD-1	1
CCR5	1	GFRα1	1	MUT	1	TLR4	1
CCR6	1	GIP	1	myostatin	2	TLR7	1
CCR7	1	GIPR	3	Nav1.7	1	TLR7/8	1
CCR8	2	GIPR GLP-1R	3	NCAM	1	TLR8	1
CD13 LIFR	1	GLP-1R	2	NFκB	1	TNF	2
CD158	1	Glucokinase	2	NK1 NK3	1	TNFR1	2
CD19	1	GluN2B	2	NKG2A	2	TNFSF15	1
CD1a	1	Gluten	1	NKG2D NKG2DL	1	TNF-α GCCR	2
CD20 CD47	1	GnRHR GPR54 Metastasin	1	NLRP3	5	TPI1	1
CD200R	1	GPC3	3	NMDAR partial agonist	1	TPL2	1
CD226	1	GPRC5D	1	Nogo A	1	TRAILR	1
CD25 IL-2RA	1	Gwt1	2	Notch	1	TRAILR2	1
CD27	1	H4	1	NPRC	1	TREM2	1
CD276	1	HBG	1	NRG4	1	TrkA	1
CD28	1	HbS	1	NY-ESO-1	8	TRPA1	1
CD29 IL10	1	HBV-PD-1/L1	1	OGT Tau	1	TRPC4/5	1
CD3 CD80	1	HDAC2 HDAC1	1	OX1R	2	TRPV1 antagonist	2
CD33	1	Hemagglutinin	3	OX2R	4	TRPV4	1
CD37	2	HER3	1	OX40	4	TSLP	3
CD38 INF-α2	1	HIV capsid	1	OX40L	2	TYK2	5
CD39	1	HIV env	2	oxLDL	1	UBE3A	1

CD40	7	HIV-1 gag	1	OXM	1	USP1	1
CD40L	3	HIV-1 integrase	1	p130Cas-associated protein	1	VEGI	1
CD40L CD47	1	HLA-A2 WT1	1	P2X3	1	vWF-cp Vwf	1
CD47	2	HPV E6	1	P2X4	1	WEE1	1
CD59	1	HPV E6 HPV E7	2	P2X7	2	Wnt/ β -catenin	1
CD66e	2	HPV E7	1	p38 MAPK	1	XIAP	1
CD71	1	HPX	1	PACAP38	1	α 2C-AR	1
CD73	5	Hsp47	1	PAR2	1	α 5 β 1	1
CD96	1	HTRA1	1	PARP1	1	α -synuclein	7
CDC7	1	HTT	2	PCCA	1	α v β 3	1
CDH3	1	IAP	1	PD-1 CTLA4 CD80 CD28	1	α v β 5 α v β 3	1
CDK2	1	ICOS	6	PD-1 TIGIT	1	α v β 8	2
CDK9	1	IDO1	1	PDE10A	1	ϕ CPG1 VP1	1
CFB	1	IGF-1R IGFBP2	1	PDE2	1		

Bi- and tri-specific antibodies

4-1BB FAP	2	CD3 Claudin 18	1	CD3 TYRP1	1	DLL4 VEGF	1
4-1BB PD-1	1	CD3 DLL3	2	CD3 CD20	4	EGFR HGFR	1
4-1BB CD19	1	CD3 EGFR	1	CD3 CD22	1	FGFR1 KLB	1
Ang2 VEGF-A	1	CD3 FCRL5	1	CD3 Fit3	1	LRP6 LRP5	1
Ang2 VEGF	4	CD3 GPC3	2	CD3 HLA-A2	3	PD-1 TIGIT	2
BCMA CD3	6	CD3 GPCRC5D	1	CD3 NCR3LG1	1	PD-1 CTLA4	1
CD3 5T4	1	CD3 HER2	2	CD3 STEAP1	1	PD-1 LAG3	1
CD3 CD123	2	CD3 KLK2	1	CD4 gp41	1	PD-1 PD-L1	1
CD3 CD33	3	CD3 Muc 17	1	CD40 MSLN	1	PD-1 TIM3	1
CD3 CD66e	2	CD3 PSMA	3	CD47 PD1	1		
CD38 CD3 CD28	8			CD3 HER2 CD28	1		

Mature target (multinational)

5-HT D2R	1	CRBN	5	HRE2 TLR7	1	PD-1	11
5-HT4	2	CSF-1	2	IDH	2	PD1 CTLA4	1
5-HT7	1	CTLA4	6	IDUA	1	PDE	1
A1AT	2	CTLA4 EGFR	1	IFN α IFN γ	1	PDE4	1
A2aR	1	CXCR4	2	IFN β	1	PDGF PD-1	1
ACC FXR	1	D1R	2	IgE	1	PDGF/PDGF R	1
AhR	1	D2R/D3R	1	IgG	1	PDGFR α	1
albumin	1	DHODH	2	IL-12 IL-23	1	PD-L1	3
ALDOS	1	DR	1	IL-13	2	PGFR VEGF	1
amylin/amylin receptor	1	dystrophin	1	IL-15	1	PGI2 receptor	1
Apoc3	1	EED	1	IL-17	1	PI3K mTOR	1
AR	1	EGFR	7	IL-17A	1	PI3K α	1
ASA	1	EGFR, BRAF, Ret	1	IL-1RA	1	PI3K δ	2
ASM	1	EGFR HER2/4	1	IL-1 β	1	PLA2	1
AT1	1	ENaC	3	IL-2	5	progesterone/progesterone receptor	1
AVPR1	1	ENaC CFTR	1	IL-2 PD-1	1	proteasome	3

AVPR1A	1	EP2	1	IL-23	3	Raf	2
AVPR1A/2	1	EP4	1	IL-4	1	RAR	2
A β	8	EPO	1	IL-5	1	Ras	3
Bcl2	4	ER	8	IL-6/IL-6R	6	Ras FTase	1
BCMA	8	ETA ETB	1	IL-8	1	Ret	1
BCMA TACI	1	EZH2 inhibitor	1	immunoglobulin	1	RSV F	4
BAFF	1	Factor IX	3	INF- α	1	RT	2
BAFF IL-17A	1	Factor IX X	1	INF- α TLR7	1	RT NNRTI	1
BRAF	1	Factor VIII	7	INF- β	1	S1PR1	3
BTK	1	FcRn	2	Insulin	7	sGC	7
BTK JAK1	3	FGF1/2/3/4	1	ISBT	1	SLGT2	1
C5	1	FGF2	1	JAK	1	Spike protein	1
C5a	5	FGFR3	1	JAK syk	1	SqE	6
cap- endonuclease	1	FR	2	JAK1/3	1	STAT3	1
CB1	1	FXR	3	KOP	1	Syk	2
CCR2 CCR5	2	GAA	1	KRAS	5	TERT	2
CCR5	1	GBA	1	KRAS G12C	1	TGF- β	2
CD123	3	GC-C	1	LSD1	2	TGF- β 1	3
CD19	8	PSMA	4	LTA4H	1	thrombin	1
CD20	1	GCGR GLP-1R	1	L-type calcium channel	1	TLR4	4
CD22	2	GCS	1	M	2	TLR7	4
CD25	1	GHSR	1	M1	1	TLR8	1
CD3 CD20	1	GLP-1	3	MALT1	1	TLR9	1
CD3 GC-C	1	GLP-1R	1	MC4R	1	TNF- α	6
CD33	1	GLP-1R Insulin	1	MEK	3	TNSALP	1
CD33 Siglec	1	GM-CSF	2	MOR	1	TPO/TPO receptor	2
CD38	3	GM-CSF INF- α	1	MPro	1	TROP2	1
CD4	1	gp120	1	MR	1	Tryptase	1
CD4 gp41	1	gp120 gp41	2	myosin	4	TTR	1
CD47	1	GPR44/CRTH2	1	NDRP	1	TYMS	1
CD52	1	GR	1	NGF	1	URAT1	2
CDK2 CDK4 CDK6	1	H3	1	NMDA	2	VEGF	3
CDK4	1	HBV	4	NNRTI	2	VEGF-2	1
CDK4 CDK6	1	HDAC	2	Nrf2	3	VEGFR	1
CFTR	6	HER2	4	NRTI	3	α 2	2
c-Kit	1	HGF	1	NS3	3	α 4 β 1	1
c-Kit PDGFR	1	HGFR	4	NS5a	1	α 4 β 1 α 4 β 7	1
c-Kit PDGFR β VEGF-1/2	1	HIF-2 mTORC1	1	NS5B	4	α 7 nAChR	1
CLL-1	1	HIV capsid	2	ODF	3	β 2	3
CMV	1	HIV protease	1	PARP	3	β 2 GR	2
COX-2 PDE	1	HIV-1 integrase	1	PCSK9	2	β 2 M3	1

Supplementary Table 4 | Target summary of clinical-stage products of the top 20 Chinese pharma companies

New targets and new MOAs (China)							
Axl DDR EPH	1	FR α tubulin	1	IDO TDO	1	OX40	2
bacterial DNA gyrase	1	FSHR	2	IL-12 agonist PD-1	1	OX1R	1
BRD4	1	FXR	1	IL-15	1	PHD2	1
ccdB	1	GCGR OXM	1	IL-21 PD-1	1	PTEN PI3K	1
CD47	3	GIPR GLP-1R	1	IRE1	1	Renin TAK1	1
CD70	1	Gja1	2	Kir1.1	1	ROS1 TrkA	1
CDC42BPA	1	GnRH	1	LAG-3	3	SOD	2
CR1 VEGFR	1	GPC3	1	LTD4	1	survivin	1
CTRP	1	GPR44 PGD2	1	MAP3K1	1	TIGIT	2
DKK1	1	HBV capsid	4	Mcl-1	1	TIM	2
EWS FLI1	1	HCN channel	1	NaV1.8	1	TYK2	1
Factor XIa	1	HGFR IgG2	1	NF κ B TNF- β TRADD	1	α v β 3	1
FFA1	1	Hsp90	1	ODF	1		
Bispecific antibodies							
4-1BB PD-1	1	CD3 DLL3	1	CD32B CD79B	1	LAG-3 PD-1	1
4-1BB FAP	1	CD3 Flt3	1	CD47 PD-1	1	PD-1 TGF- β 2	1
CD3 BCMA	1	CD3 Muc 17	1	CTLA4 PD-1	1	PD-1 TIGIT	1
CD3 CD33	1	CD3 PSMA	1	CTLA4 PD-L1	1	LAG3 PD-1	1
CD3 Claudin 18	1	CD3 STEAP1	1	HER2 PD-1	1	PD-1 TGF- β 2	1
Mature target (China)							
5-HT1A 5-HT2A D2R	1	EGFR RET VEGF	1	IL-23	2	Proteasome	1
Ab EGFR FIT3	1	EpCAM	1	IL-4	1	PTK	1
AchR BTXA	1	EPO	1	IL-5	1	RAF	1
ALK	1	EPO receptor	1	insulin	3	RafB	2
ALK/ROS1	1	ER	1	JAK	1	renin	2
ALK HGFR	2	EZH2	1	JAK SYK	1	ROCK2	1
AR	1	Factor VIIa	1	JAK1	3	RUNX1	1
Axl HGFR c-Kit ret RON	1	Factor VIII	1	JAK2	1	SLGT2	2
A β	1	Factor Xa	1	KOR	2	SOST	1
Bcl-2	2	FGFR Fit3 c-Kit PDGFR	1	KRAS	1	Spike protein	3
BCMA	1	Fit3	1	LSD1	1	tetanus toxoid	1
BTK	3	FXR	1	MEK1/2	3	thymosin α	1
CaN	1	G-CSF	2	MOR	1	TLR7	2
CaV	1	GLP-1	1	NF κ B	1	TNF	2
CD20	4	GLP-1R	7	NMDA	1	Topo I	5
CD30 Tubulin	1	glucan synthase	1	NS5A	1	Topo II	1
CDK4/6	4	GnRHR	1	ODF	3	TPO	2
COX-2	2	H ⁺ /K ⁺ ATPase	2	PCSK9	2	TPO receptor	1
CRBN	1	HER2	12	PD-1	9	Trk	2

CSF-1 FGFR VEGF	2	HER2 microtubul e	1	PD-1 TGF- β	1	TROP2	1
CTLA4	3	HER2 Tubulin	1	PD-1 VEGR	1	URAT1	2
CXCR4	1	HGFR	1	PDE4	2	VEGF	6
CYP17A1	1	HGFR	2	PDE5	2	VEGF-2	2
DPP4	5	IFN α	1	PD-L1	1	VEGFA	1
EFGR RafB	1	IgE	1	PGE1	1	α 2	1
EGFR	1 0	IL-12p40	1	PGFR VEGF	1		
EGFR HER2	5	IL-17	1	PI3K α	1		
EGFR PD-1	1	IL-2	1	PI3K δ	3		

Supplementary Table 5 | Full names and acronyms of targets

Acronym	Full name	Acronym	Full name
17β-HSD13	17 beta hydroxysteroid dehydrogenase type 13	ISBT	Ileal sodium bile acid cotransporter
4-1BB	CD137, TNFRSF9, Tumor necrosis factor receptor superfamily member 9	JAK	Janus kinase
5-HT	5-hydroxytryptamine	JNK1	c-Jun N-terminal kinase
A17	Small inducible cytokine a17	KAAG1	Kidney Associated Antigen 1
A1AT	Alpha-1 antitrypsin	KAT6A	Lysine Acetyltransferase 6A
A2aR	Adenosine 2a receptor	KHK	Ketohexokinase
A2bR	Adenosine 2b receptor	Kir	Inwardly rectifying potassium Kir channels
Abl	Abelson leukemia	KLB	Klotho Beta
ACC	Acetyl CoA carboxylase	KLK2	Kallikrein Related Peptidase 2
AchR	Acetylcholine receptor	KMO	Kynurenine 3-hydroxylase
ACVR2A	Activin A receptor type 2A	KOR	Kappa opioid receptor
ADGRL1	Adhesion G Protein-Coupled Receptor L1	KRAS	Kirsten rat sarcoma viral oncogene
ADM	Adrenomedullin	KTM2A	Lysine -specific methyltransferase 2A
AhR	Aryl hydrocarbon receptor	LAG3	Lymphocyte activation gene 3
AKT	AK mouse plus Transforming or Thymoma	LAIR2	Leukocyte Associated Immunoglobulin Like Receptor 2
AL	Amyloid	LDLR	Low Density Lipoprotein Receptor
ALDOS	Aldosterone synthase	LIF	Leukemia inhibitory factor
ALK	Anaplastic lymphoma kinase	LIV-1	zinc transporter solute carrier family 39 member 6 (SLC39A6)
AMPK	Adenosine 5'-monophosphate -activated protein kinase	LOX-1	Lectin-like Oxidized Low-density Lipoprotein Receptor 1
ANG	Angiotensin	LPA	Lysophosphatidic acid
ANGPT1	Angiotensin like 1	LPAR1	Lysophosphatidic Acid Receptor 1
L3		LRRC15	Leucine-rich repeat-containing protein 15
ANO1	Anoctamin 1	LSD1	Lysine-specific demethylase 1
APLNR	Apelin receptor	LTA4H	Leukotriene A4 Hydrolase
APOA	Apolipoprotein A	LTD4	Leukotriene D4
APOC	Apolipoprotein C	M	Muscarinic receptor
APOL1	Apolipoprotein L1	MAA	Melanoma associated antigen
APPBP1	Amyloid Precursor Protein-Binding Protein 1	MAGEA3	Melanoma antigen family A, 3
AR	Adrenergic receptor	MALT1	Mucosa-associated lymphoid tissue lymphoma translocation protein-1
ASA	Arylsulfatase A	MAP3K1	Mitogen-Activated Protein Kinase Kinase Kinase 1
ASK1	Apoptosis signal regulating kinase-1	MAPKA	Mitogen-activated protein kinase (MAPK) Activated Protein Kinase 2
ASM	Acid sphingomyelinase	PK2	

AT	Angiotensin	MAPT	Microtubule-associated protein tau
ATOH1	Atonal bHLH transcription factor 1	MC4R	Melanocortin 4 Receptor
ATP7B	ATPase Copper Transporting Beta	Mcl-1	Myeloid cell leukemia 1
ATR	Ataxia Telangiectasia and Rad3 Related Protein	MDM2	Murine double minute2
AVPR B1	Arginine Vasopressin receptor Beta-1 receptors	MECP2	Methyl-CpG Binding Protein 2
receptors B7-H4	VTCN1, V-set domain-containing T-cell activation inhibitor 1	MEK	MEK protein kinase
BAFF	B cell activating factor	Mer	Mer receptor tyrosine kinase
BB2	Bombesin receptor 2	mGluR2	Metabotropic glutamate receptor 2
Bcl	B-cell lymphoma	MOR	Mu opioid receptor
BCL11A	B-cell lymphoma/leukemia 11A	MPO	Myeloperoxidase
BCMA	B cell maturation antigen	MPro	Main proteinase
BET	Bromodomain and extraterminal domain	MR	Mineralocorticoid receptor
BMP	Bone morphogenetic protein	MSLN	Mesothelin
BMPR2	Bone Morphogenetic Protein Receptor Type 2	Mtb	Mycobacterium tuberculosis
BRAF	v-Raf murine sarcoma viral oncogene homolog B1	LeuRS	(Mtb) leucyl-tRNA synthetase
BRD	Bromodomain	mTOR	mammalian target of rapamycin
BTK	Bruton's tyrosine kinase	mTORC 1	mTOR complex 1
BTLA	B- and T-lymphocyte attenuator	Muc16	Mucin 16
BTXA	Botulinum toxin A	MUT	Methylmalonyl-CoA mutase
C1s	Complement C1s	Nav1.7	voltage-gated sodium channel NaV1.7
C3	Complement C3	NCAM	Neural cell adhesion molecule
C5	Complement C5	NDRP	Non-Nucleotide RNA-Dependent RNA
CA6	Carbonic anhydrase 6	NFκB	Nuclear factor kappa-B
CACNG 8	Calcium voltage-gated channel auxiliary subunit gamma 8	NGF	Nerve growth factor
CAIX	Carbonic anhydrase IX	NK1	Neurokinin 1
CaN	Calcineurin	NKG2A	Natural killer cell inhibitory receptor NKG2A
Cas9	CRISPR-associated protein 9	NLRP3	NACHT, LRR, and PYD Domain-Containing Protein 3
CaV	Voltage-gated calcium channels	NMDA	N-methyl-D-aspartic acid
CB1	Cannabinoid receptor 1	NNRTI	Non-nucleoside reverse transcriptase inhibitor
Cbl-b	Casitas B cell lymphoma-b	Nogo A	Neurite outgrowth inhibitor A
ccdB	Controller of cell death B	NPRC	Natriuretic peptide receptor C
CCR	C-C Motif Chemokine Receptor	Nrf2	Nuclear erythroid 2-related factor 2
		NRG4	Neuregulin 4
		NRTI	Nucleoside reverse transcriptase inhibitor

CD	Cluster of Differentiation	NS5A	non-structural 5A
CDC42B	Cell Division Cycle (CDC) 42-	NY-ESO-1	New York Esophageal Squamous Cell Carcinoma-1
PA	binding protein A	ODF	Osteoclast differentiation factor
CDC7	Cell division cycle 7	OGT	O-GlcNAc transferases
CDH3	Cadherin 3	OX1R	Orexin receptors type 1
CDK	Cyclin-dependent kinases	OX40	TNFRSF4, Tumor necrosis factor ligand superfamily member 4
CFB	Complement Factor B	oxLDL	oxidized Low Density Lipoprotein (LDL)
CFD	Complement Factor D	OXM	Oxyntomodulin
CFP	Complement Factor P	P2X3	Purinergic Receptor (P2X) 3
CFTR	Cystic fibrosis transmembrane conductance regulator	P2X4	Purinergic Receptor 4
CH24H	Cholesterol 24-hydroxylase	P2X7	Purinergic Receptor 7
ChR2	Channelrhodopsin-2	p38	p38 mitogen-activated protein kinase (MAPK)
CK1α	Casein kinase 1 α	MAPK	MAPK
c-Kit	Kit receptor tyrosine kinase	p53	p53 tumor suppressor
CLL-1	C-type lectin-like molecule-1	PACAP38	Pituitary adenylate cyclase activating polypeptide-38
CMV	Cytomegalovirus	PAR2	Protease-activated receptor 2
CNGA3	Cyclic Nucleotide Gated Channel Subunit Alpha 3	PARP	Poly (ADP-ribose) polymerase
CNGB3	Cyclic Nucleotide Gated Channel Subunit Beta 3	PCCA	Propionyl-CoA Carboxylase Subunit Alpha
COX	Cyclooxygenase	PCSK9	Proprotein convertase subtilisin/kexin type 9
CR1	Complement receptor 1	PD-1	Programmed death-1
CRBN	Cereblon	PDE	Phosphodiesterase
CRK7	CDC2-related protein kinase 7	PDGF	Platelet Derived Growth Factor
CRTH2	Chemoattractant receptor-homologous molecule expressed on Th2 cells	PD-L1	Programmed death ligand 1
CSF-1	Colony stimulating factor 1	PDR	Pleiotropic drug resistance
CTLA4	Cytotoxic T-lymphocyte-associated protein 4	PGD2	Prostaglandin D2
CTRP	Complement C1q tumor necrosis factor-related proteins	PGE1	Prostaglandin E1
CX3CR1	C-X3-C Motif Chemokine Receptor 1	PGFR	Prostaglandin F receptor
CXCR	C-X-C Motif Chemokine Receptor	PGI2	Prostaglandin I2
CYP17A1	Cytochrome P450 Family 17 Subfamily A Member 1	PGRN	Progranulin
D1R	Dopamine receptor 1	PHD2	HIF prolyl-hydroxylase 2
D2R	Dopamine receptor 2	PI3Kγ	Phosphatidylinositol 3-kinase-gamma
D3R	Dopamine receptor 3	PI4K	Phosphatidylinositol 4-kinases
DAF	Decay accelerating factor	PIP5K2B	phosphatidylinositol-4-phosphate 5-kinase, type II, beta
DARC	Duffy antigen/receptor for chemokines	PLA2	Phospholipase A2

DC-SIGN DDR	Dendritic cell-specific ICAM-grabbing non-integrin Discoidin domain receptors	PMCA4	Plasma membrane calcium ATPase 4
DGAT2	Diacylglycerol O-Acyltransferase 2	PNPLA3	Patatin Like Phospholipase Domain Containing 3
DHODH	Dihydroorotate Dehydrogenase	PORCN	Porcupine
DKK1	Dickkopf-related protein 1	PP2C	Protein phosphatase 2C
DLL3	Delta-like ligand 3	PPP1R1 A	Protein Phosphatase 1 Regulatory Inhibitor Subunit 1A
DNA-PK	DNA-dependent protein kinase	PRMT	Protein arginine methyltransferase
DNMT1	DNA Methyltransferase 1	PSMA	Prostate-specific membrane antigen
DOT1L	DOT1 Like Histone Lysine Methyltransferase	PSMB5	Proteasome 20S Subunit Beta 5
DPEP3	Dipeptidase 3	PTEN	Phosphatase and tensin homolog
DPP4	Dipeptidyl peptidase 4	PTH1R	parathyroid hormone 1 receptor
DprE1	Decaprenylphosphoryl- β -D-ribose oxidase	PTK	Protein tyrosine kinase
DR	Dopamine receptor	PTPs	6-pyruvoyl-tetrahydropterin synthase
EED	Embryonic Ectoderm Development	PYY	Peptide YY
EGFR	Epidermal growth factor receptor	Raf	Raf protein kinase
EL	Endothelial lipase	RafB	Raf B protein kinase
Ehf2	E74-Like Factor 2	RAR	Retinoic acid receptor
ENaC	Epithelial sodium channel	Ras	Ras GTPase
ENPP-2	Ectonucleotide pyrophosphatase/phosphodiesterase family member 2	Ret	Ret receptor tyrosine kinase
EP	E-type prostanoid	RIG-I	Retinoic-acid-inducible protein 1
EpCAM	Epithelial cell adhesion molecule	RIPK1	Receptor-interacting serine/threonine-protein kinase 1
EPH	Erythropoietin-producing human hepatocellular carcinoma (EPH) family tyrosine kinase inhibitor	RLBP1	Retinaldehyde binding protein 1
EPO	Erythropoietin	ROBO2	Roundabout guidance receptor 2
ER	Estrogen receptor	ROCK2	Rho associated coiled-coil containing protein kinase 2
ERK2	Extracellular regulated protein kinases	RON	Ron receptor tyrosine kinase
ETA/B	Endothelin receptor A/B	ROR1	Receptor tyrosine kinase-like orphan receptor 1
EthR	TetR-family transcriptional regulatory repressor protein	ROS1	ROS proto-oncogene 1, receptor tyrosine kinase
EWS-FLI1	Ewing sarcoma- Fli-1 Proto-Oncogene	RPGR	Retinitis Pigmentosa GTPase Regulator
		RSPO3	R-spondin 3

EZH2	Enhancer of Zeste 2	RSV F	Respiratory syncytial virus fusion glycoprotein
FAAH	Fatty acid amide hydrolase	RT	reverse transcriptase
FAK	Focal Adhesion Kinase	RUNX1	runt-related transcription factor 1
FcRn	Neonatal Fc receptor	RZRγ	retinoid Z receptor
FcγR	Fc gamma receptor	SIPR1	Sphingosine-1-phosphate receptor 1
FFA1	Free fatty acid receptor 1	SAM2	S-adenosylmethionine synthase 2
FGF	Fibroblast growth factor	SAP	Serum amyloid P
FGFR	Fibroblast growth factor receptor	SEMA3A	Semaphorin 3A
FimH	Adhesive protein FimH	SerpinB1	Serpin Family B Member 1
Fit3	Fms-like tyrosine kinase 3	SEZ6	Seizure protein 6 homolog
FLAP	5-Lipoxygenase activating protein	sGC	Soluble guanylate cyclase
FOXP3	Forkhead box protein P3	SLGT2	Sodium-glucose cotransporter 2
FPR	Formyl Peptide Receptor	SHP2	Src Homology 2 domain-containing phosphotyrosine phosphatase 2
FR	Folate receptor	Siglec	Sialic acid binding Ig-like lectin
FSHR	Follicle Stimulating Hormone Receptor	SIRPα	Signal regulatory protein α
FTase	Farnesyl Transferase	SLFN12	Schlafen family member 12
FXR	Farnesoid X receptor	SLIT2	Slit Guidance Ligand 2
Fyn	Tyrosine-protein kinase Fyn	SOD	Superoxide Dismutase
GAA	α -glucosidase	SORL1	Sortilin-related receptor
GABRA5	Gamma-Aminobutyric Acid Type A Receptor Subunit Alpha 5	SOS1	SOS Ras/Rac Guanine Nucleotide Exchange Factor 1
GAP1	General amino-acid permease 1	SOST	Sclerostin
GARP	Glycoprotein A Reiterations Predominant	SqE	Squalene epoxidase
GBA	Glucosylceramidase Beta	Src	Src receptor tyrosine kinase
GC-C	Guanylyl cyclase C	SRPK1	Serine/arginine-rich protein-specific kinase 1
GCCR	Glucocorticoid receptor	SSTR4	Somatostatin Receptor Type 4
GCGR	Glucagon receptor	STAT3	Signal transducer and activator of transcription 3
GCS	Glucosylceramide synthase	STING	Stimulator of interferon genes
G-CSF	Granulocyte colony stimulating factor	SUMO	Small ubiquitin related modifier
GDF15	Growth Differentiation Factor 15	Syk	Spleen tyrosine kinase
GFRα1	Glial cell derived neurotrophic factor (GDNF) family receptor alpha	TAAR1	Trace amine associated receptor 1
GHSR	Growth Hormone Secretagogue Receptor	TAC1	Transmembrane activator and calcium signal-modulating cyclophilic ligand (CAML) interactor
		TAK1	Transforming growth factor β -activated kinase 1

GIP	gastric inhibitory polypeptide	TASK	Tandem-pore domain in weak inward rectifier K ⁺ channels (TWIK) -related acid-sensitive K ⁺ channels
GIPR	gastric inhibitory polypeptide receptor	Tau	microtubule-associated protein tau
Gja1	Gap Junction Protein Alpha 1	TCPTP	T-cell protein tyrosine phosphatase
GLP-1	Glucagon-like peptide-1	TCR	T cell receptor
GluN2B	Glutamate Ionotropic Receptor NMDA Type Subunit 2B	TDO	Tryptophan 2,3-dioxygenase
GlyT1	Glycine transporter-1	Tec	Tec non-receptor tyrosine kinase
GM-CSF	Granulocyte-Macrophage Colony Stimulating Factor	TERT	Telomerase Reverse Transcriptase
GnRH	Gonadotropin-releasing hormone	TFPI	Tissue factor pathway inhibitor
gp120	Glycoprotein 120	TfR1	Transferrin receptor 1
gp41	Glycoprotein 41	TG2	Transglutaminase 2
GPC3	Glypican-3	TGF-β	Transforming growth factor-β
GPR44	G protein-spregnuti receptor 44	Tie-2	Tyrosine-protein kinase receptor Tie-2
GPR54	G protein-spregnuti receptor 54	TIGIT	T cell immunoreceptor with Ig and ITIM domain
GPRC5D	G protein-coupled receptor class C group 5 member D	TIM3	T cell immunoglobulin and mucin domain-containing protein 3
GR	Glucocorticoid receptor	TLR	Toll Like Receptor
Gwt1	GPI anchored wall transfer protein 1	TNF	Tumor necrosis factor
H3	Histamine H3 receptor	TNFSF15	Tumor necrosis factor Superfamily Member 15
H4	Histamine H4 receptor	TNSALP	Tissue-nonspecific isoenzyme of alkaline phosphatase
HBG	Hemoglobin Subunit Gamma	Topo	Topoisomerase
HbS	sickle cell haemoglobin	TPI1	Triosephosphate Isomerase 1
HBV	Hepatitis B virus	TPO	Thrombopoietin
HCN channel	Hyperpolarization-activated cyclic nucleotide-gated channel	TRADD	TNFRSF1A Associated Via Death Domain
HDAC	Histone deacetylase	TRAILR	TNF-related apoptosis-inducing ligand receptor
HER2	Human epidermal growth factor receptor 2	TREM2	Triggering Receptor Expressed on Myeloid Cells 2
HGF	Hepatocyte growth factor	Trk	Trk receptor tyrosine kinases
HGFR	Hepatocyte growth factor receptor	TROP2	Trophoblast cell-surface antigen 2
HIF-2	Hypoxia inducible factor-2	TRPA1	Transient receptor potential ankyrin 1
HIV env	Human Immunodeficiency Virus Envelope	TRPC4/5	Transient receptor potential canonical 4 and 5

HIV-1 gag	Human Immunodeficiency Virus type 1 (HIV-1) Group-specific antigen	TRPV1	Transient Receptor Potential Vanilloid 1
HLA-A2	Human leukocyte antigen-A2	TSLP	Thymic stromal lymphopietin
HPV E6	Human papillomavirus E6	TTR	Transthyretin
HPX	Hemopexin	TYK2	Tyrosine Kinase 2
Hsp47	Heat shock protein 47	TYMS	Thymidylate Synthetase
HTRA1	High-Temperature Requirement A1	UBE3A	Ubiquitin Protein Ligase E3A
HTT	Huntingtin	URAT1	Urate transporter 1
IAP	Inhibitor of Apoptosis Protein	USP1	Ubiquitin Specific Peptidase 1
ICAM-1	Intercellular cell adhesion molecule-1	VEGF	Vascular endothelial growth factor
ICOS	Inducible T cell CO-Stimulator	VEGI	Vascular endothelial growth inhibitor
IDH	Isocitrate dehydrogenase	vWF-cp	von Willebrand factor (Vwf) cleaving protease
IDO	Indoleamine 2, 3-dioxygenase	WEE1	Wee-1 protein kinase
IDUA	Alpha-L-Iduronidase	Wnt	wingless
IFN	Interferon	WT1	Wilm tumor protein
IgE	Immunoglobulin E	XIAP	X-linked inhibitor of apoptosis protein
IGF-1R	Insulin Like Growth Factor 1 Receptor	ZAP70	Zeta Chain of T Cell Receptor Associated Protein Kinase 70
IGFBP2	Insulin Like Growth Factor Binding Protein 2	$\alpha 2$	Alpha-2 adrenergic receptor
IgG	Immunoglobulin G	$\alpha 2C$-AR	Alpha-2C-adrenergic receptor
IKZF1	IKAROS Family Zinc Finger 1	$\alpha 4\beta 1$	Integrin alpha 4 beta 1
IL	Interleukin	$\alpha 4\beta 7$	Integrin alpha 4 beta 7
IL-12p40	Interleukin 12 p40	$\alpha 5\beta 1$	Integrin alpha 5 beta 1
IL-1RA	Interleukin 1 receptor antagonist	$\alpha 7$	$\alpha 7$ nicotinic acetylcholine receptor
IL-2Rβ	Interleukin 2 receptor subunit beta	nAChR	receptor
ILDR2	Immunoglobulin Like Domain Containing Receptor 2	$\alpha v\beta 3$	Integrin alpha-V beta 3
INF	Interferon	$\alpha v\beta 5$	Integrin alpha-V beta 5
IRAK4	Interleukin 1 Receptor Associated Kinase 4	$\alpha V\beta 8$	Integrin alpha-V beta 8
IRE1	Inositol-requiring enzyme 1	$\beta 2$	Beta-2 Adrenergic Receptor
		ϕCPG1	Chlamydiaphage ϕ CPG1
		VP1	Capsid Protein Vp1