Mutation Analysis
Whole Exome Sequencing (WES)

Champalimaud Foundation

Supplementary Data Set 1: List of immune response genes or tumor – associated genes that are particularly scrutinized in the course of tumor WES.

List of genes associated with immune – surveillance and DNA repair *(CF-Version0.3.March.25.2018)*

Gene	Description
Canonical MHC class I pathway	
HLA-A	Major human HLA class I complex for presenting protein antigens
HLA-B	Major human HLA class I complex for presenting protein antigens
HLA-C	Major human HLA class I complex for presenting protein antigens
B2M/IMD43	Beta-2-microglobulin; integral part of MHC-I complex
TAP1	Transporter associated with antigen processing 1; export of nascent peptides into the ER for MHC-I loading
TAP2	Transporter associated with antigen processing 2; export of nascent peptides into the ER for MHC-I loading
CALR	Calreticulin, involved in antigen processing and loading
PSMB5	Proteasome subunit beta type-7; belongs to catalytic unit; important for generating peptide antigens
PSMB6	Proteasome subunit beta type-6; belongs to catalytic unit; important for generating peptide antigens
PSMB7	Proteasome subunit beta type-7; belongs to catalytic unit; important for generating peptide antigens
LMP7/PSMB8	Proteasome subunit beta type-8, belongs to catalytic unit; important for generating peptide antigens
TAPBP	Tapasin, involved in the interaction between MHC class I and TAP for peptide loading
LMP2/PSMB9	Proteasome subunit beta type-9, belongs to catalytic unit; important for generating peptide antigens
MECL1/PSMB10	Proteasome subunit beta type-10; belongs to catalytic unit; important for generating peptide antigens
PDIA3/GRP58	Protein disulfide-isomerase A3/glucose-regulated protein, 58-kD; involved in export of fully formed MHC-I-peptide complex from ER
CNX	Calnexin, involved in folding of MHC-I molecules in ER
Canonical MHC class II pathway	
HLA-DR	Human Leukocyte Antigen – antigen D Related (DRA, DRB1,3,4,5)
HLA-DQ	Human Leukocyte Antigen, class II, implicated in autoimmune pathology (DQA1 & DQB1)
HLA-DP	Human Leukocyte Antigen, class II, implicated in GVHD (DPA1 & DPB1)
HLA-DOA	HLA class II histocompatibility antigen, DO alpha chain; forms dimer with DOB
HLA-DOB	HLA class II histocompatibility antigen, DO beta chain; forms dimer with DOA
HLA-DMA	HLA class II histocompatibility antigen, DM alpha chain; forms dimer with DMB; involved in MHC-II peptide loading
HLA-DMB	HLA class II histocompatibility antigen, DM beta chain; forms dimer with DMA; involved in MHC-II peptide loading

CD74	HLA-DR invariant chain; can also be epxressed on the cell surface; involved in formation and transport of HLA-DR
CLIP	Class II-associated invariant chain peptide; keeps MHC-II peptide-binding groove from binding of self-peptides until start of interaction with HLA-DM
CaM	Calmodulin; Ca2+ chaperone; probably involved in the generation of MHC-II antigens in cells
RAB5	GTPase involved in phagolysosome formation, which is essential for the generation of antigenic peptides that bind to the MHC-II groove
CIITA	MHC-II transactivator; important for IFN-γ-driven expression of HLA-DR
Non-canonical MHC class I molecules	
HLA-E	HLA class I histocompatibility antigen, alpha chain E; modulate NK-cell cytotoxicity
HLA-G	HLA-G histocompatibility antigen, class I, G; has a role in immune tolerance and also prevents NK-cell cytotoxicity
MICA	MHC class I polypeptide-related sequence A; ligand for NKG2D on gamma-delta (γδ) T cells, NK cells and conventional CD8 T cells
MICB	MHC class I polypeptide-related sequence B; ligand for NKG2D on gamma-delta (γδ) T cells, NK cells and conventional CD8 T cells
CD1a	Presentation of lipid antigens to T cells; present on professional APCs
CD1b	Presentation of lipid antigens to T cells; present on professional APCs
CD1c	Presentation of lipid antigens to T cells; present on professional APCs
CD1d	Presentation of lipid antigens to NKT cells;present on professioal APCs and other cell types
CD1e	Intermediate form of CD1 molecule that is expressed intracelularly
Surface molecules associated with T-cell function	
CD2	Also known as lymphocyte function-associated antigen-2 (LFA-2); expressed on T cells and NK cells; requires for migration; might also play a role in activation by co-stimulation during immune synapse
CD3	Indispensable co-receptor which not only identifies T cells but also is pivotal in engaging the peptide-MHC complex to trigger T-cell activation. Also important are immunoreceptor tyrosine-based activating motifs (ITAMs) found in the cytoplasmic tail of CD3 (zeta chain, CD247), contains ITAMs necessary for ZAP-70 binding and downstream signalling to initiate T-cell responses
CD4	Important helper T cell recognition receptor; attaches to MHC-II during immue synapse; also binds IL-16
CD6	Expressed on T-cell surface and has a role during the immune activation phase
CD7	Expressed on mature T-cell surface and has a role in T-cell activation and engagement with B cells
CD8A	CD8 alpha chain; Important surface receptor to identify cytotoxic T cells; binds to MHC-I during immune synapse

TRA/IMD7	T-cell receptor (TCR) alpha locus; required for TCR structure formation
TRB	TCR beta locus; required for TCR structure formaton
TRAJ10	TCR alpha joining 10; required also for generation of TCR repertoire diversity
CD80/B7-1	Expressed on target cells and APCs; binds to CD28 to induce T-cell activation or CTLA-4 to induce tolerance
CD86/B7-2	Expressed on target cells and APCs; binds to CD28 to induce T-cell activation or CTLA-4 to induce tolerance
CD28	Expressed on T cells; involved in T-cell activation by binding to CD80/86
BTN	Butyrophilins; members of this large famiy of B7-related surface-bound molecules are involved in immune cell signalling, largely focussed on T-cell activation and function
BTN3A1	Butyrophilin subfamily 3 member A1; activation of Vγ9Vδ2 T cells
PDCD1	Programmed cell death 1 (PD-1); mainly expressed on T cells; some tumour cells too; inhibits T-cell function
PDCD1LG1/CD274	PD-1 ligand 1; expressed on target cells, including cancer cells; impedes T-cell function
PDCD1LG2/CD273	PD-1 ligand 2; expressed on target cells, including cancer cells; impedes T-cell function
CTLA4/CD152	Cytotoxic T-lymphocyte associated antigen 4; mainly expressed on T cells; binds to CD80/86; inhibits T-cell function
HAVCR2/TIM3	T-cell immunoglobulin and mucin-domain containing-3; mainly expressed on CD8 T cells; activated by galectin-9; inhibits T-cell function
LAG3/CD223	Lymphocyte-activation gene 3; mainly expressed on T cells; binds to MHC-II molecules; inhibits T-cell function
VISTA	V-domain Ig suppressor of T cell activation; mainly expressed on myeloid cells; inhibits T-cell function
FAS/CD95	first apoptosis signal (Fas) receptor; expressed on a variety cell of types; can be overexpressed on tumour cells; binds to FasL on T cells to block apoptosis and allow immune evasion
FASLG/CD95L	Fas ligand; bind to FasR; expressed on T cells
NKG2D/KLRK1	Also known as CD314; expressed on CD8 T cells, NK cell, γδ T cells; involved in cytotoxic activity upon recognition of and binding to non-canonical MHC-I molecules i.e. MICA/B on target cells
OX40	Alos known as tumor necrosis factor receptor superfamily, member 4 (TNFRSF4), CD134 or OX40 receptor; expressed on activated T cells
OX40L	OX40 ligand, also known as CD252; expressed of dendritic cells as well as tumour cells; binds to OX40R/CD134
CD62L/SELL	Also known as L-selectin; binds to GlyCAM-1; expressed on T cells for homing to secondary lymphoid organs; necessary for central memory T cells to elicit recall responses upon antigen encounter

TNFRSF9/4-1BB	Also known as TNFR superfamily member 9 (TNFRSF9) or CD137; binds to TNFR-associated factor 2 (TRAF2); expressed on T cells, mainly CD8 T cells; essential for cytototoxic activity
ICOS/CD278	Inducible T-cell costimulator; expressed on activated T cells
BTLA/CD272	B- and T-lymphocyte attenuator; expressed on activated T cells and B cells; binds TNFR superfamily member 14 (TNFRS14)
VLA1/ITGA1-ITGB1	Very-late-Antigen 1; also known as alpha integrin 1 beta integrin 1; collagen receptor expressed on memory CD4 T cells; also involved in T-cell penetration into the skin and lung, particularly in inflammation
CD27	Interacts with CD70; expressed on activated T cells; has immune checkpoint properties
CD69	Expressed on T cells and is involved in T-cell differentiation; also associated with retention of T cells in lymphoid organs as well as tissue residency
CD70	Ligand for CD27; expressed on activated T cells
LAMP1/CD107a	Lysosome-associated membrane protein 1; mainly expressed on lysosomal membranes and plays a role in cytotoxicity of T and NK cells; can also be detected on the cell surface - serves as a marker of degranulation
CD16/FCGR3A	Although not expressed on the surface of T cells, CD16 (also known a Fcγ receptor III) expressed on the surface of tumour cells or other such target cells is needed for eliciting antibody-dependent cytotoxicity (ADCC) which involves NK cells and CD8 T cells; important for tumour control
Cytokines/chemokines	
IL1A/haematopoeitin 1	IL-1α; produced by myeloid cells upon activation; involved in TNF-α synthesis
IL1B	IL-1β; produced by myeloid cells following inflammasome activation
IL2	Produced by T cells as an essential growth factor
IL3	Produced by T cells, mast cells and eosinophils; can activate APC functions and induce inflammation
IL4	Produced by T cells; mainly involved in orchestration of Th2 responses and antibody production by B cells/plasma cells
IL5	Anti-inflammatory cytokine produced by Th2 cells and mast cells; also involved in antibody production by B cells
IL6	Pleiotropic cytokine released by activated myeloid cells; involved in pro-inflammatory activity by T cells; can also induce anti-inflammatory activity by Th2
IL7	Important CD4-centric gamma-chain cytokine required for their growth and maintenance of memory pools; produced by stromal cells, epithelial cells, hepatocytes, keratinocytes
IL8/CXCL8	Important for neutrophil chemoattraction; produced by activated myeloid cells
IL9	Produced by Th9 cells and may have a role in anti-tumour responses

IL10	Generally anti-inflammatory in nature, IL-10 also has some inflammatory properties as seen in chronic diseases; produced by myeloid cells (mainly monocytes but also macrophages and dendritic cells, DCs)
IL11	Produced mainly by stromal cells; important for megakaryocyte maturation
IL12	A cardinal pro-inflammatory cytokine produced by activated macrophages and DCs; essential for production of IFN-gamma by Th1 cells, jointly with IL-18
IL13	Involved in the production of IgE antibodies and is secreted by several cells types; including Th2 cells, mast cells and NK T cells; also has a role in tumour progression
IL14	Also known as alpha-taxilin; produced mainly by T cells and some malignant B cells; involved in expansion of B-cell subsets but inhibits antibody production
IL15	Important gamma-chain cytokine involved in generation and maintenance of memory CD8 T cells; involved in promoting anti-tumour immune responses by memory T cells and NK cells
IL16	Produced by various cell types, including T cells; potent chemoattractant for activated T cells
IL17	Pro-inflammatory cytokine produced by Th17 cells and some gamma-delta (γδ) subsets; role in cancer remains controversial and the same for chronic infections
IL18	Pro-inflammatory cytokine produced by M1 macrophages and DCs upon inflammasome activation; essential for inducing IFN-gamma production by Th1 cells jointly with IL-12 activity
IL19	Produced by monocytes; may a have a role in orchestrating inflammation and apoptosis
IL20	Produced by activated keratinocytes and monocytes; has a role in pro-inflammatory immune responses; belong to the IL-10 family of molecules
IL21	Important gamma-chain cytokine involved in maintenance of immunological memory in pools of high-affinity CD8 T cells; essential for antiviral immune responses and downregulation of regulatory T-cell (Treg) responses
IL22	Generally pro-inflammatory in nature; produced by innate lymphoid cells and Th22 cells; may have a role in promoting anti-tumour immune responses
IL23	Comprises IL-12β and IL-23α subunits; involved in pro-inflammatory activity; produced by activated myeloid cells
IL24	Pro-inflammatory cytokine produced by activated myeloid cells and Th2 cells; can induce cell death in responsive cells
IL25	Also known as IL-17E and can induce NF-κB activation; produced by Th2 cells and mast cells during inflammation
IL26	Produced by herpesvirus-infected T cells; induces expression of IL-10 and IL-8; structurally similar to IL-10

IL27	Comprises Epstein-Barr virus-induced gene 3 (EBI3 or IL-27β) and IL-27p28; produced by APCs; upregulates IL-10; may have a role in differentiation of T cells; previously known as IL-30
IL28	Two isoforms exists - IL-28A and IL-28B; type III interferon; very similar to IL-29 in structure; important in antiviral immune defence; produced by myeloid cells
IL29	Very similar to IL-28 in structure; type III interferon; important in antiviral immune defence; produced by myeloid cells
IL31	Has a pro-inflammatory activity profile but is produced by Th2 cells as well as other cell types
IL32	Generally pro-inflammatory in nature; is involved in vitamin D3 and IFN-gamma signalling axis; produced by DCs and macrophages; may have a role in augmenting IL-15 activity and memory CD8 T-cell maintenance
IL33	Produced by a myriad of cell types; including mast cells, activated myeloid cells, APCs; promotes IL-4 production by Th2
IL34	Produced largely by splenocytes; involved in promoting monocyte survival
IL35	Produced by Tregs; comprises IL-12Rα and IL-27β; has immune-suppressive properties
IL36	Three main agonistic forms (alpha, beta and gamma) and one antagonistic form (Rα) Produced by epithelial cells; can induce NF-κB and MAPK activation, and T-cell activtion as well as subsequent IL-2 production
IL37	Belongs to IL-1 family; inhibits innate immune activation; produced by macrophages and epithelial cells
IL38	Belongs to IL-1 family; produced by myeloid cells and a large variety of parenchymal cell types; inhibits IL-17 and IL-22 production by T cells
IL39	Comprises IL-23p19 and EBI3; produced by activated B cells; has an effect on neutrophil expansion and activation
IL40	Expressed by activated human B cells; may have an autocrine effect on B-cell expansion
IFNA1	Interferon alpha (IFN-α); produced by activated myeloid cells; involved in initiation of inflammatory activity by innate immune cells and antiviral responses; might also play a role in anti-cancer responses
IFNA2	Interferon alpha 2; important for antiviral defence; might play a role in STING pathway and anti-cancer responses
IFNA17	Interferon alpha 17; important for antiviral defence; might play a role in STING pathway and anti-cancer responses
IFNB1	Interferon beta (IFN-β); produced by fibroblasts; major role in amplifying innate immune responses and antiviral defence
IFNG	Interferon gamma (IFN-γ); Major Th1 cytokine also produced by other T cells with inflammatory properties as well as NK cells; important against viruses, tumours and intracellular bacteria

TNFA	Tumour necrosis factor alpha; crucical anti-tumour defence molecule, also against intracellular bacteria and viruses; produced by activated myeloid cells and T cells; induces apoptosis of target cells
CXCL1/SCYB1	Produced by activated myeloid cells, neutrophils, epithelial cells and importanty melanoma cells; impacts on various physiological processes including angiogenesis and wound healing
CXCL2/SCYB2	Also known as macrophage inhibitory protein 2 alpha (MIP2α); produced by monocytes and macrophages; chemoattractant for neutrophils and haematopoeitic stem cells
CXCL3/SCYB3	Also known as macrophage inhibitory protein 2 betaa (MIP2β); produced by myeloid cells and epithelial cells; involved in monocyte migration and adhesion; also functions as a neutrophil chemoattractant
CXCL4/SCYB4	Released by platelets; promotes blood coagulation; also involved in inflammation and wound healing
CXCL5/SCYB5	Produced by epithelial cells; has inflammatory activity; expressed in response to IL-1β and TNF-α exposure
CXCL6/SCYB6	Also known as granulocyte chemotactic protein 2 (GCP2); produced by endothelial cells; chemoattractant for neutrophils
CXCL7/SCYB7	Produced by platelets; involved in mitogenesis, glucose metabolism, extracellular matrix synthesis; also neutrophil trafficking
CXCL8/SCYB8	Also known as IL-8; produced by macrophages and epithelial cells; involved in neutrophil chemoattraction
CXCL9/SCYB9	Produced by activated neutrophils and mast cells; T-cell chemoattractant; involved in amplification of Th1 responses in tissue, also CD8 T cell responses
CXCL10/SCYB10	Also known as IFN-gamma-induced protein 10 kDa (IP-10); produced by activated marophages, monocytes and DCs; also by mast cells and neutrophils; strong T-cell chemoattractant but also chemotactic for monocytes, macrophages and DCs; involved in amplification of Th1 responses in tissue, also CD8 T cell responses
CXCL11/SCYB11	Produced by mast cells; T-cell chemoattractant; involved in amplification of Th1 responses in tissue, also CD8 T cell responses
CXCL12/SCYB12	Produced by CXCL12-abundant reticular cells and epithelial cells; functions as a B-cell chemoattractant; also involved in central memory T-cell trafficking
CXCL13/SCYB13	Produced by ollicular DCs and mesencymal stromal cells; important function in the B-cell zone and interaction with T cells in lymph nodes
CXCL14/SCYB14	Produced by fibroblasts; an important DC and monocyte chemoattractant
CXCL16/SCYB16	Produced by DC in response to viral infections; involved in migration and survival of NKT cells as well as innate lymphoid cells
CXCL17/VCC1	Constitutively expressed by lung cells; DC and monocyte chemoattractant

XCL1/SCYC1	A type of lymphotactin; found in various tissue including spleen, intestines and peripheral blood; CD8 T cells in blood, NK cells and DCs also produce this chemokine; chemoattractant for T cells; macrophages and fibroblasts
XCL2/SCYC2	A type of lymphotactin; produced mainly by T cells; chemoattractant for T cells; macrophages and fibroblasts
CX3CL1/SCYD1	Also known as fractalkine; produced by activated DCs and macrophages; soluble and cell-bound versions exist; acts as a chemoattractant of T cells and monocytes
CCL1/SCYA1	Produced by activated T cells; chemoattractant for monocytes, DCs, NK cells and immature B cells; also involved in Th2 cell and Treg trafficking
CCL2/SCYA2	Also known as monocyte chemoattractant protein 1 (MCP-1); produced by activated myeloid cells; chemoattractant for monocytes, DCs and T cells; involved in amplifying the inflammatory response
CCL3/SCYA3	Also known as macrophage inflammatory protein 1-alpha (MIP-1α); produced by activated macrophages; is chemotactic for neutrophils
CCL4/SCYA4	Also known as macrophage inflammatory protein 1-beta (MIP-1β); produced by monocytes, B Cells, T Cells, fibroblasts, endothelial as well as epithelial cells.; is chemotactic for monocytes, NK cells
CCL5/SCYA5	Also known as RANTES; produced by Th1 cells and CD8 T cells; can activated NK cells and myeloid cells (also APCs); has suppressive effects on HIV-infected cells
CCL7/SCYA7	Produced by macrophages and some tumour cell lines as well as stromal cells; chemoattractant for monocytes and regulation of T-cell function
CCL8/SCYA8	Also known as monocyte chemoattractant protein 2 (MCP-2); produced by fibroblasts and endothelial cells; chemotactic for various immune cell types including T cells, NK cells, mast cells, monocytes; also involved in T-cell homing to skin
CCL9/SCYA9	Previously known as CCL10; now also known as macrophage inflammatory protein-1 gamma (MIP-1γ); produced by macrophages and other myeloid cell types; also by follicle-associated epithelial cells
CCL11/SCYA11	Also known as eotaxin; produced by stromal cells and activated myeloid cells; chemotactic for eosinophils
CCL13/SCYA13	Also known as monocyte chemotactic protein 4 (MCP-4); produced by airway epithelial cells; chemotactic for eosinophils; T cells; basophils; monocytes
CCL14/SCYA14	Produced by various cells types including splenocytes, myocyes and hepatocytes; activates monocytes
CCL15/SCYA15	Also known as leukotactin-1; expressed by cells in the liver and gut; function is not very clear
CCL16/SCYA16	Also known as monotactin-1; produced by cells in the liver, thymus and spleen; chemotactic for lymphocytes and monocytes

CCL17/SCYA17	Also known as thymus and activation regulated chemokine (TARC); produced in thymic cells; is chemotactic for T cells;
CCL18/SCYA18	Produced mainly by monocytes, DCs and macrophages; chemotactic for T cells and immature B cells; also DCs
CCL19/SCYA19	Produced by activated macrophages and DCs; involved in thymic T-cell trafficking and lymphocyte migration to secondary lymphoid organs; also attracts CCR7+ central memory T cells
CCL20/SCYA20	Also known as macrophage inflammatory protein 3 (MIP-3A); chemotactic for lymphocytes; also DCs to a lesser extent; produced by various cells types including APCs
CCL21/SCYA20	Produced by stromal cells and fibroblastic reticular cells; cell-bound form of CCL21 expressed by activated DCs; involved in homing of T cells and DCs to lymph nodes
CCL22/SCYA22	Produced by DCs and macrophages; important for Th2 and Treg migration into lymph nodes during inflammation
CCL23/SCYA23	Also known as myeloid progenitor inhibitory factor 1 (MPIF-1); expressed mainly by cells in the lung and liver; chemotactic for resting T cells and monocytes; lesser extent for neutrophils
CCL24/SCYA24	Also known as myeloid progenitor inhibitory factor 2 (MPIF-2); chemotactic for resting T cells and to lesser extent for neutrophils
CCL25/SCYA25	Also known as thymus-expressed chemokine (TECK); produced by epithelial cells; involved in T-cell development; chemotactic for macrophages, DCs and thymocytes
CCL26/SCYA26	Also known as eotaxin-3; expressed by several cell types including heart and liver cells; chemotactic for neutrophils and basophils
CCL27/SCYA27	Also known as cutaneous T-cell-attracting chemokine (CTACK); expressed in several tissue types including thymus, placenta and skin; involved in T-cell trafficking to the skin
CCL28/SCYA28	Also known as mucosae-associated epithelial chemokine (MEC); produced by several tissue types including gut, lung and breast involved in T-cell and IgA+ plasma cell trafficking/homing to mucosal tissues i.e. pulmonary, mammary glands; intestines
CSF2	Also known as granulocyte-macrophage colony-stimulating factor (GM-CSF); important for differentiation of macrophages from monocytes; T cells also respond to this cytokine and in fact produce them; also DCs, mast cells, fibroblasts and NK cells
LTA/TNFB	Lymphotoxin alpha (LTα); previously known as TNF-β; produced by T cells; enhances cell adhesion to endothelia, thus cell migtation and trafficking; also involved in apoptosis induction, similar to TNF-α
LTB/TNFC	Lymphotoxin beta (LTβ); previously known as TNF-C; type II membrane-bound protein; can form a heterodimer with LTα; involved in apoptosis induction
Cytokine/chemokine receptors	
IFNAR1	Interferon alpha receptor 1; binds IFN-α/β; expressed on T cells

IFNAR2	Interferon alpha receptor 2; binds IFN-α/β; expressed on T cells
IFNGR1	Interferon gamma receptor 1; mandatory for IFN-gamma signalling in cells
IFNGR2	Interferon gamma receptor 2; mandatory for IFN-gamma signalling in cells
TNFRSF1A	Tumor necrosis factor receptor superfamily member 1A; binds to and is essential for TNF-alpha signalling in cells
TNFRSF1B	Tumor necrosis factor receptor superfamily member 1B; binds to and is essential for TNF-alpha signalling in cells
IL1R1/CD121A	Interleukin 1 receptor; important for IL-1β-mediated pro-inflammatory activity produced by inflammasome activation; expresse on T cells
IL2RA/CD25	IL-2 receptor alpha subunit; binds to IL-2, the most important T-cell growth factor produced by T cells themselves.
IL2RB	IL-2 receptor beta subunit; forms a trimer with CD25 and CD132 to constitute the IL-2R complex for binding IL-2
IL2RG/CD132	IL-2 receptor gamma subunit; also known as common gamma chain, essential for gamma-chain cytokine signalling
IL3RA/CD123	IL-3 receptor alpha; forms a dimer with CD131 (common beta chain) to bind IL-3; expressed on pluripotent progenitor cells
IL4R/CD124	IL-4 receptor; necessary for binding to IL-4 and downstream signalling; also binds to IL-13
IL5RA/CD125	IL-5 receptor alpha subunit; forms a dimer with CSF2RB to form IL-5R; binds IL-5; expressed on eosinophils and some basophils
IL5RB/CSF2RB	IL-5 receptor beta subunit; forms a dimer with CSF2RB to form IL-5R; binds IL-5, IL-3 and GM-CSF; expressed on leukocytes
IL6R/CD126	IL-6 receptor; forms a dimer with gp130 to bind IL-6 and is necessary for signalling in cells
IL6ST/gp130	IL-6 signal transducer; also known as glycoprotein 130 (gp130); forms a dimer with CD126/IL6R for IL-6 signalling in cells
IL7R/CD127	IL-7 receptor alpha subunit; essential for IL-7 signalling; forms a dimer with CD132; also a marker for memory CD4 T cells
IL8RA/CXCR1	IL-8 receptor alpha subunit; important for IL-8 signalling, expressed on neutrophils
IL9R/CD129	IL-9 receptor; forms a complex with CD132 to bind IL-9; is found on a variety of cell types
IL10RA/CD210a	IL-10 receptor alpha subunit; expressed on haematopoeitic cells; important for IL-10 signalling
IL10RB/CDw210b	IL-10 receptor beta subunit; ubiquitously expressed; important for IL-10 signalling; also forms a dimer with IL-20Rα to bind IL-26
IL11RA/CRSDA	IL-11 receptor alpha subunit; forms a dimer with gp130 to bind IL-11; expressed on haematopoeitic cells and signalling is essential for early development in the bone marrow

IL12RB1/CD212	IL-12 receptor beta subunit 1; forms a dimer with IL-12Rβ2; necessary for binding to IL-12; expressed on T cells and needed for inducing IFN-gamma production jointly with IL-18
IL12RB2	IL-12 receptor beta subunit 2; necessary for binding to IL-12; expressed on T cells and needed for inducing IFN-gamma production jointly with IL-18; may also form a dimer with gp130 to bind IL-35 but the downstream signalling suppresses inflammation
IL13RA1/CD213A1	IL-13 receptor alpha subunit 1; forms a dimer with IL-4Rα to bind IL-13; also binds IL-4; expressed on B cells
IL13RA2/CD213A2	IL-13 receptor alpha subunit 2; binds IL-13 with higher affinity than IL-13Rα1; expressed on some tumour cell types i.e. glioma
IL14R	Binds to IL-14 (also known as alpha-taxilin) produced by T cells; expressed on B cells and required for activation, cytokine and antibody production
IL15RA/CD215	IL-15 receptor alpha subunit; forms a complex with IL-2Rβ and CD132 to bind to IL-15 for signalling; expressed on T cells
CD4 as IL-16R	The CD4 co-receptor acts as a receptor for IL-16 and is considered important for CD4 T-cell chemoattraction
IL17RA/CD217	IL-17 receptor alpha subunit; involved in IL-17 binding and downstream signalling; usually part of a heteromeric structure consisting of several other members i.e. IL-17Rβ, IL-17Rc; expressed on many cell types and also on CD8 T cells
IL17RB/CRL4	IL-17 receptor beta subunit; involved in heterodimersation with IL-17R members to bind IL-17; also IL-25 (IL-17E)
IL18RA/CD218a	IL-18 receptor alpha; important for pro-inflammatory activity and IFN-γ production jointly with IL-12; produced by inflammasome activation; may also bind IL-37 with IL-1 receptor 8
IL20RA/CRF2-8	IL-20 receptor alpha subunit; forms a dimer with IL-20Rβ to bind IL-20; expressed on keratinocytes and epithelial cells; also required for IL-19 and IL-24 signalling; dimerises with IL-10Rβ to bind IL-26
IL20RB/DIRS1	IL-20 receptor beta subunit; forms a dimer with IL-20Rα to bind IL-20; expressed on keratinocytes and epithelial cells; also required for IL-19 and IL-24 signalling
IL21R/CD360	IL-21 receptor; forms a dimer with the common gamma chain (CD132) and binds to IL-21 for downstream signalling; expressed on T cells, particularly high-affinity memory subsets
IL22RA1/CRF2-9	IL-22 receptor alpha subunit 1; forms a dimer with IL-10Rβ2 for binding IL-22 and downstream signalling; important for pro-inflammatory activity; expressed on parenchymal cells but not on immune cells; also involved in IL-24 signalling
IL23RA	IL-23 receptor alpha; forms a dimer with IL-12Rβ1 to bind IL-23; expressed on immune cells, including myeloid cells and Th17 cells; also binds IL-39

IL27RA/CRL1	IL-27 receptor alpha subunit; forms a dimer with gp130 to bind IL-27 (also known as IL-30); expressed on T cells
IL28RA/IFNLR1	IL-28 receptor alpha; also known as IFN lambda receptor 1; forms a dimer with IL-10Rβ2 for binding IL-28 and IL-29; expressed on T cells and plays a role in augmenting antigen-specific CD8 T-cell responses
IL31RA/CRL3	IL-31 receptor alpha subunit; similar to gp130, and is expressed on monocytes; important for IL-31 binding and signalling
IL32R	Probably an intracellular receptor that bind IL-32 (alpha, beta, gamma)
IL33R/IL1RL1	IL-1 receptor-like 1 (IL-1RL1); binds IL-33; expressed on T cells and innate lymphoid cells; signalling is important for Th2 development
IL34R/PTP-ζ	Receptor-type protein-tyrosine phosphatase zeta; binds IL-34; expressed on neuronal progenitors and glial cells
IL36R/IL1RL2	IL-1 receptor-like 2 (IL-1RL2); forms a dimer with IL-1 receptor-like 2 (IL-1RL2) to bind IL-36; expressed on T cells; also binds IL-38
IL40R	Binds IL-40; yet to be described
TRAILR1/TNFRSF10A	TNF receptor superfamily member 10a; forms a dimer with TRAILR2 to bind TRAIL for induction of apoptosis; expressed on a variety of cell types
TRAILR2/TNFRSF10B	TNF receptor superfamily member 10b; forms a dimer with TRAILR1 to bind TRAIL for induction of apoptosis; expressed on a variety of cell types
TRAILR3/TNFRSF10C	TNF receptor superfamily member 10c; forms a dimer with TRAILR4 to bind TRAIL for subverting apoptosis induction; expressed on a variety on cell types
TRAILR4/TNFRSF10D	TNF receptor superfamily member 1d; forms a dimer with TRAILR3 to bind TRAIL for subverting apoptosis induction; expressed on a variety on cell types
OPG/TNFRSF11B	Osteoprogeterin; also known as TNF receptor superfamily ember 11b; binds TRAIL; expressed on innate immune cells
CCR1	Chemokine receptor CCR1; binds CXCL3, 4, 6, 8, 9, 10, 14, 15 ,16, 23
CCR2	Chemokine receptor CCR2; binds CCL2, 7, 11, 13, 16
CCR3	Chemokine receptor CCR3; binds CCL11, 13, 15, 24, 26, 28
CCR4/CD194	Chemokine receptor CCR4; binds CCL2 (MCP-1), CCL4 (MIP-1), CCL5 (RANTES), CCL17 (TARC), CCL22 (Macrophage-derived chemokine); involved in monocyte chemoattraction and activation; also in identification of Th2 cells; also involved in T-cell penetration into cardiac, lung and skin tissue
CCR5/CD195	Chemokine receptor CCR5; also important for HIV binding and entry into CD4 T cells; binds CCL4, 5, 8, 11, 13, 16,

CCR6/CD196	Chemokine receptor CCR6; binds MIP-3α; also important for identifcation of Th17 cells and Th1* cells (with CCR4); also involved in T-cell penetration into the lung
CCR7/CD197	Chemokine receptor CCR7; binds CXCL20 and CXCL21; also a marker for central memory T cells
CCR8/CDw198	Chemokine receptor CCR8; binds CCL1, 16
CCR9/CDw199	Chemokine receptor CCR9; binds CCL25; also involved in T-cell penetration into the gut and liver
CCR10/GPR2	Chemokine receptor CCR10; binds CCL28, 28
CXCR1/CD181	Chemokine receptor CXCR1; binds CXCL6, 8
CXCR2/IL8RB	Chemokine receptor CXCR2; also known as IL.8 receptor beta; binds CXCL1, 2, 3, 5, 6, 8
CXCR3A/GPR9	Chemokine receptor CXCR3; binds CXCL9, 10 and 11; CXCR3B
CXCR3B	Chemokine receptor CXCR3A isoform CXCR3B; binds CXCL4,9,10,11. Also involved in T-cell penetration into lung and cardiac tissue, and identification of Th1 cells
CXCR4/CD184	Chemokine receptor CXCR4; binds SDF-1/CXCL12; important for T-cell penetration into the lung
CXCR5/CD185	Chemokine receptor CXCR5; binds CXCL13; involved in T-cell migration to B-cell zones in lymph nodes
CXCR6/CD186	Chemokine receptor CXCR6; binds CXCL16; involved in T-cell penetration into the liver
CXCR7/ACKR3	Chemokine receptor CXCR7; also known as atypical chemokine receptor 3; binds CXCL11, 12
TGFBR1/ALK5	Transforming growth factor beta receptor 1; also known as anaplastic lymphoma kinase 5 (ALK5); binds with affinity to TGF-β1
TGFBR2	Transforming growth factor beta receptor 2; binds with affinity to TGF-β1
CD117/KIT	Mast/stem cell growth factor receptor (SCFR); also known as c-Kit; expressed on haematopoietic precursors as well as some antigen-specific precursor CD8 T cells; important growth factor
LTBR/CD18	Also known as TNFR superfamily member 3 (TNFRSF3); binds lymphotoxin; expressed on various cell types including parenchymal and stromal cells
VLA4/ITGA4-ITGB1	Very-late-antigen 4, comprising alpha integrin 4 and beta integrin 1; binds VCAM-1, SDF-1 and fibronectin; involved in T-cell traffciking to the brain
XCR1	Receptor for lymphotactins XCL1 and XCL2; expressed on T cells, macrophages, fibroblasts
Toll-like receptors	
TLR1/CD281	Toll-like receptor 1; forms a dimer with TLR2 to recognise peptidoglycan; expressed on the cell surface
TLR2/CD282	Toll-like receptor 2; forms a dimer with TLR1 to recognise peptidoglycan; also recognises a myriad of bacterial cell components; expressed on the cell surface; regulates CYP1A1 activity in the intestine
TLR3/CD283	Toll-like receptor 3; recognises dsRNA of viral origin; expressed intracellularly
TLR4/CD284	Toll-like receptor 4; recognises bacterial lipopolysaccharide; important for NF-κB activation and subsequent TNF-α production by APCs; expressed on the cell surface

TLR5/MELIOS	Toll-like receptor 5; recognises bacterial flagellin; also implicated in NF-κB activation and subsequent TNF-α production by APCs
TLR6/CD286	Toll-like receptor 6; synergises with TLR2 to recognise bacterial lipoproteins; expressed on the cell surface
TLR7	Toll-like receptor 7; recognises endosome-encapsulated ssRNA; generally expressed intracellularly
TLR8/CD288	Toll-like receptor 8; endosomal molecule which recognises ssRNA, akin to TLR7; expressed intracellularly
TLR9/CD289	Toll-like receptor 9; recognises bacterial and viral DNA; expressed intracellularly
TLR10/CD290	Toll-like receptor 10; shown to be expressed on B cells and neutrophils; expressed intracellularly in epithelial cells; has anti-inflammatory and inflammatory downstream effects; likely to activated by bacterial ligand i.e. *Listeria monocytogenes* components
Immune-related intracellular molecules	
ZAP-70	Zeta-chain-associated protein kinase 70; expressed intracellularly in T cells; involved in TCR signalling and T-cell activation
MyD88	Myeloid differentiation primary response 88; adapter molecule indispensable for TLR2/4-mediated anti-microbial protection
NF-κB	Nuclear factor kappa-light-chain-enhancer of activated B cells; essential for TLR4-mediated primary immune responses
IKBKB	Inhibitor Of Nuclear Factor Kappa B Kinase Subunit Beta; phosphorylates the inhibitor in the inhibitor/NF-κB complex, leading to dissociation of the inhibitor and NF-κB activation
STING/TMEM173	Stimulator of interferon genes; found in many cell types; important for intracellular pro-inflammatory activity
TBK1	TANK-binding kinase 1; necessary for phosphorylation of STING to activate it
CGAS	Cyclic GMP-AMP synthase; generates cyclic GMP-AMP leads to STING activation in cells
IDO1	Indoleamine 2,3-dioxygenase 1; heme-containing enzyme important in converting typtophan to kynurenines; upregulated by IFN-gamma signalling and has immuno-suppressive function
IDO2	Indoleamine 2,3-dioxygenase 2; heme-containing enzyme important in converting typtophan to kynurenines; upregulated by IFN-gamma signalling and has immuno-suppressive function
JAK1	Janus kinase 1; involved in IFN and other pro-inflammatory cytokine signalling pathways
JAK2	Janus kinase 2; involved in IFN and other pro-inflammatory cytokine signalling pathways
STAT1	Signal transducer and activator of transcription 1; involved in IFN-mediated inflammatory cell signalling in conjuction with JAK1/2
STAT2	Signal transducer and activator of transcription 2; involved in IFN-γ signalling pathway

STAT3	Signal transducer and activator of transcription 3; various cytokine-mediated cell signalling pathways; also important for Th17 activation
STAT4	Signal transducer and activator of transcription 4; important for Th1 development
STAT5	Signal transducer and activator of transcription 5; important for IL-2 and IL-7-mediated cell proliferation (T cells); also activated downstream of CSF2/GM-CSF signalling
STAT6	Signal transducer and activator of transcription 6; involved in Th2 responses and induction of an anti-apoptosis state in cells
MAPK1	Mitogen-activated protein kinase 1; an extracellular signal-regulated kinase (ERK); involved in various cellular processes; important in pro-inflammatory signalling i.e. IL-6, TNF-alpha, IL-18, type 1 IFNs
IRF1	Interferon regulatory factor 1; involved in amplification of JAK/STAT pathway after IFN-gamma signalling initiates; CD8 T cells responses and Th1 responses
IRF2	Interferon regulatory factor 2; activation inhibits IFN-alpha/beta production
IRF3	Interferon regulatory factor 3; activated by TLR4 signalling and thus may play arole in antibacterial defence; pro-apoptotic properties
IRF4	Interferon regulatory factor 4; has a role in MHC-I regulation and thus, CD8 T-cell responses
IRF5	Interferon regulatory factor 5; involved in induction of inflammation in response to viruses; apoptosis of infected cells; amplifiction of primary (innate) responses
IRF6	Interferon regulatory factor 6; has development roles in skin tissue, and potentially tumour-suppressive properties
IRF7	Interferon regulatory factor 7; involved in type I interferon production and antiviral defence; constitutively expressed in lymphoid tissue
IRF8	Interferon regulatory factor 8; involved in myeloid-cell differentiation, at the commitment step where common lymphoid progenitors (CMP) differentiate into monocyte precursors
IRF9	Interferon regulatory factor 9; interacts with STAT1/2; promotes the cellular toxicity of IFN-alpha potentially through TRAIL activity
IRF10	Interferon regulatory factor 10; downstream of IFN-gamma signalling and involved in MHC-I regulation; not associated with cytotoxicity
NLRP3	NACHT, LRR and PYD domains-containing protein 3 (NALP3); essential for inflammasome activation
NLRP4	NACHT, LRR and PYD domains-containing protein 3 (NALP4); also involved in inflammasome activation
MDA-5	Melanoma Differentiation-Associated protein 5; recognises intracellular dsRNA
RIG-I	Retinoic acid-inducible gene I; dsRNA helicase enzyme with a prominent role in protection against viral infections; may play a role in augmenting clinical responses to cancer therapies
RAG-1/2	Recombination-activating genes 1/2; indispensable for rearrangement of TCR and BCR

Caspases	Intracellular enzymes with a myriad of functions, including processing of pro-inflamatory cytokines such as IL-1β to initiate and/or amplify immune responses
Granzyme B	Important cytotoxic effector molecule produced by CD8 T cells and NK cells; involved in lysing target cells via apoptosis
Perforin	Important effector molecules produced by cytotoxic T cells and NK cells; causes perforations in target cells to allow granzyme penetration to trigger apoptosis
Granulysin	Lytic molecule produced by cytotoxic lymphocytes including CD8 T cells and γδ T cells
TBX21	Also known as T-bet; crucial transcription factor for Th1 maturation and production of IFN-gamma; may also negativelyt regulate Th22 development
GATA3	GATA-3 transcription factor necessary for Th2 polarisation and associated cytokine production by T cells i.e. IL-4, IL-5, IL-13
RORC	Encodes RORγt, transcription factor necessary for Th17 and Th22 development
AHR	Aryl hydrocarbon receptor; transcription factor which recognises dioxin-like compound intracellularly and in response induces pro-inflammatory responses; important in antibacterial defence
DNA repair genes (taken directly from Wood et al., 2001. Science. 291: 1284-89)	
Base excision repair (BER)	
DNA glycosylases: major altered base released	
UNG	U
SMUG1	U
MBD4	U or T opposite G at CpG sequences
TDG	U, T or ethenoC opposite G
OGG1	8-oxoG opposite C
MYH	A opposite 8-oxoG
NTH1	Ring-saturated or fragmented pyrimidines
MPG	3-meA, ethenoA, hypoxanthine
Other BER factors	
APE1 (HAP1, APEX, REF1)	AP endonuclease
APE2 (APEXL2)	AP endonuclease
LIG3	Main ligation function
XRCC1	Main ligation function
Poly(ADP-ribose) polymerase (PARP) enzymes	
ADPRT	Protects strand interruptions
ADPRTL2	PARP-like enzyme

ADPRTL3	PARP-like enzyme
Direct reversal of damage	
MGMT	O6-meG alkyltransferase
Mismatch excision repair (MMR)	
MSH2	Mismatch and loop recognition
MSH3	Mismatch and loop recognition
MSH6	Mismatch recognition
MSH4	MutS homolog specialized for meiosis
MSH5	MutS homolog specialized for meiosis
PMS1	Mitochondrial MutL homolog
MLH1	MutL homolog
PMS2	MutL homolog
MLH3	MutL homolog of unknown function
PMS2L3	MutL homolog of unknown function
PMS2L4	MutL homolog of unknown function
Nucleotide excision repair (NER)	
XPC	Binds damaged DNA as complex
RAD23B (HR23B)	Binds damaged DNA as complex
CETN2	Binds damaged DNA as complex
RAD23A (HR23A)	Substitutes for HR23B
XPA	Binds damaged DNA in preincision complex
RPA1	Binds DNA in preincision complex
RPA2	Binds DNA in preincision complex
RPA3	Binds DNA in preincision complex
TFIIH	Catalyzes unwinding in preincision complex
XPB (ERCC3)	3' to 5' DNA helicase
XPD (ERCC2)	5' to 3' DNA helicase
GTF2H1	Core TFIIH subunit p62
GTF2H2	Core TFIIH subunit p44
GTF2H3	Core TFIIH subunit p34
GTF2H4	Core TFIIH subunit p52
CDK7	Kinase subunit of TFIIH
CCNH	Kinase subunit of TFIIH
MNAT1	Kinase subunit of TFIIH

XPG (ERCC5)	3' incision
ERCC1	5' incision subunit
XPF (ERCC4)	5' incision subunit
LIG1	DNA joining
NER-related	
CSA (CKN1)	Cockayne syndrome; needed for transcription-coupled NER
CSB (ERCC6)	Cockayne syndrome; needed for transcription-coupled NER
XAB2 (HCNP)	Cockayne syndrome; needed for transcription-coupled NER
DDB1	Complex defective in XP group E
DDB2	Mutated in XP group E
MMS19	Transcription and NER
Homologous recombination	
RAD51	Homologous pairing
RAD51L1 (RAD51B)	Rad51 homolog
RAD51C	Rad51 homolog
RAD51L3 (RAD51D)	Rad51 homolog
DMC1	Rad51 homolog, meiosis
XRCC2	DNA break and cross-link repair
XRCC3	DNA break and cross-link repair
RAD52	Accessory factor for recombination
RAD54L	Accessory factor for recombination
RAD54B	Accessory factor for recombination
BRCA1	Accessory factor for transcription and recombination
BRCA2	Cooperation with RAD51, essential function
RAD50	ATPase in complex with MRE11A, NBS1
MRE11A	3' exonuclease
NBS1	Mutated in Nijmegen breakage syndrome
Nonhomologous end-joining	
Ku70 (G22P1)	DNA end binding
Ku80 (XRCC5)	DNA end binding
PRKDC	DNA-dependent protein kinase catalytic subunit
LIG4	Nonhomologous end-joining
XRCC4	Nonhomologous end-joining
	Sanitization of nucleotide pools

MTH1 (NUDT1)	8-oxoGTPase
DUT	dUTPase
DNA polymerases (catalytic subunits)	
POLB	BER in nuclear DNA
POLG	BER in mitochondrial DNA
POLD1	NER and MMR
POLE1	NER and MMR
PCNA	Sliding clamp for pol delta and pol epsilon
REV3L (POLZ)	DNA pol zeta catalytic subunit, essential function
REV7 (MAD2L2)	DNA pol zeta subunit
REV1	dCMP transferase
POLH	XP variant
POLI (RAD30B)	Lesion bypass
POLQ	DNA cross-link repair
DINB1 (POLK)	Lesion bypass
POLL	Meiotic function
POLM	Presumed specialized lymphoid function
TRF4-1	Sister-chromatid cohesion
TRF4-2	Sister-chromatid cohesion
Editing and processing nucleases	
FEN1 (DNase IV)	5' nuclease
TREX1 (DNase III)	3' exonuclease
TREX2	3' exonuclease
EX01 (HEX1)	5' exonuclease
SPO11	endonuclease
Rad6 pathway	
UBE2A (RAD6A)	Ubiquitin-conjugating enzyme
UBE2B (RAD6B)	Ubiquitin-conjugating enzyme
RAD18	Assists repair or replication of damaged DNA
UBE2VE (MMS2)	Ubiquitin-conjugating complex
UBE2N (UBC13, BTG1)	Ubiquitin-conjugating complex
Genes defective in diseases associated with sensitivity to DNA damaging agents	
BLM	Bloom syndrome helicase
WRN	Werner syndrome helicase/3'-exonuclease

RECQL4	Rothmund-Thompson syndrome
ATM	Ataxia telangiectasia
Fanconi anemia	
FANCA	Involved in tolerance or repair of DNA cross-links
FANCB	Involved in tolerance or repair of DNA cross-links
FANCC	Involved in tolerance or repair of DNA cross-links
FANCD	Involved in tolerance or repair of DNA cross-links
FANCE	Involved in tolerance or repair of DNA cross-links
FANCF	Involved in tolerance or repair of DNA cross-links
FANCG (XRCC9)	Involved in tolerance or repair of DNA cross-links
Other identified genes with a suspected DNA repair function	
SNM1 (PS02)	DNA cross-link repair
SNM1B	Related to SNM1
SNM1C	Related to SNM1
RPA4	Similar to RPA2
ABH (ALKB)	Resistance to alkylation damage
PNKP	Converts some DNA breaks to ligatable ends
Other conserved DNA damage response genes	
ATR	ATM- and PI-3K–like essential kinase
RAD1 (S. pombe) homolog	PCNA-like DNA damage sensor
RAD9 (S. pombe) homolog	PCNA-like DNA damage sensor
HUS1 (S. pombe) homolog	PCNA-like DNA damage sensor
RAD17 (RAD24)	RFC-like DNA damage sensor
TP53BP1	BRCT protein
CHEK1	Effector kinase
CHK2 (Rad53)	Effector kinase