Components		Functions
Immune cells	T cells	CTLs directly kill tumors by secreting granzymes and perforins, while Tregs promote tumor cell escape directly by secreting cytokines (such as TGF-β and IL-10) and by indirect pathways (such as CAF activity)
	Natural killer cells (NK cells)	Inhibit tumor progression through perforin and granzyme B
	B cells	Secrete antibodies and cytokines, participate in tumor immune response, and promote the differentiation of Treg
	Dendritic cells (DCs)	Modulation of immune responses through antigen presentation and cytokine secretion
	Neutrophils	Secrete IL-10 and CCL2 to promote tumor cell growth, metastasis and angiogenesis
	Macrophages	Regulate T cells by releasing cytokines (such as TGF-β, IL-10) and chemokines (such as CCL22), thereby indirectly promoting tumor cell escape
Stromal cells	Hepatic stellate cells (HSCs)	After activation, it secretes angiogenic growth factors, promoting the formation of new blood vessels and supporting tumor growth
Tumor cells	Cancer-associated fibroblasts (CAFs)	Promotes tumor cell invasion and metastasis by secreting collagen and extracellular matrix proteins
Enzymes	Glucose-6-phosphate dehydrogenase (G6PD)	Boosts metabolic pathways such as the pentose phosphate pathway, supporting tumor cell growth and DNA synthesis
	Matrix metalloproteinases (MMPs)	Degrade extracellular matrix

		and promote tumor metastasis
	CD39,CD73	The synergistic effect of the two inhibits the function of effector T cells
Cellular factors	Vascular endothelial growth factor (VEGF)	Stimulates new blood vessel formation, inhibits the antigen presentation function of dendritic cells, and enhances the immunosuppressive function of Treg
	Transforming growth factor-β (TGF-β)	Induces epithelial-mesenchymal transition (EMT) of liver cancer cells, enhances migration and invasion ability, and promotes immune escape
	Interferon-γ (IFN-γ)	Synergizes with IL-1β to enhance PD-L1 expression and reduce Treg suppressive activity
	Interleukin 10 and Interleukin 35 (IL-10 and IL-35)	Inhibits immune response by inhibiting cell proliferation, reducing the production of inflammatory mediators, promoting the development and function of Treg cells, and assisting immune escape
Immune-related proteins	Leukocyte function associated antigen-1 (LFA-1)	Forms aggregates with dendritic cells, inhibiting the co-stimulation process between dendritic cells and effector T cells
Ligands and receptors	Programmed Death-1/Programmed Death - Ligand 1 (PD-1/PD-L1)	After binding, it transmits inhibitory signals, reduces T cell activity, proliferation and cytokine production, and helps tumor immune escape
	CD276	Inhibit T cell activity, reduce cytokine secretion, and stimulate angiogenesis
	CD40	Stimulates the production of cytokines and chemokines, thereby promoting anti-tumor effects

	V-domain Ig suppressor of T-cell activation (VISTA)	Inhibit T cell proliferation and activation and Treg transformation, and reduce the production of cytokines
	4-1BB	Interaction with 4-1BBL enhances T cell proliferation, differentiation and effector function
Chemokines	C-C Motif Chemokine Ligand 1 (CCL1)/ Characteristic Chemokine Receptor 8 (CCR 8)	Enhance the immunosuppressive activity of Treg and promote tumor cell proliferation, anti-apoptosis and inflammatory response
	C-C Motif Chemokine Ligand 22 (CCL22)/Characteristic Chemokine Receptor 4 (CCR4)	Recruited Tregs gather at tumor sites and induce local immune escape in hepatocellular carcinoma by secreting a large amount of IL-10 and TGF-β while inhibiting IL-2 secretion
Metabolites	lactic acid	Transform the tumor microenvironment into an environment suitable for tumor cell proliferation
Exosomes		Promotes angiogenesis and tumor growth, regulates immune escape, and affects the tumor microenvironment
Extracellular matrix		Helps tumor cells invade and metastasize, and promotes the metastasis of hepatocellular carcinoma