

*Opinion Article*

# Activation of cytotoxic T lymphocytes and its role, functions of immune defense

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## DESCRIPTION

Cytotoxic T lymphocytes (CTLs), also known as CD8+ T cells, are a vital component of the adaptive immune system. These specialized immune cells play a critical role in identifying and eliminating infected or abnormal cells in the body. This study discusses about cytotoxic T lymphocytes, examining their development, mechanisms of action, and importance in immune defense.

### Development and activation of cytotoxic T lymphocytes

**T cell maturation:** Cytotoxic T lymphocytes originate from hematopoietic stem cells in the bone marrow and undergo maturation in the thymus. During this process, T cells undergo positive and negative selection to ensure they recognize foreign antigens without attacking self-tissues.

**Antigen presentation and activation:** Cytotoxic T lymphocytes are activated by antigen-presenting cells (APCs), primarily dendritic cells. APCs capture and process antigens from infected cells and present them on their surface using major histocompatibility complex class I (MHC-I) molecules. When a T cell receptor (TCR) on a cytotoxic T lymphocyte recognizes a specific antigen-MHC-I complex, it triggers the activation of the T cell.

### Mechanisms of cytotoxic T lymphocyte action

**Target Cell Recognition:** Cytotoxic T lymphocytes possess T-cell receptors (TCRs) that are highly specific for antigens presented on MHC-I molecules. The TCR binds to the antigen-MHC-I complex, allowing the cytotoxic T lymphocyte to recognize infected or abnormal cells.

**Cytotoxic granule release:** Once activated, cytotoxic T lymphocytes release cytotoxic granules containing perforin and granzymes. Perforin creates pores in the target cell's membrane, allowing the entry of granzymes. Granzymes trigger various cellular processes leading to apoptosis, such as activation of

caspases and deoxyribonucleic acid fragmentation.

**Fas-fas ligand interaction:** Cytotoxic T lymphocytes can also induce apoptosis in target cells by interacting with the Fas receptor (CD95) on the target cell surface. Binding of Fas ligand (FasL) on the cytotoxic T lymphocyte to Fas receptor triggers a signaling cascade, resulting in programmed cell death.

**Secretion of cytokines:** In addition to their cytotoxic abilities, cytotoxic T lymphocytes secrete cytokines, such as interferon-gamma (IFN- $\gamma$ ) and tumor necrosis factor-alpha (TNF- $\alpha$ ). These cytokines have multiple functions, including enhancing the immune response, activating other immune cells, and promoting inflammation.

### Role of cytotoxic T lymphocytes in immune defense

**Viral infections:** Cytotoxic T lymphocytes play a crucial role in clearing viral infections by identifying and eliminating virus-infected cells. They recognize viral antigens presented on major histocompatibility complex type 1 (MHC-I) molecules and selectively kill these infected cells, limiting viral replication and spread.

**Tumor surveillance:** Cytotoxic T lymphocytes also play a critical role in immune surveillance against cancerous cells. They can recognize tumor-specific antigens presented on MHC-I molecules and eliminate these abnormal cells, preventing the development and progression of tumors.

**Transplant rejection:** Cytotoxic T lymphocytes are involved in transplant rejection. When transplanted tissues express foreign antigens, cytotoxic T lymphocytes can recognize these antigens and initiate an immune response against the graft, leading to its rejection.

**Immune memory:** Cytotoxic T lymphocytes are capable of generating immunological memory. Following an initial encounter with an antigen

### Functions

**Cell-mediated cytotoxicity:** The primary function of cytotoxic T lymphocytes is to directly kill target cells. CTLs

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recognize and destroy cells that are infected with intracellular pathogens, such as viruses or intracellular bacteria, as well as cancerous cells.

**Tumor surveillance:** Cytotoxic T lymphocytes are instrumental in immune surveillance against cancer cells. They can recognize and eliminate tumor cells expressing tumor-specific antigens on MHC-I molecules. By targeting and eliminating cancerous cells, cytotoxic T lymphocytes contribute to the prevention of tumor development and progression.

**Memory and long-term immunity:** Following an initial encounter with an antigen, cytotoxic T lymphocytes can generate immunological memory. Memory cytotoxic T lymphocytes are long-lived cells that provide a more rapid and robust immune response upon re-exposure to the same antigen. This memory

response contributes to long-term immunity against specific pathogens and helps prevent reinfection.

**Regulatory functions:** In addition to their cytotoxic abilities, cytotoxic T lymphocytes also have regulatory functions. They can produce cytokines, such as interferon-gamma (IFN- $\gamma$ ) and tumor necrosis factor-alpha (TNF- $\alpha$ ), which modulate the immune response. These cytokines can enhance the activity of other immune cells, promote inflammation, and help coordinate immune defense against infections. In summary, cytotoxic T lymphocytes are specialized immune cells that play a critical role in immune defense. They directly kill infected or abnormal cells, contribute to viral clearance, surveil and eliminate tumor cells, generate immunological memory, and have regulatory functions within the immune system.