

## ZINC BIOCHEMICAL FUNCTIONS

### *Cellular Enzymes (continued)*

secrete **insulin**, as well as provide **antioxidant** functions. **Carboxypeptidase A** is a zinc-containing pancreatic enzyme involved in **protein degradation**. The zinc enzyme, **lactic dehydrogenase**, converts **glucose to lactate (glycolysis)**, storing energy as **ATP**. Zinc is a constituent of **retinol dehydrogenase**, facilitating **alcohol metabolism in the liver**. The zinc-containing cardiac enzyme, **ACE (angiotensin-converting enzyme)** converts **angiotensin I to angiotensin II**, and helps degrade the vasodilator, **bradykinin**, aiding in the regulation of vascular tone and cardiac functions (Baudin B, 2002).

### *Immune Function*

\*Zinc is required for virtually all components of the immune system from the **barrier of the skin to leukocyte activity** (Shankar AH, 1998). It is particularly involved in the production and regulation of **lymphocytes and their messenger molecules (cytokines) and cytotoxins in cell-mediated (type-1) immune response** to foreign invaders such as viruses (antigens and mitogens) (Baum MK, 2000, Rink L, 2000). Zinc is the catalyst that propels the thymic hormone, **thymulin**, into action (Bach JF, 1989). Thymulin stimulates the **division, differentiation, and maturation of the immune fighting thymus lymphocytes (T-cells)**, such as **T-helper cells (or th1 cells), cytotoxic T-cells, and suppressor T-cells** which adapt to recognize and combat pathogens and foreign substances. **Resistance to fungal, bacterial and viral infections, including HIV, is significantly enhanced by zinc's ability to activate thymulin** (Mocchegiani E, 2000 Sprietsma JE, 1999).

### *T-helper Cell Secretions*

\*T-helper lymphocytes secrete the signaling and regulating **cytokines (lymphokines), interleukin-2 (IL2), interferon-gamma (IFN-gamma), and lymphotoxin-alpha [or tumor necrosis factor-alpha (TNF-alpha)]** in response to pathogens, resulting in intense **phagocytic activity** (Spellberg B, 2001, Bodey B, 1998). All of these appear to be **modulated by zinc**. IL-2 stimulates and enhances natural killer cell activity (Miller-Keane, 1992), but lytic activity of these cells is reduced when zinc is deficient (Prasad AS, 2000). **Interferon helps inhibit viral multiplication in cells, but it is reduced when zinc is deficient** (Cousins RJ, 2000). Zinc helps **regulate the cytotoxic behavior of TNF-alpha** stimulated macrophages which are involved in the killing or break-down (necrosis) of tumor cells (Prasad AS, 2000). Catabolic (destructive) behavior of TNF is mediated by zinc, helping to **prevent cachexia/wasting** which can be fatal to patients with chronic diseases such as AIDS (Baum MK, 2000, Hennig B 1993). **Zinc also induces monocytes to produce interleukin-1, interleukin-6 and TNF-alpha** (Rink L, 2000). Under the influence of T-helper cells, zinc helps **decrease tumor growth by stimulating the production of endostatin**, an agent known to suppress angiogenesis (blood vessel growth) in tumors (Sprietsma JE, 1999).

### *Growth Hormone and Insulin-Like Growth Factor*

\*The pituitary growth hormone (GH) stimulates thymic activity, lymphocyte proliferation, and cytotoxic activity of **natural killer cells (NK cells)**. NK cells are large, specialized granule-filled cytotoxic lymphocytes that play a key role in **natural immunity**. They recognize pathogen infected cells and tumor cells, and produce toxins to kill them without having to first develop adaptations, unlike T-cells. **NK cells and T-cells have been shown to decrease with age, but to increase in number and function in association with positive zinc status** (Ravaglia G, 2000, Prasad AS, 1998). GH activates expression of the gene of **IGF-I (insulin-like growth factor-I)** and stimulates its secretion by the thymus and other tissues (Pankov YA, 1999). GH binds to receptors on T-cells, stimulating IGF-I production which functions to mediate T-cell proliferation (Geffner M, 1997). **Studies show IGF-I levels reflect zinc and thymulin levels, and that zinc is required for IGF-I activation** (MacDonald RS, 2000, Mocchegiani E, 1991).