Intricacies of neurogenesis development to regeneration.

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Introduction

The human brain, with its vast network of neurons and intricate circuitry, is a marvel of biological complexity. Central to its dynamic nature is the process of neurogenesis, the generation of new neurons from neural stem cells. Once thought to be confined to early development, neurogenesis has emerged as a phenomenon that persists throughout life in select regions of the brain. In this in-depth exploration, we embark on a journey through the fascinating realm of neurogenesis, delving into its mechanisms, regulation, functional significance, and therapeutic potential [1].

Neurogenesis is a highly orchestrated process that unfolds in distinct stages, encompassing proliferation, differentiation, migration, and integration of neural precursor cells. Neural stem cells residing in specialized niches within the adult brain, such as the Sub Ventricular Zone (SVZ) and the Dentate Gyrus (DG) of the hippocampus, undergo mitotic division to generate progenitor cells called neuroblasts [2].

Neuroblasts commit to a neuronal fate and differentiate into immature neurons, characterized by the expression of neuronal markers and the initiation of neurite outgrowth. Immature neurons migrate from their site of origin to their final destination within the brain parenchyma, guided by a complex interplay of molecular cues and signalling pathways. Once settled in their destination, immature neurons undergo maturation processes, including dendritic and axonal growth, synaptogenesis, and neurotransmitter specification, before integrating into existing neural circuits [3].

Sub ventricular Zone located adjacent to the lateral ventricles, the SVZ serves as a reservoir of neural stem cells that give rise to new neurons destined for the olfactory bulb. Neuroblasts generated in the SVZ migrate along the Rostral Migratory Stream (RMS) to the olfactory bulb, where they differentiate into interneurons involved in olfactory processing. The DG, a region critical for learning and memory, harbours neural stem cells that generate new granule neurons throughout life. Adult hippocampal neurogenesis is thought to play a role in hippocampal-dependent functions, such as spatial navigation, pattern separation, and memory consolidation [4, 5].

Environmental stimuli, such as physical exercise, cognitive stimulation, social interaction, and exposure to enriched environments, have been shown to enhance neurogenesis by promoting progenitor cell proliferation, survival, and differentiation. Growth factors, such as Brain-Derived Neurotrophic Factor (BDNF), Fibroblast Growth Factor 2 (FGF2), and Vascular Endothelial Growth Factor (VEGF), play crucial roles in regulating neurogenesis by promoting cell proliferation, differentiation, and survival [6].

Hormonal signals, including glucocorticoids, gonadal steroids (estrogen, testosterone), and thyroid hormones, modulate neurogenesis in response to physiological and environmental cues, such as stress, aging, and reproductive status. Inflammatory signals and cytokines released in response to injury, infection, or neurodegeneration can influence neurogenesis by altering the microenvironment of neural stem cells and affecting their proliferation, differentiation, and survival [7].

Adult neurogenesis has been implicated in a wide range of brain functions and behaviours, including learning, memory, mood regulation, and cognitive flexibility. Adult neurogenesis has been linked to various forms of learning and memory, including spatial learning, pattern separation, and contextual fear conditioning. Manipulations that enhance or impair neurogenesis can modulate cognitive performance, suggesting a causal relationship between neurogenesis and memory function [8].

Neurogenesis has been implicated in mood regulation and emotional processing, with alterations in hippocampal neurogenesis observed in animal models of depression, anxiety, and stress-related disorders. Antidepressant treatments have been shown to increase hippocampal neurogenesis, highlighting the potential therapeutic implications of targeting neurogenesis for mood disorders. Adult neurogenesis may play a role in cognitive flexibility and adaptive behavior, allowing the brain to integrate new information, update existing memories, and respond to changing environmental demands. Neurogenesis has been associated with enhanced behavioural flexibility, resilience to stress, and adaptive responses to novelty and uncertainty [9].

The regenerative capacity of neurogenesis holds promise for developing novel therapeutic strategies for neurological and psychiatric disorders. Interventions aimed at enhancing neurogenesis, such as pharmacological agents, stem cell therapies, and neurostimulation techniques, are being explored for their potential to promote brain repair, functional recovery, and cognitive enhancement [10].

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