Zoology 119 (2016) 153–157

Contents lists available at ScienceDirect

Zoology

journal homepage: www.elsevier.com/locate/zool

Invited Perspectives

A possible role for the immune system in adult neurogenesis: new insights from an invertebrate model

Steffen Harzsch[a,*], Oliver von Bohlen und Halbach[b]

[a] Zoological Institute and Museum, Department of Cytology and Evolutionary Biology, Ernst-Moritz-Arndt University Greifswald, Soldmannstrasse 23, D-17489 Greifswald, Germany
[b] Institut für Anatomie und Zellbiologie, Universitätsmedizin Greifswald, Friedrich-Loeffler-Str. 23c, D-17489 Greifswald, Germany

ARTICLE INFO

Article history:
Received 12 November 2015
Accepted 30 November 2015
Available online 19 December 2015

Keywords:
Neuronal stem cells
Persistent neurogenesis
Self renewal
Immune system
Neurogenic niche

ABSTRACT

Persistent neurogenesis in the adult brain of both vertebrates and invertebrates was previously considered to be driven by self-renewing neuronal stem cells of ectodermal origin. Recent findings in an invertebrate model challenge this view and instead provide evidence for a recruitment of neuronal precursors from a non-neuronal source. In the brain of adult crayfish, a neurogenic niche was identified that contributes progeny to the adult central olfactory pathway. The niche may function in attracting cells from the hemolymph and transforming them into cells with a neuronal fate. This finding implies that the first-generation neuronal precursors located in the crayfish neurogenic niche are not self-renewing. Evidence is summarized in support of a critical re-evaluation of long-term self-renewal of mammalian neuronal stem cells. Latest findings suggest that a tight link between the immune system and the system driving adult neurogenesis may not only exist in the crayfish but also in mammals.

© 2015 Elsevier GmbH. All rights reserved.

1. Persistent neurogenesis in the crustacean brain

In recent years, evidence has accumulated suggesting that persistent neurogenesis is more widespread in the animal kingdom than previously thought (for reviews see, e.g., Kempermann, 2006; Kaslin et al., 2008; Aimone et al., 2010; Lazarini and Lledo, 2010; Kempermann, 2012; Sandeman et al., 2015). In addition to several vertebrate species, including representatives of fishes, amphibians, reptiles, birds and mammals, a few insect species also display ongoing adult neurogenesis (Cayre et al., 2002, 2007; Dokter and von Bohlen und Halbach, 2012; Kempermann, 2012; Walton et al., 2012). As for other arthropods, decapod crustaceans may not be a group of animals that most of us would intuitively list as prime examples of persistent neurogenesis because their nervous systems, as those of most invertebrates, are often considered to be more hard-wired than plastic. However, in the past two decades, crustaceans have emerged as models for the analysis of the life-long generation of neurons within the central olfactory pathway (for latest reviews see Sandeman et al., 2011; Benton et al., 2013; Schmidt, 2014; Sandeman et al., 2015). The investigation of this system began with the discovery of proliferating cells in juvenile crabs using the S-phase-specific mitosis marker bromodeoxyuridine (BrdU) (Harzsch and Dawirs, 1996). This was followed by the study of Schmidt (1997) on sexually mature specimens of the green crab *Carcinus maenas*. By counting the axons of the olfactory projection neurons, this author showed that over the adult life span of this crab the number of olfactory projection neurons doubles from ca. 15,000 to 30,000. In the following years, pulse-chase experiments with BrdU provided strong evidence that the newly born projection neurons survive and are integrated into the existing circuitry of the central olfactory pathway in clawed lobsters (Harzsch et al., 1999), spiny lobsters (Schmidt, 2001) and crayfish (Sullivan and Beltz, 2005; Sullivan et al., 2007a,b; Kim et al., 2014). Subsequently, this system was explored to identify factors that modulate mitosis, survival of the newly born cells and their differentiation. These studies include: ingrowth of axons from olfactory sensory neurons (Hansen and Schmidt, 2001; Sullivan and Beltz, 2005); rearing conditions ("impoverished versus enriched environment"; Ayub et al., 2011; Hansen and Schmidt, 2004; Sandeman and Sandeman, 2000); circadian effects (Goergen et al., 2002); seasonal effects (Hansen and Schmidt, 2004); social interactions (Song et al., 2007); the neuromodulator serotonin (Benton and Beltz, 2001; Benton et al., 2008; Sandeman et al., 2009; Zhang et al., 2011); locomotory activity (Kim et al., 2014).

The year 2007 marked a milestone in the research on this system when Sullivan et al. (2007a,b) reported the unexpected finding that adult neurogenesis in crayfish is driven by a neurogenic niche associated superficially with the deutocerebrum (Fig. 1A).

* Corresponding author.
E-mail address: steffen.harzsch@uni-greifswald.de (S. Harzsch).

http://dx.doi.org/10.1016/j.zool.2015.11.003
0944-2006/© 2015 Elsevier GmbH. All rights reserved.

Fibrous migratory streams from the neurogenic niche serve as pathways from which neuronal precursors from the niche, mediated by dynein-binding proteins (Zhang et al., 2009), travel towards two proliferation zones associated with the clusters of olfactory interneurons. The niche in crayfish is a spherical cluster of cells with glial characteristics and a core of extracellular matrix (cadherins). Dextran injections into the crayfish circulatory system showed that the niche is associated with the vascular system (Sullivan et al., 2007a; Sandeman et al., 2009). First-generation precursors undergo mitosis in the niche, and their progeny, the second-generation precursors, travel along the migratory streams. On reaching the lateral and medial proliferation zones, they undergo an additional mitosis to generate third-generation precursors. These further proliferate and give rise to olfactory interneurons. The entire system of niche, streams and proliferation zones was termed "deutocerebral proliferative system" (Sintoni et al., 2012). Analyses of the embryonic emergence of the niche in crayfish showed that the deutocerebral proliferative system develops towards the end of embryogenesis and is present at hatching with its characteristic mitotic cycles (Sintoni et al., 2012).

2. Recruitment of neuronal precursors from non-neuronal sources

Further analyses of the dynamics of proliferation in this complex system by Barbara Beltz and co-workers yielded new and unexpected insights (see reviews by Sandeman et al., 2011; Benton et al., 2013; Beltz et al., 2015; Sandeman et al., 2015). This work suggested that, contrary to what was previously thought, the neurogenic niche most likely is *not* a closed system that houses asymmetrically dividing stem cells (Zhang et al., 2009). Rather, these authors, based on pulse-chase double nucleoside labelling suggested that the niche is an open system that recruits cells from the hemolymph and transforms these into cells with a neuronal fate; thus, the pool of neuronal stem cells in the niche is replenished from a source extrinsic to the niche (Benton et al., 2011; Fig. 1B). This finding implies that the first-generation neuronal precursors in the niche are not self-renewing, a critical distinction between adult neurogenesis in crustaceans and in mammals (see Section 3). This challenging hypothesis was subsequently substantiated by experiments that showed that an experimental modulation of the first-generation precursor cells in the niche is intimately coupled to changes in the cellular composition of the crayfish hemolymph (Ayub et al., 2011). Crustacean blood lacks oxygen-carrying erythrocytes; instead, their blood cells, the hemocytes, function primarily in the innate immune system (Lin and Söderhäll, 2011). Ultrastructural studies on the cellular micro-environment of the niche confirmed a connection to the hemolymph system and showed histological specializations that display similarities to the vertebrate subventricular zone, a major site of adult neurogenesis in the vertebrate brain (Chaves da Silva et al., 2013). Noonin et al. (2012) found a specialized region within crayfish hematopoietic tissue, the "anterior proliferation center" (APC), which is located close to the brain and contains multipotent stem cells. These crustacean hematopoietic tissues are considered functionally equivalent to bone marrow in mammals (Sandeman et al., 2015). In a follow-up

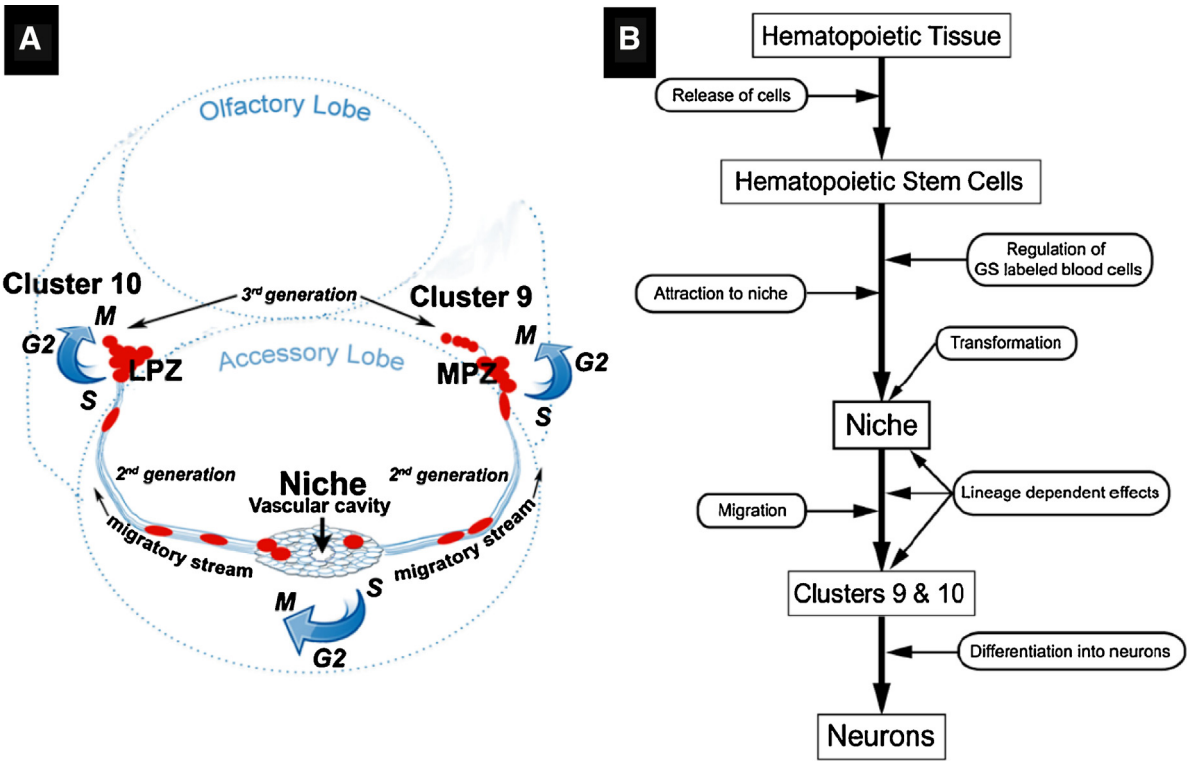

Fig. 1. (A) Schematic drawing of the deutocerebral proliferative system in the adult crayfish brain (reprinted from Beltz et al., 2015; with permission); only one side of the brain is shown. The cellular machinery producing adult-born neurons consists of a neurogenic niche containing first-generation precursors, migratory streams containing second-generation precursors, and two clusters of olfactory interneurons (clusters 9 and 10). The niche containing bipolar cells lies on the surface of the two accessory lobes, and has streams that project to the medial proliferation zone (MPZ) near cluster 9 and the lateral proliferation zone (LPZ) in cluster 10. First-generation precursors in the neurogenic niche divide symmetrically, both daughters migrating to the proliferation zones (MPZ, LPZ), where they divide at least once more before progeny differentiate into neurons. Black arrows next to the streams indicate the direction of migration; curved, thick blue arrows indicate locations of cell divisions. The niche is connected to the blood system via a central "vascular cavity" in the niche. (B) Model of adult neurogenesis in the crayfish as proposed by Beltz et al. (2011; reprinted with permission). Depicted is the hematopoietic tissue, the release of hematopoietic stem cells, their attraction to the niche and transformation into niche cells. The niche cells (first-generation neuronal precursors), which express glutamine synthetase (GS), divide symmetrically to produce daughters that migrate along processes of the niche cells towards cell cluster 9 or 10. These second-generation neuronal precursors divide at least once more in the proliferation zones in the cell clusters, before differentiating into neurons.

Download English Version:

https://daneshyari.com/en/article/2790978

Download Persian Version:

https://daneshyari.com/article/2790978

Daneshyari.com