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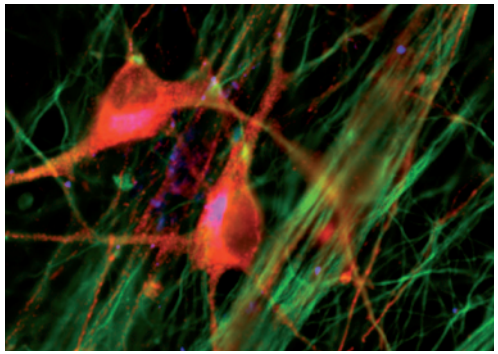
Institute of Anatomy and Cell Biology

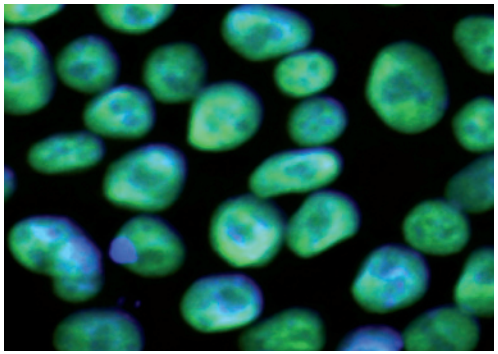
Stem Cell Biology and Proteins of Synaptic Contacts: Functional Characterization of iPS Cells and Synapses in the Context of Neuropsychiatric Diseases

Head: Tobias M. Böckers

Stem cells are considered a very valuable tool for dissecting developmental aspects and investigating pathomechanisms, and can be used for cell-based therapies. Stem cells are characterized by their abilities of symmetrical cell division and their potential to give rise to different cells in organisms. Pluripotent, embryonic stem cells of the blastocyst's inner cell mass can even generate all the cells of an organism. Since the first generation of the so-called induced pluripotent stem cells (hiPS) by Yamanaka, pluripotent stem cells can be reprogrammed from several kinds of somatic cells. This offers the chance of investigating stem cells and their differentiated progeny in disease-specific settings. In this respect, we generated iPS cells from patients with defined genetic defects that either lead to developmental defects in the central nervous system or cause neurodegeneration. In our



Neuron derived from a human induced pluripotent stem cell (iPS-cell). iPS cells were generated from hair keratinocytes. The cell is immunostained for thyrosin hydroxylase (red), tubulin (magenta), the synaptic protein synaptophysin (green) and nuclei are labeled by DAPI (blue). (Photo by Stefan Liebau)



Plucked Hair Keratinocyte-derived induced human pluripotent stem cells expressing the stem cell marker Oct4 (green). Nuclei are stained with DAPI (blue). (Photo by Stefan Liebau)

studies including stem cell biology, we are investigating human and patient-specific iPS cells of several neurological disorders such as ProSAP/SHANK-related autism spectrum disorders (Leonhard Linta), LRRK2-related M. Parkinson (Stefanie Raab), developmental defects of the nervous system related to dysfunctional translation initiation (Maira Bertolessi), developmental disorders related to mutations in an RNA Polymerase (Moritz Klingenstein) as well as neurodegeneration (ALS).

In addition, we concentrate on glutamatergic synapses of the central nervous system that are specific cellular junctions characterized by an electron-dense web underneath the postsynaptic membrane known as the postsynaptic density (PSD). PSDs are composed of a dense network of several hundred different proteins that creates a macromolecular complex serving a wide range of different functions. Prominent PSD proteins, such as members of the MaGuk or ProSAP/Shank family, build up a dense scaffold that creates an interface between clustered membrane-bound receptors, cell adhesion molecules and the actin-based cytoskeleton. The synaptic rearrangement (structural plasticity) is a rapid process and is believed to underlie learning and memory formation. The characterization of synapse/PSD proteins is especially important in light of recent data suggesting that several mental disorders have their molecular defect at the synapse/PSD level. Anna-Lena Jansen, Michael Schmeisser and Noreen Kanwal's projects concentrate on the role of ProSAP/Shank molecules and interacting proteins within the PSD. The self-assembly of these proteins is zinc dependent and zinc seems to play a key role in the local rearrangement of structural PSD components. This is followed up by Stefanie Pfänder in human neurons derived from induced pluripotent stem cells (iPS). In addition, we are working on drugs influencing synapse number and maturity (Patrick Udvardi) as well as on neuronal heat shock protein expression.

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Selected Publications:

- *Schmeisser MJ, Baumann B, Johannsen S, Vindedal GM, Jensen V, Hvalby Ø, Sprengel R, Seither J, Lattke M, Oswald F, Boeckers TM and Wirth T (2012): IKK/NF-κB signaling dynamically regulates synapse formation and spine maturation via Igf2/Igf2R. J Neurosci 32(16):5688-5703.*
- *Leblond CS, Heinrich J, Delorme R, Proepper C, Betancur C, Huguet G, Konyukh M, Chaste P, Ey E, Rastam M, Anckarsäter H, Nygren G, Ståhlberg O, Gillberg IC, Melke J, Toro R, Regnault B, Fauchereau F, Mercati O, Lemière N, Skuse D, Poot M, Holt R, Curran S, Collier D, Bolton P, Chiocchetti A, Klauck SM, Poustka F, Freitag CM, Bacchelli E, Minopoli F, Maestrini E, Mazzone L, Ruta L, Sousa I, Vicente A, Oliveira G, Pinto D, Scherer S, Zelenika D, Delepine M, Lathrop M, Guinchat V, Devillard F, Assouline B, Mouren MC, Leboyer M, Gillberg C, Boeckers TM and Bourgeron T (2012): Genetic and functional analyses of SHANK2 mutations provide evidence for a multiple hit model of autism spectrum disorders. Plos Genetics 8, 2; e1002521.*
- *Schmeisser MJ, Ey E, Wegener S, Bockmann J, Stempel AV, Kuebler A, Janssen AL, Udvardi PT, Shiban E, Spilker C, Balschun D, Skryabin BV, Dieck St, Smalla KH, Montag D, Leblond CS, Faure P, Torquet N, Le Sourd AM, Toro R, Grabrucker AM, Shoichet SA, Schmitz D, Kreutz MR, Bourgeron T, Gundelfinger ED, Boeckers TM (2012): Autistic-like behaviours and hyperactivity in mice lacking ProSAP1/Shank2. Nature, 486: 256-260.*
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- *Proepper C, Steinestel K, Schmeisser M, Heinrich J, Langer J, Bockmann J, Liebau S and Boeckers TM (2011): Heterogenous nuclear ribonucleoprotein K (hnRNPK) binds Abi-1 at synaptic sites. Plos One 6,(11), e27045.*