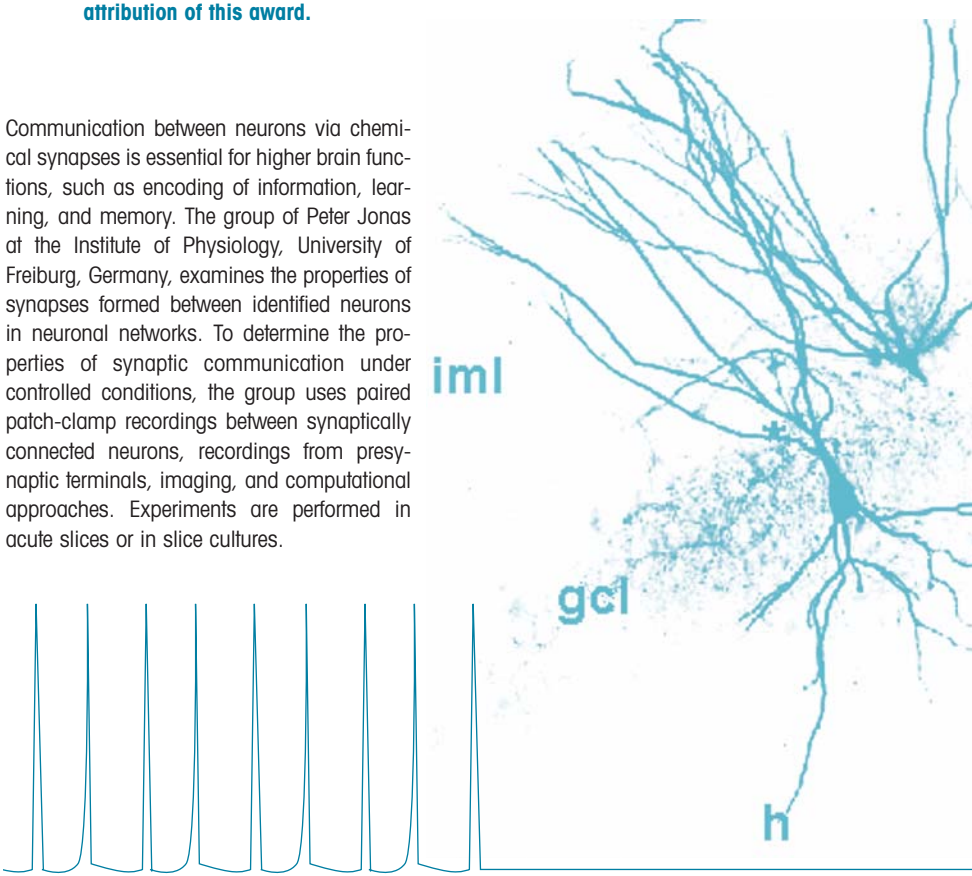
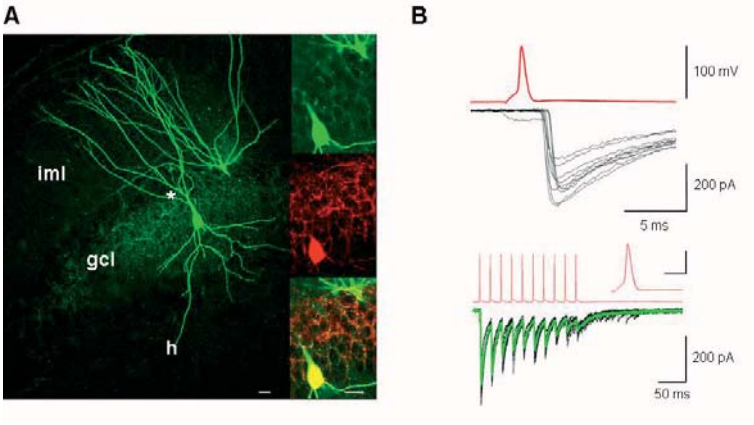
SYNAPTIC TRANSMISSION AWARDED

For his outstanding research on synaptic transmission in the mammalian brain, Prof. Peter Jonas (Institute of Physiology, Freiburg) recently received the Leibniz award of the Deutsche Forschungsgemeinschaft. The Leibniz Prize, valued 1.55 million €, is the most prestigious research award in Germany. Part of the work is being done within the recently founded Bernstein Center for Computational Neuroscience in Freiburg. Prof Jonas describes here for us a summary of the research activities which led to the attribution of this award.

Communication between neurons via chemical synapses is essential for higher brain functions, such as encoding of information, learning, and memory. The group of Peter Jonas at the Institute of Physiology, University of Freiburg, Germany, examines the properties of synapses formed between identified neurons in neuronal networks. To determine the properties of synaptic communication under controlled conditions, the group uses paired patch-clamp recordings between synaptically connected neurons, recordings from presynaptic terminals, imaging, and computational approaches. Experiments are performed in acute slices or in slice cultures.





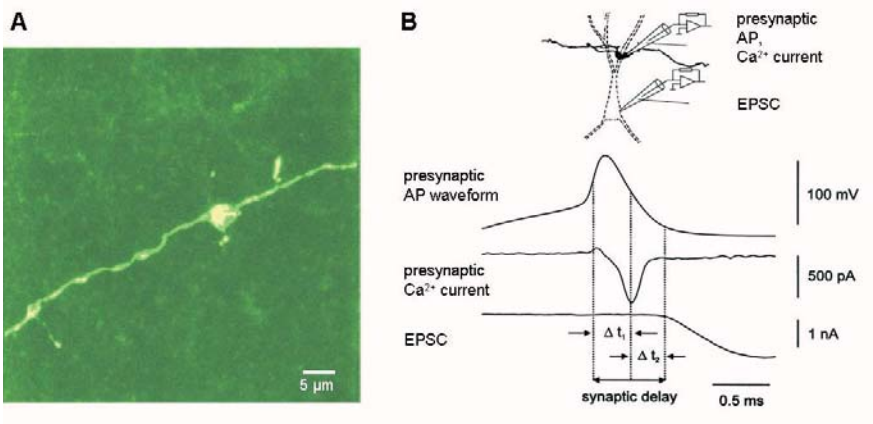
One major focus of the lab is the characterization of inhibitory interneurons and their synaptic connections. The group found that the parvalbumin-expressing interneuron, a major subtype of inhibitory interneuron in the hippocampus, is a highly specialized cell. Synapses that excite these interneurons generate fast currents, due to the expression of glutamate receptors of specific subunit composition. Parvalbumin-expressing interneurons fire brief action potentials in response to transient synaptic activation and discharge repetitively at very high frequencies during sustained stimulation. The ability to generate short-duration actio potentials at high frequencies depends on the expression of specific voltagegated K+ channels. Finally, GABA release at interneuron output synapses is rapid and highly synchronized, leading to fast inhibition, particularly in postsynaptic interneurons. Thus the expression of distinct transmitter receptors and voltage-gated ion channels ensures that parvalbumin-expressing interneurons operate with high speed and temporal precision [1,2,3] [Fig. 1].

Figure 1.
A, Confocal image of a synaptically connected parvalbumin-expressing interneuron and a postsynaptic granule cell filled with biocytin during patch-clamp recording and stained with fluorescent avidin. Insets show that the presynaptic neuron is immunopositive for parvalbumin. **B**, Presynaptic action potentials (red traces) and inhibitory postsynaptic currents (black traces) in a parvalbuminexpressing interneuron-granule cell pair. Data are taken from Ref. 3.

1
Jonas P, Bischofberger J, Fricker D, Miles R (2004) Interneuron diversity series: Fast in, fast out - temporal and spatial signal processing in hippocampal interneurons. TINS 27:30-40.

2
Bartos M, Vida I, Frotscher M, Meyer A, Monyer H, Geiger JRP, Jonas P (2002) Fast synaptic inhibition promotes synchronized gamma oscillations in hippocampal interneuron networks. Proc Natl Acad Sci USA 99: 13222-13227.

3
Hefft S, Jonas P (2005) Asynchronous GABA release generates long-lasting inhibition at a hippocampal interneuron–principal neuron synapse. Nature Neuroscience 8:1319-1328.



Another main focus of the Jonas lab is the characterization of presynaptic terminals. Whereas presynaptic elements at peripheral synapses are well studied, the relatively small size of presynaptic terminals in the central nervous system has prevented a direct analysis. Together with Jörg Geiger and Josef Bischofberger, Peter Jonas concentrated on mossy fiber terminals in the hippocampus, the «largest» (3-5 µm diameter) among the «small» terminals. This enabled the group to make the first direct recordings of action potentials and presynaptic voltage-gated currents from a presynaptic terminal in the cortex. The group found that hippocampal mossy fiber terminals express presynaptic K+ channels with fast inactivation. Making capacitance measurements from these terminals, they found that the releasable pool of synaptic vesicles was very large. Finally, the Jonas group discovered that these terminals express voltage-gated Na^+ channels with very high densities, conferring axon-like properties to these presynaptic elements. Collectively, these properties explain the high efficacy of the hippocampal mossy fiber synapse [4,5,6] [Fig. 2].■ P.J.

Figure 2.

A, Confocal image of a hippocampal mossy fiber bouton filled with biocytin during direct patch-clamp recording and stained with fluorescent avidin.

B, Recording of presynaptic action potential, presynaptic Ca2+ current, and postsynaptic EPSC in a paired recording between a mossy fiber bouton and a synaptically connected CA3 cell. The inset shows a schematic illustration of the recording configuration. Data are taken from Refs. 4 and 6.

4
Bischofberger J, Jonas P (2002) TwoB or not TwoB: differential transmission at glutamatergic mossy fiber-interneuron synapses in the hippocampus. TINS 25:600-603.

5
Engel D, Jonas P (2005) Presynaptic action potential amplification by voltage-gated Na+ channels in hippocampal mossy fiber boutons. Neuron 45:405-417.

6
Geiger JRP, Jonas P (2000) Dynamic control of presynaptic Ca2+ inflow by fast-inactivating K+ channels in hippocampal mossy fiber boutons. Neuron 28:927-939.