

6 LITERATUR

- Acevez-Pina, E.O., Booker, R., Duerr, J.S., Livingstone, M.S., Quinn, W.G., Smith, R.F., Sziber, P.P., Tempel, B.L. und Tully, T.P.: Learning und memory in *Drosophila*, studied with mutants. *Cold Spring Harbor Symp. Quant. Biol.* **48**: 831 (1983).
- Adamski, F.M., Zhu, M.Y., Bahiraei, F., Shieh, B.H.: Interaction of eye protein kinase C and INAD in *Drosophila*. Localization of binding domains and electrophysiological characterization of a loss of association in transgenic flies. *J Biol Chem.* **273**: 17713-17719 (1998).
- Arnold, G., Masson, C. und Budharugsa, S.: Comparative study of the antennal lobes and their afferent pathway in the worker bee and drone. *Cell Tissue Res.* **242**: 593-605 (1985).
- Bacskai, B.J., Hochner, B., Mahaut-Smith, M., Adams, S.R., Kaang, B.-K., Kandel, E.R. und Tsien, R.Y.: Spatially resolved dynamics of cAMP and protein kinase A subunits in *Aplysia* sensory neurons. *Science* **260**: 222-226 (1993).
- Bailey, C.H. und Kandel, E.R.: Structural changes accompanying memory storage. *Annu. Rev. Physiol.* **55**: 397-426 (1993).
- Bank, B., DeWeer, A., Kuzirian, A.M., Rasmussen, H. und Alkon, D.L.: Classical conditioning induces long-term translocation of protein kinase C in rabbit hippocampal CA1 cells. *Proc. Natl. Acad. Sci. USA* **85**: 1988-1992 (1988).
- Bartschat, D.K. und Rhodes, T.E.: Protein kinase C modulates calcium channels in isolated presynaptic nerve terminals of rat hippocampus. *J. Neurochem.* **64**: 2064-2072 (1995).
- Bernier, L., Castellucci, V.F., Kandel, E.R., Schwartz, J.H.: Facilitatory transmitter causes a selective and prolonged increase in adenosine 3':5'-monophosphate in sensory neurons mediating the gill and siphon withdrawal reflex in *Aplysia*. *J Neurosci.* **2** (12): 1682-1691 (1982).
- Bitterman, M.E., Menzel, R., Fietz, A. und Schäfer, 5.: Classical conditioning of proboscis extension in honeybees (*Apis mellifera*). *J. Comp. Psychol.* **97**: 107-119 (1983).
- Bliss, T.V.P. und Collingridge, G.L.: A synaptic model of memory: long-term potentiation in the hippocampus. *Nature* **361**: 3 1-39 (1993).

- Bliss, T.V., Lomo, T.: Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path. *J Physiol.* **232**(2): 331-356 (1973).
- Bourtchuladze, R., Frenguelli, B., Blendy, J., Cioffi, D., Schutz, G. und Silva, A.J.: Deficient long-term memory in mice with a targeted mutation of the cAMP-responsive element-binding protein. *Cell* **79**: 59-68 (1994).
- Brindle, P., Nakajima, T., Montminy, M.: Multiple protein kinase A-regulated events are required for transcriptional induction by cAMP. *Proc Natl Acad Sci USA.* **92**: 10521-10525 (1995).
- Buchner, K.: Protein kinase C in the transduction of signals toward and within the cell nucleus. *Eur. J. Biochem.* **228**: 211-221 (1995).
- Burchuladze, R., Potter, J., Rose, S.P.: Memory formation in the chick depends on membrane-bound protein kinase C. *Brain Res.* **535**: 131-138 (1990).
- Cambier, J.C., Newell, M.K., Justement, L.B., McGuire, J.C., Leach, K.L., Chen, Z.Z.: Ia binding ligands and cAMP stimulate nuclear translocation of PKC in B lymphocytes. *Nature.* **327**: 629-32 (1987).
- Carew, T.J., Pinsker, H.M. und Kandel, E.R.: Long-term habituation of a defensive withdrawal reflex in *Aplysia*. *Science* **175**: 451-454 (1972).
- Castellucci, V.F., Kandel, E.R., Schwartz, J.H., Wilson, F.D., Nairn, A.C., Greengard, P.: Intracellular injection of the catalytic subunit of cyclic AMP-dependent protein kinase simulates facilitation of transmitter release underlying behavioral sensitization in *Aplysia*. *Proc Natl Acad Sci USA.* **77**: 7492-7496 (1980).
- Chen, L. und Huang, L.-Y.-M.: Protein kinase C reduces Mg²⁺ block of NMDA-receptor channels as a mechanism of modulation. *Nature* **356**, 521-523 (1992).
- Choi, K.W., Smith, R.F., Buratowski, R.M., Quinn, W.G.: Deficient protein kinase C activity in turnip, a *Drosophila* learning mutant. *J Biol Chem.* **266**: 15999-16006 (1991).
- Colley, P.A., Sheu, F.-S. und Routtenberg, A.: Inhibition of protein kinase C blocks two components of LTP persistence, leaving initial potentiation intact. *J. Neurosci.* **10**: 3353-3360 (1990).
- Csukai, M., Chen, C.H., De Matteis, M.A., Mochly-Rosen, D.: The coatamer protein beta¹-COP, a selective binding protein (RACK) for protein kinase Cepsilon. *J Biol Chem.* **272**: 29200-29206 (1997).
- Dash, P.K., Hochner, B. und Kandel, E.R.: Injection of the cAMP-responsive element into the nucleus of *Aplysia* sensory neurons blocks long-term facilitation. *Nature* **345**: 718-721 (1990).

- Dash, P.K., Karl, K.A., Colicos, M.A., Prywes, R., Kandel, E.R.: cAMP response element-binding protein is activated by Ca²⁺/calmodulin- as well as cAMP-dependent protein kinase. *Proc Natl Acad Sci USA*. **88**: 5061-5065 (1991).
- Davis, H.P., Squire, L.R.: Protein synthesis and memory: a review. *Psychol Bull.* **96**: 518-559 (1984).
- Daw, M.I., Chittajallu, R., Bortolotto, Z.A., Dev, K.K., Duprat, F., Henley, J.M., Collingridge, G.L., Isaac, J.T.: PDZ proteins interacting with C-terminal GluR2/3 are involved in a PKC-dependent regulation of AMPA receptors at hippocampal synapses. *Neuron*. **28**: 873-886 (2000).
- deBelle, J.S. und Heisenberg, M.: Associative odor learning in *Drosophila* abolished by chemical ablation of mushroom bodies. *Science* **263**: 692-695 (1994).
- Deisseroth, K., Heist, E.K., Tsien, R.W.: Translocation of calmodulin to the nucleus supports CREB phosphorylation in hippocampal neurons. *Nature*. **392**: 198-202 (1998).
- DeZazzo, J., und Tully, T.: Dissection of memory formation: from behavioral pharmacology to molecular genetics. *Trends Neurosci.* **18**: 212-218 (1995)
- Disatnik, M.H., Winnier, A.R., Mochly-Rosen, D., Arteaga, C.L.: Distinct responses of protein kinase C isozymes to c-erbB-2 activation in SKBR-3 human breast carcinoma cells. *Cell Growth Differ.* **5**: 873-880 (1994a).
- Disatnik, M.H., Buraggi, G., Mochly-Rosen, D.: Localization of protein kinase C isozymes in cardiac myocytes. *Exp Cell Res.* **210**: 287-297 (1994b).
- Drier, E.A., Tello, M.K., Cowan, M., Wu, P., Blace, N., Sacktor, T.C., Yin, J.C.: Memory enhancement and formation by atypical PKM activity in *Drosophila melanogaster*. *Nat Neurosci.* **5**: 316-324 (2002).
- Dubnau, J., Tully, T.: Gene discovery in *Drosophila*: new insights for learning and memory. *Annu Rev Neurosci.* **21**: 407-444 (1998).
- Eisenhardt, D.: Der Transkriptionsfaktor CREB im Gehirn der Honigbiene (*Apis mellifera*): Charakterisierung der Variabilität der Transkripte und Klonierung einer cDNA, die die katalytische Untereinheit der Proteinkinase A, einer CREB-Kinase, kodiert. *Inaugural Dissertation am Fachbereich Biologie, Chemie und Pharmazie*, Frei Universität Berlin, (1998).
- Erber, J., Masuhr, T. und Menzel, R.: Localization of short-term memory in the brain of the honeybee *Apis mellifera*. *Physiol. Entomol.* **5**: 343-358 (1980).

- Erber, J., Homberg, U., Gronenberg, W.: Functional Roles of the Mushroom Bodies in Insects. In A.P.Gupta (eds.): *Arthropod brain: its evolution, development, structure and functions*. Wiley, J. and sons, Inc.: 485-511 (1987)
- Faber, T., Joerges, J., Menzel, R.: Associative learning modifies neural representations of odors in the insect brain. *Nat Neurosci.* **2**: 74-78 (1999).
- Faux, M.C., Rollins, E.N., Edwards, A.S., Langeberg, L.K., Newton, A.C., Scott, J.D.: Mechanism of A-kinase-anchoring protein 79 (AKAP79) and protein kinase C interaction. *Biochem J.* **343**: 443-452 (1999).
- Feany, M.B. und Quinn, W.G.: A neuropeptide gene defined by the *Drosophila* memory mutant *amnesiac*. *Science* **268**:869-873 (1995).
- Feng, J., Cai, X., Zhao, J., Yan, Z.: Serotonin receptors modulate GABA(A) receptor channels through activation of anchored protein kinase C in prefrontal cortical neurons. *J Neurosci.* **21**: 6502-11 (2001).
- Fiala, A., Müller, U., Menzel, R.: Reversible downregulation of protein kinase A during olfactory learning using antisense technique impairs long-term memory formation in the honeybee, *Apis mellifera*. *J Neurosci.* **19**: 10125-10134 (1999).
- Frey, U., Huang, Y.-Y. und Kandel, E.R.: Effects of cAMP stimulate a late stage of LTP in hippocampal CA1 neurons. *Science* **260**: 1661-1664 (1993).
- Frey, U., Krug, M., Reymann, K.G. und Matthies, H.: Anisomycin, an inhibitor of protein synthesis, blocks late phases of LTP phenomena in hippocampal CA1 neurons. *Brain Res.* **452**: 57-65 (1988).
- Friedrich, A.: CREB Isoformen – Modulation durch Lernen und interne Faktoren. *Inaugural Dissertation am Fachbereich Biologie, Chemie und Pharmazie*, Frei Universität Berlin, (2001).
- Frost, W.N., Castellucci, V.F., Hawkins, R.D. und Kandel, E.R.: Monosynaptic connections from the sensory neurons of the gill- and siphon-withdrawal reflex in *Aplysia* participate in the storage of long-term memory for sensitization. *Proc. Natl. Acad. Sci. USA* **82**: 8266-8269 (1985).
- Galizia, C.G., McIlwrath, S.L., Menzel, R.: A digital three-dimensional atlas of the honeybee antennal lobe based on optical sections acquired by confocal microscopy. *Cell Tissue Res.* **295**: 383-394 (1999).
- Ghirardi, M., Montarolo, P.G., Kandel, E.R.: A novel intermediate stage in the transition between short- and long-term facilitation in the sensory to motor neuron synapse of *aplysia*. *Neuron* **14**(2):413-420 (1995).

- Giurfa, M., Zhang, S., Jenett, A., Menzel, R., Srinivasan MV.: The concepts of 'sameness' and 'difference' in an insect. *Nature*. **410**: 930-933 (2001).
- Giurfa, M., Menzel, R.: Insect visual perception: complex abilities of simple nervous systems. *Curr Opin Neurobiol.* **7**: 505-513 (1997).
- Gonzalez, G.A., Montminy, M.R.: Cyclic AMP stimulates somatostatin gene transcription by phosphorylation of CREB at serine 133. *Cell*. **59**: 675-680 (1989).
- Gopalakrishna, R., Barsky, S.H., Thomas, T.P., Anderson, W.B.: Factors influencing chelator-stable, detergent-extractable, phorbol diester-induced membrane association of protein kinase C. Differences between Ca²⁺-induced and phorbol ester-stabilized membrane bindings of protein kinase C. *J Biol Chem*. **261**: 16438-45 (1986).
- Greggers, U. und Menzel, R.: Memory dynamics and foraging strategies of honeybees. *Behavioral Ecology and Sociobiology* **32**: 17-29 (1993)
- Gronenberg, W.: Anatomical and physiological properties of feedback neurons of the mushroom bodies in the bee brain. *Exp Biol*. **46**(3):115-125 (1987).
- Grünbaum, L.: Die Modulation der Aktivität der Proteinkinase C bei assoziativen olfaktorischen Lernprozessen der Honigbiene, *Apis mellifera*. *Inaugural Dissertation am Fachbereich Chemie, Freie Universität Berlin*, (1997).
- Grünbaum, L., Müller, U.: Induction of a specific olfactory memory leads to a long-lasting activation of protein kinase C in the antennal lobe of the honeybee. *J Neurosci*. **18**: 4384-4892 (1998).
- Guillemot, F., Billault, A., Auffray, C.: Physical linkage of a guanine nucleotide-binding protein-related gene to the chicken major histocompatibility complex. *Proc Natl Acad Sci USA*. **86**: 4594-4598 (1989).
- Hammer, M. und Menzel, R. Learning and memory in the honeybee. *J. Neurosci*. **15**: 1617-1630 (1995).
- Hammer, M., Braun, G. und Mauerlshagen, J.: Food induced arousal and nonassociative -learning in honeybees: dependence of sensitization on the application site and duration of food stimulation. *Behav. Neur. Biol.* **62**: 210-223 (1994).
- Hammer, M.: An identified neuron mediates the unconditioned stimulus in associative olfactory learning in honeybees. *Nature* **366**: 59-63 (1993).
- Han, P.-L., Levin, L.R., Reed, R.R. und Davis, R.L.: Preferential expression of the *Drosophila* rutabaga gene in mushroom bodies, neural centers for learning in insects. *Neuron* **9**: 619-627 (1992).

- Hähnlein, I., Bicker, G.: Morphology of neuroglia in the antennal lobes and mushroom bodies of the brain of the honeybee. *J Comp Neurol.* **367**: 235-45 (1996).
- Heisenberg, M., Borst, A., Wagner, S. und Byers, D.: *Drosophila* mushroom body mutants are deficient in olfactory learning. *J. Neurogenet.* **2**:1-30 (1985).
- Hildebrandt, H., Müller, U.: PKA activity in the antennal lobe of honeybees is regulated by chemosensory stimulation *in vivo*. *Brain Res.* **15**: 281-288 (1995).
- House, C., Kemp, B.E.: Protein kinase C contains a pseudosubstrate prototope in its regulatory domain. *Science.* **238**: 1726-1728 (1987).
- Huang, K.P.: The mechanism of protein kinase C activation. *Trends Neurosci.* **12**: 425-432 (1989).
- Izquierdo, I., Medina, J.H.: Correlation between the pharmacology of long-term potentiation and the pharmacology of memory. *Neurobiol Learn Mem.* **63**(1): 19-32 (1995).
- Johannes, F.J., Prestle, J., Eis, S., Oberhagemann, P., Pfizenmaier, K.: PKC α is a novel, atypical member of the protein kinase C family. *J Biol Chem.* **269**: 6140-6148 (1994).
- Kaang, B.K., Kandel, E.R. und Grant, S.G.: Activation of cAMP-responsive genes by stimuli that produce long-term facilitation in *Aplysia* sensory neurons. *Neuron* **10**: 427-435 (1993).
- Kandel, E.R., Schwartz, J.H.: Molecular biology of learning: modulation of transmitter release. *Science.* **218**: 433-443(1982).
- Kane, N.S., Robichon, A., Dickinson, J.A. und Greenspan, R.J.: Learning without performance in PKC-deficient *Drosophila*. *Neuron* **18**:1-8 (1997).
- Kishimoto, A., Kajikawa, N., Shiota, M. und Nishizuka, Y.: Proteolytic activation of calcium-activated, phospholipid-dependent protein kinase by calcium-dependent neutral protease. *J. Biol. Chem.* **258**: 1156-1164 (1983).
- Klauck, T.M., Faux, M.C., Labudda, K., Langeberg, L.K., Jaken, S., Scott, J.D.: Coordination of three signaling enzymes by AKAP79, a mammalian scaffold protein. *Science.* **271**: 1589-1592 (1996).
- Klein, M., Kandel, E.R.: Mechanism of calcium current modulation underlying pre-synaptic facilitation and behavioral sensitization in *Aplysia*. *Proc Natl Acad Sci USA.* **77**: 6912-6916 (1980).

- Lamprecht, R., Hazvi, S., Dudai, Y.: cAMP response element-binding protein in the amygdala is required for long- but not short-term conditioned taste aversion memory. *J Neurosci.* **17**: 8443-8450 (1997).
- Laemmli, U.K.: Cleavage of structural proteins during assembly of the head of the bacteriophage T4. *Nature* **227**: 680-685 (1970)
- Le Panse, R., Mitev, V., Lebreton, C., Coulomb, B.: Modulation of epidermal growth factor and keratinocyte growth factor effects on human keratinocyte growth by protein kinase C inhibitor, GF 109203X: comparison to fibroblast growth modulation. *Biochem Biophys Res Commun.* **204**:1081-1087 (1994).
- Levin, L.R., Han, P.-L., Huang, P.M., Feinstein, P.G., Davis, R.L. und Reed, R.R.: The *Drosophila* learning and memory gene *rutabaga* encodes a Ca^{2+} / calmodulin-responsive adenylyl cyclase. *Cell* **68**: 479-489 (1992).
- Li, M., West, J.W., Numann, R., Murphy, B.J., Scheuer, T. und Catterall, W.A.: Convergent regulation of sodium channels by protein kinase C and cAMP-dependent protein kinase. *Science* **261**: 1439-1442 (1993).
- Ling, D.S., Benardo, L.S., Serrano, P.A., Blace, N., Kelly, M.T., Crary, J.F., Sacktor, T.C.: Protein kinase Mzeta is necessary and sufficient for LTP maintenance. *Nat Neurosci.* **5**: 295-296 (2002).
- Malinow, R., Schulman, H. und Tsien, R.W.: Inhibition of postsynaptic PKC or CaMK II blocks induction but not expression of LTP. *Science* **245**: 862-866 (1989).
- Manseau, F., Sossin, W.S., Castellucci, V.F.: Long-term changes in excitability induced by protein kinase C activation in *Aplysia* sensory neurons. *J Neurophysiol.* **79**: 1210-1218 (1998).
- Martin, S.J., Grimwood, P.D., Morris, R.G.: Synaptic plasticity and memory: an evaluation of the hypothesis. *Annu Rev Neurosci.* **23**: 649-711 (2000).
- Mathis, C., Lehmann, J. und Ungerer, A.: The selective protein kinase C inhibitor, NPC 15437, induces specific deficits in memory retention in mice. *Eur. J. Pharmacol.* **220**:107-110--“(1992).
- Menzel, R.: Gedächtnis der Honigbiene für Spektralfarben, Kurzzeitiges und Langzeitiges Behalten. *Zeitschrift für vergleichende Physiologie* **60**: 82-102 (1968).
- Menzel, R.: Learning, memory and “cognition“ in honey bees. In: *Neurobiology of Comparative Cognition*: 237-292. R.P. Kesner und D.S. Olten (Hrsg.), New York: Hillsdale (1990).

- Menzel, R., Erber, J. und Masuhr, T.: Learning and memory in the honeybee. *Experimental analysis of insect behaviour*. 195-217. L. Barton-Browne (Hrsg.), Berlin: Springer (1974).
- Menzel, R. und Bitterman, M. E.: Learning by honeybees in an unnatural situation. In: Huber, F. und Markel, H. (eds.): *Behavioral physiology and neuro-ethology: roots and growing points*. Berlin Springer: 206-215 (1983).
- Menzel, R., Hammer, M., Braun, G., Mauelshagen, J. und Sugawa, M.: Neurobiology of learning and memory in honeybees. In: The behaviour and physiology of bees: 323-353. L.J. Goodman und R.C. Fisher (Hrsg.), Wallingford, UK: CAB (1991).
- Menzel, R., Müller, U.: Learning and memory in honeybees: from behavior to neural substrates. *Annu Rev Neurosci*. **19**: 379-404 (1996).
- Menzel, R., Heyne, A., Kinzel, C., Gerber, B., Fiala, A.: Pharmacological dissociation between the reinforcing, sensitizing, and response-releasing functions of reward in honeybee classical conditioning. *Behav Neurosci*. **113**: 744-754 (1999).
- Menzel, R., Brandt, R., Gumbert, A., Komischke, B., Kunze, J.: Two spatial memories for honeybee navigation. *Proc R Soc Lond B Biol Sci*. **22**: 961-968 (2000).
- Mobbs, P.G.: Brain structure. In: *Comprehensive Insect Physiology' Pharmacology and Biochemistry* **5**: 299-370. G.Kerkut und L.I. Gilbert (Hrsg.), Oxford, UK: Pergamon (1985).
- Mochly-Rosen, D.: Localization of protein kinases by anchoring proteins: a theme in signal transduction. *Science*. **14**: 247-251 (1995).
- Mochly-Rosen, D., Henrich, C.J., Cheever, L., Khaner, H., Simpson, P.C.: A protein kinase C isozyme is translocated to cytoskeletal elements on activation. *Cell Regul*. **1**: 693-706 (1990).
- Mochly-Rosen, D., Khaner, H. und Lopez, J.: Identification of intracellular receptor proteins for activated protein kinase C. *Proc. Natl. Acad. Sci. USA* **88**: 3997-4000 (1991).
- Mochly-Rosen, D., Smith, B.L., Chen, C.H., Disatnik, M.H., Ron, D.: Interaction of protein kinase C with RACK1, a receptor for activated C-kinase: a role in beta protein kinase C mediated signal transduction. *Biochem Soc Trans*. **23**: 596-600 (1995)
- Mochly-Rosen, D., Gordon, A.S.: Anchoring proteins for protein kinase C: a means for isozyme selectivity. *FASEB J*. **12**(1): 35-42 (1998).

- Müller, U.: Inhibition of nitric oxide synthase impairs a distinct form of long-term memory in the honeybee, *Apis mellifera*. *Neuron* **16**: 541-549 (1996).
- Müller, U.: Insect 86 kDa protein kinase C substrate is a filament interacting protein regulated by Ca²⁺/calmodulin and phosphorylation. *Brain Res.* **16** :24-30 (1997).
- Müller, U.: Prolonged activation of cAMP-dependent protein kinase during conditioning induces long-term memory in honeybees. *Neuron.* **27**: 159-68 (2000).
- Müller, U. und Hildebrandt, H.: The nitric oxide/cGMP system in the antennal lobe of *Apis mellifera* is implicated in integrative processing of chemosensory stimuli. *Eur. J. Neurosci.* **7**: 2240-2248 (1995).
- Newton, A.C.: Protein kinase C: ports of anchor in the cell. *Curr Biol.* **6**: 806-809 (1996).
- Nguyen, P.V., Abel, T. und Kandel, E.R.: Requirement for a critical period of transcription for a late phase of LTP. *Science* **265**: 1104-1107 (1994).
- Nighorn, A., Healy, M.J. und Davis R.L.: The cyclic AMP phosphodiesterase encoded by the *Drosophila* dunce gene is concentrated in the mushroom body neuropil. *Neuron* **6**: 455-467 (1991).
- Nishizuka, Y.: Studies and perspectives of protein kinase C. *Science.* **18**: 305-312. (1986)
- Nishizuka, Y.: Protein kinase C and lipid signaling for sustained cellular responses. *FASEB J.* **9**: 484-496 (1995).
- Nishizuka, Y.: Intracellular signaling by hydrolysis of phospholipids and activation of protein kinase C. *Science.* **258**: 607-614 (1992).
- Papadopoulos, V., Hall, P.F.: Isolation and characterization of protein kinase C from Y-1 adrenal cell cytoskeleton. *J Cell Biol.* **108**: 553-567 (1989).
- Paratcha, G., Furman, M., Bevilaqua, L., Cammarota, M., Vianna, M., de Stein, M.L., Izquierdo, I., Medina, J.H.: Involvement of hippocampal PKC β isoform in the early phase of memory formation of an inhibitory avoidance learning. *Brain Res.* **855**: 199-205 (2000).
- Pavlov, I.P.: 1927 "Conditioned Reflexes" London Hrsg.: Oxford University Press.

- Pawson, T., Scott, J.D.: Signaling through scaffold, anchoring, and adaptor proteins. *Science*. **19**: 2075-2080 (1997).
- Perez, J.L., Khatri, L., Chang, C., Srivastava, S., Osten, P., Ziff, E.B.: PICK1 targets activated protein kinase Calpha to AMPA receptor clusters in spines of hippocampal neurons and reduces surface levels of the AMPA-type glutamate receptor subunit 2. *J Neurosci*. **21**: 5417-5428 (2001) .
- Pinsker, H., Kupfermann, I., Castellucci, V., Kandel, E.: Habituation and dishabituation of the gill-withdrawal reflex in *Aplysia*. *Science* **167**: 1740-1742 (1970).
- Powell, C.M., Johnston, D., und Sweatt, J.D.: Autonomously active protein kinase C in the maintenance phase of N-methyl-D-aspartate receptor-independent long term potentiation. *J. Biol. Chem.* **269**: 27958-27963 (1994).
- Prekeris, R., Mayhew, M.W., Cooper, J.B., Terrian, D.M.: localization of an actin-binding motif that is unique to the epsilon isoform of protein kinase C and participates in the regulation of synaptic function. *J Cell Biol.* **132**: 77-90 (1996).
- Quinn, W.G., Harris, W.A., Benzer, S.: Conditioned behavior in *Drosophila melanogaster*. *Proc Natl Acad Sci USA* **71**(3):708-712 (1974).
- Quinn, W.G., Sziber, P.P., Booker, R.: The *Drosophila* memory mutant amnesiac. *Nature*. **277**: 212-214 (1979).
- Ramakers, G.M., Pasinelli, P., Hens, J.J., Gispen, W.H., De Graan, P.N.: Protein kinase C in synaptic plasticity: changes in the in situ phosphorylation state of identified pre- and postsynaptic substrates. *Prog Neuropsychopharmacol Biol Psychiatry*. **21**: 455-486 (1997).
- Rehder, V.: Sensory pathways and motoneurons of the proboscis reflex in the suboesophageal ganglion of the honey bee. *J. Comp. Neurol.* **279**: 499-5 13 (1989).
- Reymann, K.G., Frey, U., Jork, R., Matthies, H.: Polymyxin B, an inhibitor of protein kinase C, prevents the maintenance of synaptic long-term potentiation in hippocampal CA1 neurons. *Brain Res.* **440**: 305-314 (1988).
- Roberson, E.D., English, J.D. und Sweatt, J.D.: A biochemist's view of long-term potentiation. *Learn. Mem.* **3**:1-24 (1996).
- Roisin, M., Leinekugel, X. und Iremblay, E.: Implication of protein kinase C in mechanisms of potassium-induced long-term potentiation in rat hippocampal slices. *Brain Res.* **745**: 222-230 (1997).

- Ron, D., Luo, J., Mochly-Rosen, D.: C2 region-derived peptides inhibit translocation and function of beta protein kinase C in vivo. *J Biol Chem.* **270**: 24180-24187 (1995).
- Ron, D., Jiang, Z., Yao, L., Vagts, A., Diamond, I., Gordon, A.: Coordinated movement of RACK1 with activated betaIIIPKC. *J Biol Chem.* **274**: 27039-27046 (1999).
- Rybak, J. und Menzel, R.: Anatomy of the mushroom bodies in the honey bee brain: the neuronal connections of the alpha-lobe. *J. Comp. Neurol.* **334**: 444-465 (1993).
- Sacchetti, B., Bielavska, E.: Chelerythrine, a specific PKC inhibitor, blocks acquisition but not consolidation and retrieval of conditioned taste aversion in rat. *Brain Res.* **799**: 84-90 (1998).
- Sacktor, T.C., Osten, P., Valsamis, H., Jiang, X., Naik, M.U. und Sublette, E.: Persistent activation of the ζ isoform of protein kinase C in the maintenance of long-term potentiation. *Proc. Natl. Acad. Sci. USA* **90**: 8342-8346 (1993).
- Schaeffer, E., Smith, D., Mardon, G., Quinn, W., Zuker, C.: Isolation and characterization of two new *Drosophila* protein kinase C genes including one specifically expressed in photoreceptor cells. *Cell* **57**: 403-412 (1989).
- Serrano, P.A., Rodriguez, W.A., Pope, B., Bennett, E.L., Rosenzweig, M.R.: Protein kinase C inhibitor chelerythrine disrupts memory formation in chicks. *Behav Neurosci.* **109**: 278-284 (1995).
- Serrano, P.A., Beniston, D.S, Oxonian, M.G., Rodriguez, W.A., Rosenzweig, M.R., Bennett, E.L.: Differential effects of protein kinase inhibitors and activators on memory formation in the 2-day-old chick. *Behav Neural Biol.* **61**: 60-72 (1994).
- Sessoms, J.S., Chen, S.J., Chetkovich, D.M., Powell, C.M., Roberson, E.D., Sweatt, J.D., Klann, E.: Ca(2+)-induced persistent protein kinase C activation in rat hippocampal homogenates. *Second Messengers Phosphoproteins*.**14**: 109-126 (1992-93).
- Sheng, M., McFadden, G., Greenberg, M.E.: Membrane depolarization and calcium induce c-fos transcription via phosphorylation of transcription factor CREB. *Neuron.* **4**: 571-582 (1990).

- Sheng, M., Thompson, M.A., Greenberg, M.E.: CREB: a Ca(2+)-regulated transcription factor phosphorylated by calmodulin-dependent kinases. *Science*. **252**: 1427-1430 (1991).
- Shieh, B.H., Niemeyer, B.: A novel protein encoded by the InaD gene regulates recovery of visual transduction in *Drosophila*. *Neuron*. **14**: 201-210 (1995).
- Shoji, M., Girard, P.R., Mazzei, G.J., Vogler, W.R., Kuo, J.F.: Immunocytochemical evidence for phorbol ester-induced protein kinase C translocation in HL60 cells. *Biochem Biophys Res Commun*. **135**: 1144-1149 (1986).
- Siegelbaum, S.A., Camardo, J.S. und Kandel, E.R.: Serotonin and cyclic AMP close single K⁺ channels in *Aplysia* sensory neurons. *Nature* **299**: 413-417 (1982).
- Silva, A.J., Stevens, C.F., Tonegawa, S. und Wang, Y.: Deficient hippocampal long-term potentiation in calcium-calmodulin kinase II mutant mice. *Science* **257**: 201-206 (1992).
- Sossin, W.S., Sacktor, T.C., Schwartz, J.H.: Persistent activation of protein kinase C during the development of long-term facilitation in *Aplysia*. *Learn Mem*. **1**: 189-202 (1994).
- Squire, L.R.: Memory and brain. New York/ Oxford: Oxford University Press (1987).
- Staudinger, J., Zhou, J., Burgess, R., Elledge, S.J., Olson, E.N.: PICK1: a perinuclear binding protein and substrate for protein kinase C isolated by the yeast two-hybrid system. *J Cell Biol*. **128**: 263-271 (1995).
- Stebbins, E.G., Mochly-Rosen, D.: Binding specificity for RACK1 resides in the V5 region of beta II protein kinase C. *J Biol Chem*. **276**:29644-29650 (2001).
- Stemmelin, J., Mathis, C., Ungerer, A.: GF 109203X, a selective inhibitor of protein kinase C, impairs retention performance in an operant task. *Neuroreport*. **10**: 2805-2809 (1999).
- Stevens, C.F.: A million dollar question: does LTP = memory? *Neuron*. **20**: 1-2 (1998).
- Sun, Z., Sassone-Corsi, P., Means, A.R.: Calspermin gene transcription is regulated by two cyclic AMP response elements contained in an alternative promoter in the calmodulin kinase IV gene. *Mol Cell Biol*. **15**: 561-71 (1995).

- Sweatt, J.D.: Toward a molecular explanation for long-term potentiation. *Learn Mem.* **6**:399-416 (1999).
- Takeda, K.: Classical conditioned response in the honey bee. *J. Insect Physiol.* **6**: 168-179 (1961)
- Tempel, B.L., Bonini, N., Dawson, D.R., Quinn, W.G.: Reward learning in normal and mutant *Drosophila*. *Proc Natl Acad Sci USA.* **80**: 1482-1486 (1983).
- Toullec, D., Pianetti, P., Coste, H., Bellevergue, P., Grand-Perret, T., Ajakane, M., Baudet, V., Boissin, P., Boursier, E., Loriolle, F.: The bisindolylmaleimide GF 109203X is a potent and selective inhibitor of protein kinase C. *J Biol Chem.* **266**: 15771-15781 (1991).
- Tsunoda, S., Sierralta, J., Sun, Y., Bodner, R., Suzuki, E., Becker, A., Socolich, M., Zuker, C.S.: A multivalent PDZ-domain protein assembles signalling complexes in a G-protein-coupled cascade. *Nature.* **388**: 243-249 (1997).
- Tully, T.: Induction of a dominant-negative CREB transgene specifically blocks long-term memory in *Drosophila*. *Cell* **79**: 49-58 (1994).
- Van der Zee, E.A., Luiten, P.G., Disterhoft, J.F.: Learning-induced alterations in hippocampal PKC-immunoreactivity: a review and hypothesis of its functional significance. *Prog Neuropsychopharmacol Biol Psychiatry.* **21**:531-572 (1997).
- Van der Zee, E.A., Douma, B.R.: Historical review of research on protein kinase C in learning and memory. *Prog Neuropsychopharmacol Biol Psychiatry.* **21**: 379-406 (1997).
- Vianna, M.R., Barros, D.M., Silva, T., Choi, H., Madche, C., Rodrigues, C., Medina, J.H., Izquierdo, I.: Pharmacological demonstration of the differential involvement of protein kinase C isoforms in short- and long-term memory formation and retrieval of one-trial avoidance in rats. *Psychopharmacology (Berl).* **150**: 77-84 (2000).
- Weeber, E.J., Atkins, C.M., Selcher, J.C., Varga, A.W., Mirnikjoo, B., Paylor, R., Leitges, M., Sweatt, J.D.: A role for the beta isoform of protein kinase C in fear conditioning. *J Neurosci.* **20**: 5906-5914 (2000).
- Wolf, M., LeVine, H. 3rd, May, W.S. Jr, Cuatrecasas, P., Sahyoun, N.: A model for intracellular translocation of protein kinase C involving synergism between Ca²⁺ and phorbol esters. *Nature.* **317**: 546-549 (1985).
- Wüstenberg, D., Gerber, B., Menzel, R.: Short communication: long- but not medium-term retention of olfactory memories in honeybees is impaired by actinomycin D and anisomycin. *Eur J Neurosci.* **10**: 2742-2745 (1998).
- Yamamoto, K.K., Gonzalez, G.A., Biggs, W.H. 3rd, Montminy MR.: Phosphorylation-induced binding and transcriptional efficacy of nuclear factor CREB. *Nature.* **334**: 494-498 (1988).

Yin, J.C.P., Del Vecchio, M., Zhou, H. und Tully, T.: CREB as a memory modulator: Induced expression of a dCREB2 isoform enhances long-term memory in *Drosophila*. *Cell* **81**: 107-115 (1995).

Yin, J.C.P., Wallach, J.S., Del Vecchio M., Wilder, E.L., Zhou, H., Quinn, W.G. und Tully, T.: Induction of a dominant-negative CREB transgene specifically blocks long-term memory in *Drosophila*. *Cell* **79**: 49-58 (1994).

Liste der verwendeten Abkürzungen

AL	Antennalloben
ATP	3'5' Adenosintriphosphat
C	katalytische Domäne der PKC
CaMK	Ca ²⁺ -Calmodulin-abhängige Proteinkinase
cAMP	zyklisches 3'5' Adenosinmonophosphat
CREB	cAMP Responsive Element Binding Protein
CS	konditionierter Stimulus
DAG	Diacylglycerol
EGTA	Ethylen-bis(oxyethylen-nitrilo)-tetraessigsäure
ELISA	Enzymgebundener Immunoassay (enzyme linked sorbent assay)
G-Protein	GTP bindendes Protein
LTM	Langzeitgedächtnis (long term memory)
LTP	Langzeitpotenzierung
MARCKS	Myrotiliertes Alanin Reiches C-Kinase Substrat
NMDA	N-Methyl-D-Aspartat
MTM	Mittelzeitgedächtnis (medium-term-memory)
NO	Stickstoffmonoxyd
PBS	phosphatgepufferte Salzlösung (phosphate buffered saline)
PER	Proboscis Extension Response
PK	Pilzkörper
PKA	Protein Kinase A
PKC	Protein Kinase C
PKM	Katalytische Domäne der PKC
PS	Phosphatidylserin
R	regulatorische Domäne der PKC
RACK	Rezeptor für aktivierte C-Kinase (receptor for activated C-kinase)
SDS	Natriumlaurylsulfat (sodium dodecyl sulfate)
S.E.	Standard Error
STM	Kurzzeitgedächtnis (short term memory)
US	unkonditionierter Stimulus

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Thomas, U. und Müller, U. (2000): Protein Kinase C in the mushroom bodies of *Apis mellifera* and its function in memory formation. *European Journal of Neuroscience* Vol. 12, Supplement 11. 046.12. S. 93 (2000)

Thomas, U. und Müller, U.: Learning-induced changes of PKC and its function in the formation of long-term memory in the mushroom bodies of *Apis mellifera*. *Göttingen Neurobiology Report*. S. 657 (2001).

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