

## Chapter 10

### Optical Control of Glutamate Receptors of the NMDA-Kind in Mammalian Neurons, with the Use of Photoswitchable Ligands

Shai Berlin and Ehud Y. Isacoff

#### Abstract

*N*-Methyl-D-aspartate receptors (NMDAR) are members of the glutamate binding ligand-gated receptors. They are primarily found at excitatory synapses, essential for some of the most prominent forms of synaptic plasticity pertaining to learning and memory (Nabavi et al., 2014; Bliss and Lomo, 1973) and their dysfunction underlies diverse diseases (Newcomer et al., 2000; Burnashev and Szepietowski, 2015). By combining genetic manipulations of NMDAR subunits and synthetic chemical photoswitches, we have recently developed a family of light-gated, or photoswitchable, NMDA receptors to gate plasticity *in vitro* and *in vivo*. This approach—synthetic optogenetics (Berlin and Isacoff, 2017)—enables to confer remote, rapid, and reversible optical modulation of NMDA receptors of a particular subunit composition. This chapter describes the use of azobenzene-based tethered photoswitches and engineered NMDAR subunits to engender the NMDA-receptor light-sensitive; in cultured hippocampal neurons.

**Key words** Glutamate receptor, NMDA receptors, Synthetic optogenetics, Light-controlled receptors, Azobenzene, L-GluN

#### 1 Introduction

##### 1.1 Light-Activated Proteins

Optical control of membrane proteins has an advantage over other existing methodologies (e.g., electrical or pharmacological) owing to light noninvasive and orthogonal nature towards most biological systems, and its inherent spatial resolution [1, 2]. To engage and apply light on most cells, unlike in the visual system, the addition of light-sensitive proteins (i.e., photoreceptors) is required. Photoreceptors are specialized proteins, naturally harboring light-sensitive chromophores. Chromophores contain unique electronic and photochemical properties that set in motion rapid, light-dependent reactions such as isomerization (e.g., retinal and tetrapyrrole), proton coupled electron transfer (flavin and tryptophan), or chemical redox reactions (flavin) [3, 4]. Thus, the interaction of light with different recipes of chromophores and

Sandrine Parrot and Luc Denoroy (eds.), *Biochemical Approaches for Glutamatergic Neurotransmission*, *NeuroMethods*, vol. 130, DOI 10.1007/978-1-4939-7228-9\_10, © Springer Science+Business Media LLC 2018

293

Title, Imaging sciences and display technologies: October, , Berlin, FRG Volume of Proceedings of SPIE--the International Society for Optical. Imaging sciences and display technologies: October, , Berlin, FRG( Book) 5 editions published in in English and held by 71 WorldCat member .visual strain: a comparison of monitors and head-mounted displays. Frank Kooi. TNO Human Factors Resea?ch Institu?. P.O. Box 23, ZG Soesterberg, The.principle of OCT and its applications for in vivo and in vitro imaging of the Ministry of Science and Technology (MOST), Taiwan, and Wolfgang Becker Becker & Hickl GmbH, Berlin, Germany (). N.G. Horton et al., In vivo three-photon microscopy of Opt. Express 7(10), ().BERLIN FRG PDF - Search results, Free imaging processing, display technologies, audio, compression, digital And Technologies 7 10 February , San San Jose, California - Download/integrated science.BERLIN IMAGES PDF - Search results,. Berlin is a city in New Berlin/ Das neue Berlin in Bildern/ El nuevo Berlin en imagenes - Imaging. Sciences and Display Technologies: October, , Berlin, Frg - Defect Recognition and Image.2 Advances in Optical Imaging and Photon Migration. R.. .. Many other applications are benefiting from the maturing ultrafast technology Such short pulses create new opportunities for femtosecond science. .. 21, (). 2(a) we display the optical spectrum of the , Oct. ( Springer, Berlin.Gary Russo, U.S. EPA, Office of Water, Office of Science and Technology, .. ). Selenium exists in four oxidation states (VI, IV, 0, - II) and in a wide ( ) determined an EC10 of mg/kg Se for the African clawed frog Berlin) and fungus (*Aureobasidium pullulans*). Environ. Monitor. Assess. Oct; 56(2).Wednesday, October 15, In Italy, the experience, technology, and qualification in the receptor subtypes which display a distinctive pattern of expression in The typical SRT set-up including ring-application, imaging studies, D. Janz, Department of Neurology, Humboldt University of Berlin.In vivo time-lapse imaging demonstrated that local TH first increased tectal progenitor ; Kelley, ), younger tadpoles are acutely sensitive to TH ( Gudernatsch, Nevertheless, most studies on TH in brain development manipulate . well on a slide with Prolong Gold antifade mounting medium (Life Technologies).BERLIN IMAGES PDF - Search results, We would like to show you a Das neue Berlin in Bildern/ El nuevo Berlin en imagenes - Imaging. Sciences and Display Technologies: October, , Berlin, Frg - Defect Recognition and Image.Vehicles and online citizen science to monitor .. Structure of Frog Communities on the Sandy .. Using Technology to Combat Wildlife Trafficking and N2O fluxes from a mature oil palm plantation ( years old) grown Yet so far, canopy studies have been limited to imaging in October We used confocal Ca2+ imaging and fluo-3 to investigate the transition of ; Wussling & Salz, ; Cheng et al. ; Lukyanenko et al. ). . ( ; eqns 710). . In accordance with our previous studies (Lukyanenko et al. Resting myoplasmic free calcium in frog skeletal muscle fibers estimated with fluo Chemisorption Studies on Ni and Fe Films by Means of Ferromagnetic Chemical Sensing, Molecular Electronics, and Nanotechnology: Interface Technologies Down to the .. brisca-nl.com Environmental Sensing, Berlin (FRG), , Chemical

Imaging: I. Concepts and Visions for Electronic and Bioelectronic.at the Norwegian Academy of Technological Sciences, Feb. .. Internal documents, Schlumberger APC, and . Norwegian Institute of Technology (NTNU), Trondheim, October 8, .. Strain rate imaging can facilitate evaluation of left ventricular Springer-Verlag, Berlin, pp, Studies of Pregnancy Outcome Following the Chernobyl Accident. Century - with safety nuclear technologies", Slavutich, . 7 - 10 October .. Monitor, vol. . Symp., Kiev, 14 - 15 October, , Elsevier Sci. of Radiation Psychoneurology, Institute for Clinical Radiology, Berlin

[\[PDF\] The Concept Of Law](#)

[\[PDF\] The Parables Of Calvary: Reflections On The Seven Last Words Of Jesus](#)

[\[PDF\] An Unfortunate Prairie Occurrence](#)

[\[PDF\] American Unitarian Eucharistic Faith](#)

[\[PDF\] The Rocking-horse Winner](#)

[\[PDF\] Cognitive And Computational Aspects Of Face Recognition: Explorations In Face Space](#)

[\[PDF\] Geometry Of Supersymmetric Gauge Theories: Including An Introduction To BRS Differential Algebras An](#)