Published in final edited form as:

Sci Signal. ; 3(147): tr5. doi:10.1126/scisignal.3147tr5.

Visualizing Calcium Signaling in Astrocytes

R. Douglas Fields

National Institute of Child Health and Human Development, National Institutes of Health, Building 35, Room 2A211, MSC3713, Bethesda, MD 20892, USA

R. Douglas Fields: fieldsd@mail.nih.gov

Abstract

Astrocytes are nonneuronal cells in the brain (glia) that do not generate electrical impulses but communicate by chemical signaling. This communication can be observed under a microscope with fluorescent calcium indicators that glow more brightly when the concentration of calcium increases inside the cell. Astrocytes release adenosine 5′-triphosphate and other cell signaling molecules that excite membrane receptors on other astrocytes to cause an increase in intracellular calcium in the recipient cell. Many of the substances released by astrocytes also excite neurons, and astrocytes have on their own cell membrane many of the same neurotransmitter receptors used by neurons to communicate across synapses. This allows astrocytes to respond to neural impulse activity, communicate among other astrocytes, and influence neuronal communication by taking up or releasing neurotransmitters from synapses.

Keywords

neuron-glia interactions; calcium wave; glial cell; imaging; movie

Description

This set of movies shows calcium signaling in cultured astrocytes from the cerebral cortex of rats. These movies are intended as educational tools that may be useful in a neuroscience course or in a course focused on imaging techniques or lectures about cellular communication, calcium signaling, or the roles of glia.

Movies 1 and 2 are high-magnification and low-magnification views of astrocytes from the cerebral cortex of rats communicating spontaneously by calcium signaling in cell culture. Although astrocytes do not generate electrical impulses, as nerves do, they communicate with other glial cells and nerves by chemical signaling (1, 2). Both movies are time-lapse recordings acquired by confocal microscopy of experiments lasting approximately 20 min. Still images from each are shown as Figs. 1 and 2. The cells contain calcium indicators that

Educational Details

Learning Resource Type: *Video*
Context: *Undergraduate upper division, graduate, professional (degree program)*
Intended Users: *Teacher, learner*
Intended Educational Use: *Learn, research, teach*
Discipline: *Neuroscience*

allow changes in intracellular calcium concentration to be visualized as increases in brightness. Movie 1 is a high-magnification video showing that calcium is released from internal stores and also enters the cytoplasm through calcium-permeable channels in the cell membrane, and that inter- and intracellular calcium waves are evident during cell signaling in astrocytes. Movie 2 shows a low-magnification video of spontaneous signaling among astrocytes and the response to adding the neurotransmitter glutamate. In this video, glutamate activates membrane receptors that cause an increase in intracellular calcium concentration (visible as a brief flash among all cells in the field), followed by increased signaling activity among astrocytes. Waves of calcium are seen sweeping through long, slender cellular processes.

The time-lapse video in Movie 3 shows spontaneous signaling among astrocytes in coculture with dorsal root ganglion (DRG) neurons and the response of astrocytes to electrical impulses firing in DRG axons (see Fig. 3 for a still image). Axons firing electrical impulses release adenosine 5′-triphosphate (ATP) in part by a nonsynaptic and nonvesicular mechanism involving stretch-activated channels (volume-activated anion channels) (1). Calcium increases when the axons fire electrical impulses (action potentials). Action potentials cause the axons to swell, activating volume-activated anion channels that release ATP and other small molecules. The ATP stimulates purinergic receptors on astrocytes, causing an increase in intracellular calcium and stimulating the release of substances from astrocytes that stimulate calcium responses in nearby astrocytes. This signaling between axons and astrocytes can be disrupted by electrical stimulation in the presence of compounds that block the ATP-permeable volume-activated anion channels in the axon membrane. Astrocytes near synapses can also respond to neurotransmitters released by neurons at synapses (although there are no synapses in this preparation). This activates neurotransmitter receptors on astrocytes, causing a rise in intracellular calcium concentration. The time-lapse movie compresses observations of approximately 15 min.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Fields RD, Ni Y. Nonsynaptic communication through ATP release from volume-activated anion channels in axons. Sci Signal. 2010; 3:ra73. [PubMed: 20923934]
2. Fields RD, Stevens-Graham B. New insights into neuron-glia communication. Science. 2002; 298:556–562. [PubMed: 12386325]

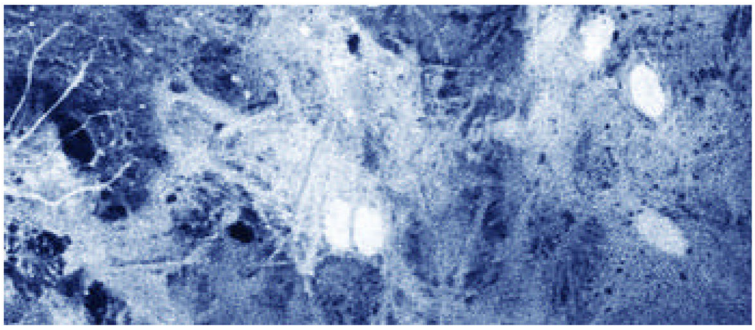

Fig. 1.

High-magnification image of astrocytes communicating by calcium signaling. This still image is from Movie 1 (http://stke.sciencemag.org/cgi/content/full/3/147/tr5/DC1). Brig ht cells have a higher concentration of intracellular calcium. Brig ht ovals are nuclei.

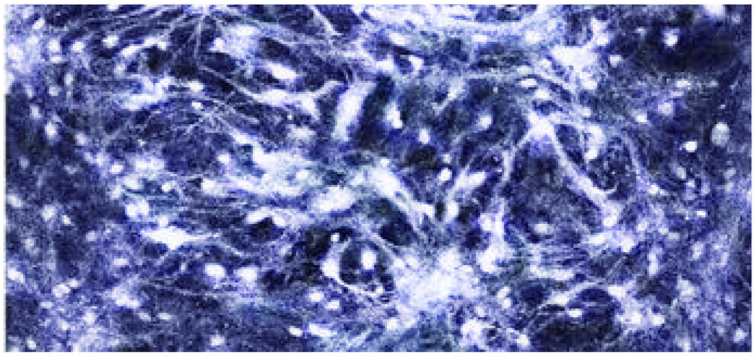

Fig. 2.

Low-magnification image of astrocytes communicating by calcium signaling. This still image is from Movie 2 (http://stke.sciencemag.org/cgi/content/full/3/147/tr5/DC1). Brig ht cells have a higher concentration of intracellular calcium. Brig ht ovals are nuclei.

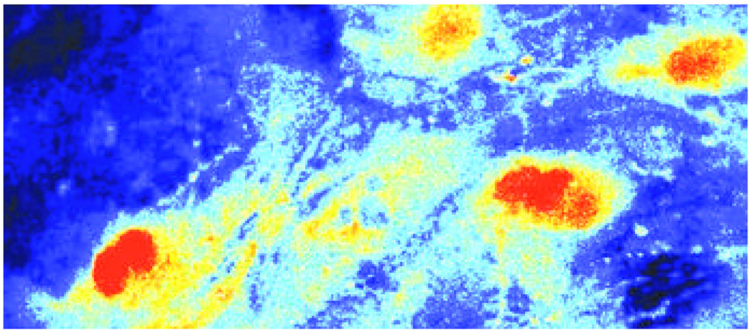

Fig. 3.

High-magnification image of calcium signaling in a coculture containing astrocytes and neurons from Movie 3 (http://stke.sciencemag.org/cgi/content/full/3/147/tr5/DC1). Brighter fluorescence, indicative of calcium signaling, is color-coded into warmer colors.