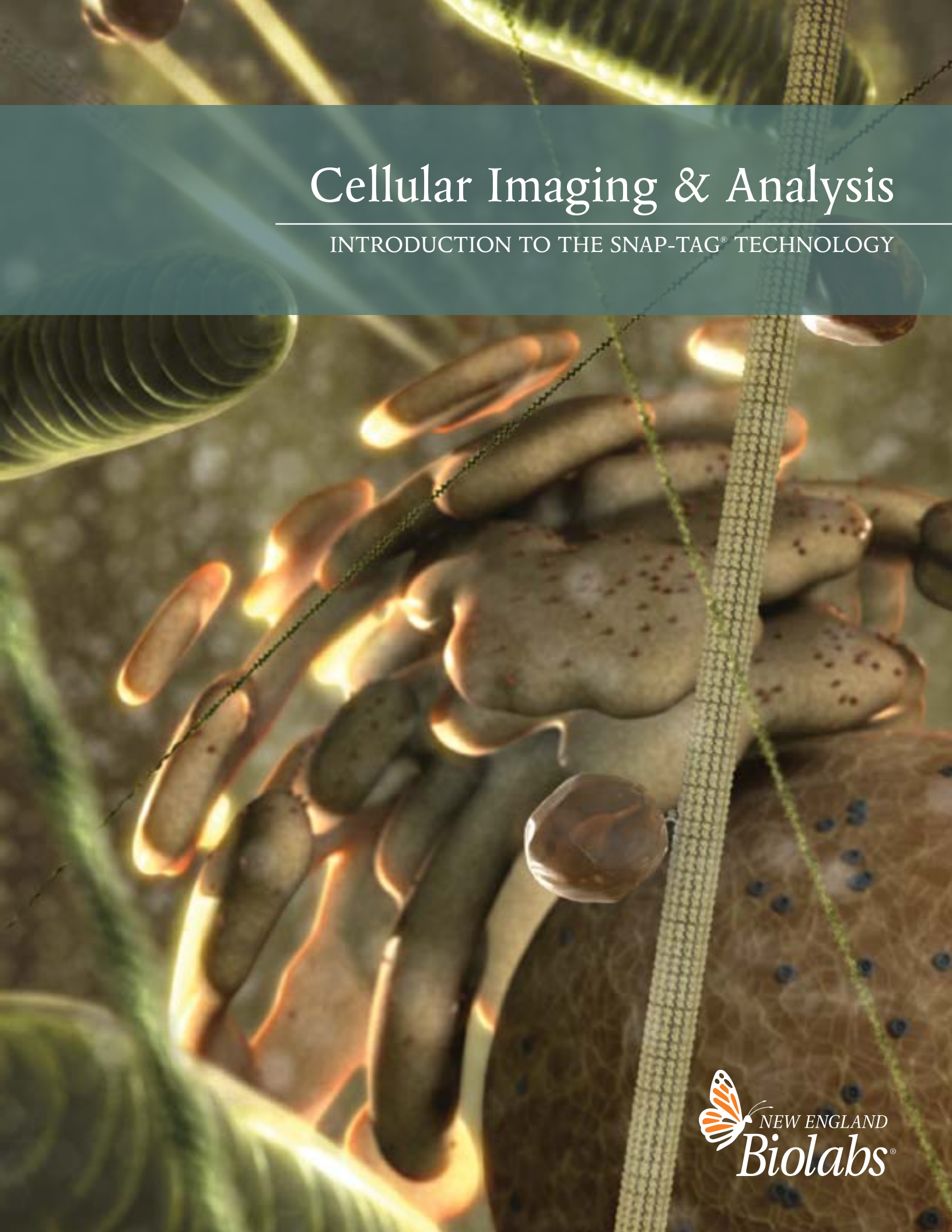
Cellular Imaging & Analysis

INTRODUCTION TO THE SNAP-TAG® TECHNOLOGY



NEW ENGLAND Biolabs®

Self-Labeling Tag Technology

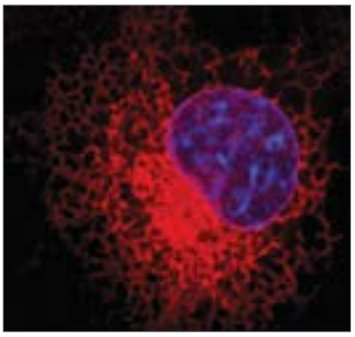
New England Biolabs offers an innovative technology for studying the function and localization of proteins in living and fixed cells. Covalent protein labeling offers simplicity and versatility to the imaging of mammalian proteins in live cells, as well as the ability to capture proteins *in vitro*. A single genetic construct generates a fusion protein which, when covalently attached to a variety of labels such as fluorophores, biotin or beads, provides a powerful tool for studying protein dynamics. In this system the protein is labeled by a self-labeling fusion protein; SNAP-tag® or CLIP-tag®.

ADVANTAGES

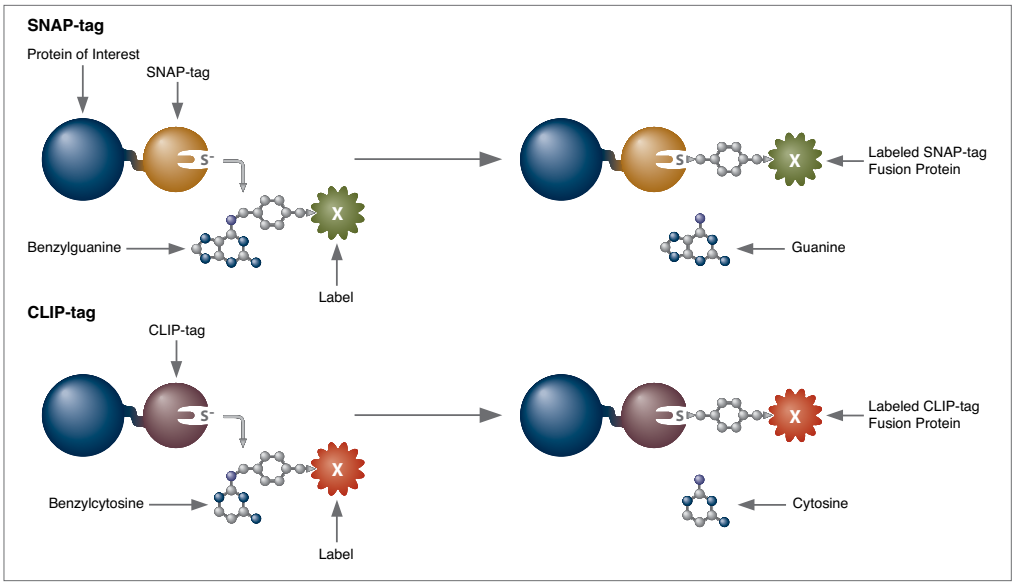
- **Flexible** - Clone and express once, then use with a variety of fluorescent or nonfluorescent substrates
- **Fast** - Easy-to-use protocols
- **Specific** - Very low background staining
- **Precise** - Label is covalently bound under biological conditions in a defined position
- **Non-toxic** - Substrates are non-toxic to living cells
- **Direct covalent labeling** - No antibodies, leaching or drift
- **Selection** - Choose from a broad selection of commercial substrates, optimized for a range of imaging instrumentation

SNAP-tag and CLIP-tag

The SNAP- and CLIP-tag protein labeling systems enable the specific, covalent attachment of virtually any molecule to a protein of interest. There are two steps to using this system: cloning and expression of the protein of interest as a SNAP-tag fusion, and labeling of the fusion with the SNAP-tag substrate of choice. The SNAP-tag is a small protein based on human O^6-alkylguanine-DNA-alkyltransferase (hAGT), a DNA repair protein. SNAP-tag substrates are fluorophores, biotin, or beads conjugated to guanine or chloropyrimidine leaving groups via a benzyl linker. In the labeling reaction, the substituted benzyl group of the substrate is covalently attached to the SNAP-tag. CLIP-tag is a modified version of SNAP-tag, engineered to react with benzylcytosine rather than benzylguanine derivatives. When used along with SNAP-tag, CLIP-tag enables the orthogonal and complementary labeling of two proteins simultaneously in the same cells.



Live COS-7 cell transiently transfected with pSNAP$_f$-ER. Cells were labeled with SNAP-Cell TMR-Star (red) for 15 minutes and counterstained with Hoechst 33342 (blue) for nuclei.



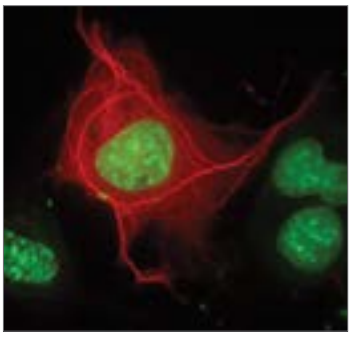
Protein labeling with SNAP-tag (gold) and CLIP-tag (purple). *The SNAP- or CLIP-tag is fused to the protein of interest (blue). Labeling occurs through covalent attachment to the tag, releasing either a guanine or a cytosine moeity.*

Flexibility & Selection

SNAP-tag and CLIP-tag protein labeling systems offer a broad selection of fluorescent substrates optimized for a range of imaging instrumentation. Once cloned and expressed, the tagged protein can be used with a variety of substrates for numerous downstream applications without having to clone again.

Applications of SNAP-tag and CLIP-tag:

- Simultaneous dual protein labeling inside or on the surface of live cells
- Protein localization and translocation
- Pulse-chase experiments
- Receptor internalization studies
- Selective cell surface labeling
- Protein pull down assays
- Protein detection in SDS-PAGE
- Flow cytometry
- High throughput binding assays in microtiter plates
- Biosensor interaction experiments
- FRET-based binding assays
- Single-molecule labeling
- Super-resolution microscopy
- Live animal imaging



Live COS-7 cells transiently transfected with pSNAP$_f$-Cytokeratin13. Cells were labeled with SNAP-Cell TMR-Star (red) for 15 minutes and counterstained with Hoechst 33342 (green pseudocolor) for nuclei.

Comparison of SNAP-tag/CLIP-tag Technologies to GFP

While SNAP-tag/CLIP-tag technologies are complementary to GFP (Green Fluorescent Protein), there are several applications in which SNAP- and CLIP-tag self-labeling approaches may be advantageous.

APPLICATION	SNAP-tag/CLIP-tag	GFP AND OTHER FLUORESCENT PROTEINS
Time-resolved fluorescence	Fluorescence can be initiated upon addition of label	Color is genetically encoded and always expressed. Photoactivatable fluorescent proteins require high intensity laser light, which may activate undesired cellular pathways (e.g., apoptosis)
Pulse-chase analysis	Labeling of newly synthesized proteins can be turned off using available blocking reagents (e.g., SNAP-Cell® Block)	Fluorescence of newly synthesized proteins cannot be specifically quenched to investigate dynamic processes
Ability to change colors	A single construct can be used with different fluorophore substrates to label with multiple colors	Requires separate cloning and expression for each color
Surface specific labeling	Can specifically label subpopulation of target protein expressed on cell surface using non-cell permeant substrates	Surface subpopulation cannot be specifically visualized
Single-molecule detection	Conjugation with high quantum yield and photostable fluorophores	Fluorescent proteins are generally less bright and photobleach quicker than most organic fluorophores
Visualizing fixed cells	Resistant to fixation; strong labeling	Labile to fixation; weak labeling
Pull-down studies	"Bait" proteins can be covalently captured on BG beads	Requires anti-GFP antibody to non-covalently capture “bait" protein, complicating downstream analysis
Live animal imaging	Cell permeable, near-IR dye available, permitting deep tissue visualization	Signal is easily quenched by fixation (whole-mount specimens or thick sections); limited spectral flexibility and weaker fluorescence

Cloning Vectors

Cloning vectors are available for SNAP-tag and CLIP-tag fusion protein expression in mammalian and bacterial systems.

PRODUCT	NEB #	FEATURES	SIZE
pSNAP$_f$ Vector	N9183S	stable and transient mammalian expression	20 µg
pSNAP-tag(T7)-2 Vector	N9181S	bacterial expression under T7 control	20 µg
pCLIP$_f$ Vector	N9215S	stable and transient mammalian expression	20 µg

Antibodies

The Anti-SNAP-tag Antibody (Polyclonal) can be used in Western blots with SNAP-tag and CLIP-tag proteins. Polyclonal antibodies are produced from the immunization of rabbit with purified recombinant SNAP-tag protein and affinity purified using SNAP-BG resin.

PRODUCT	NEB #	SIZE
Anti-SNAP-tag Antibody (Polyclonal)	P9310S	100 µl

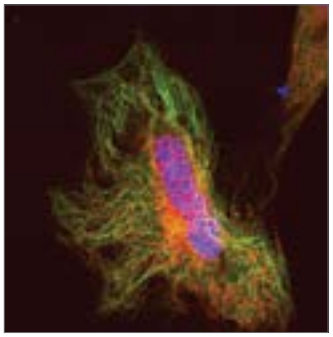
Fluorescent Substrates

NEB offers a large selection of fluorescent labels (substrates) for SNAP-tag and CLIP-tag fusion proteins. Cell-permeable substrates (SNAP- and CLIP-Cell) are suitable for both intracellular and cell-surface labeling, whereas non-cell-permeable substrates (SNAP- and CLIP-Surface) are specific for fusion proteins expressed on the cell surface only. The labeling reaction is specific for fusion proteins expressed on the cell surface.

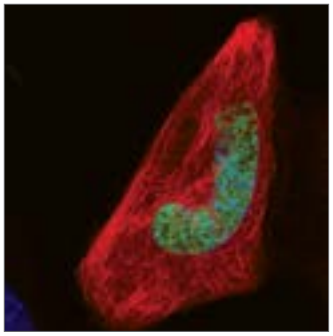
SELF-LABELING TAG					
	APPLICATIONS	NEB #	EXCITATION*	EMISSION**	SIZE
SNAP-tag	Cell-Permeable				
	SNAP-Cell 430	S9109S	421	444,484	50 nmol
	SNAP-Cell 505-Star	S9103S	504	532	50 nmol
	SNAP-Cell Oregon Green®	S9104S	490	514	50 nmol
	SNAP-Cell TMR-Star	S9105S	554	580	30 nmol
	SNAP-Cell 647-SiR	S9102S	645	661	30 nmol
	Non-cell-permeable				
	SNAP-Surface Alexa Fluor® 488	S9129S	496	520	50 nmol
	SNAP-Surface 488	S9124S	506	526	50 nmol
	SNAP-Surface Alexa Fluor 546	S9132S	558	574	50 nmol
	SNAP-Surface 549	S9112S	560	575	50 nmol
	SNAP-Surface 594	S9134S	606	626	50 nmol
	SNAP-Surface Alexa Fluor 647	S9136S	652	670	50 nmol
	SNAP-Surface 649	S9159S	655	676	50 nmol
CLIP-tag	APPLICATIONS	NEB #	EXCITATION*	EMISSION**	SIZE
	Cell-Permeable				
	CLIP-Cell 505	S9217S	504	532	50 nmol
	CLIP-Cell TMR-Star	S9219S	554	580	30 nmol
	Non-cell-permeable				
	CLIP-Surface 488	S9232S	506	526	50 nmol
	CLIP-Surface 547	S9233S	554	568	50 nmol
	CLIP-Surface 647	S9234S	660	673	50 nmol

* Excitation and emission values determined experimentally for labeled protein tag.
** Colors are based on the electromagnetic spectrum. Actual color visualization may vary.

This table lists all currently available fluorescent substrates for SNAP-tag and CLIP-tag, along with excitation and emission wavelengths (determined from a labeled fusion tag, rather than the unreacted substrate).



Live HeLa cell transfected with $pSNAP_f$-ER (endoplasmic reticulum) and $pCLIP_f$-tubulin. Cells were labeled with 3 µM SNAP-Cell TMR-Star (red) and 5 µM CLIP-Cell 505 (green) for 25 minutes and counterstained with Hoechst 33342 (blue) for nuclei.



Live HeLa cell transfected with $pSNAP_f$-tubulin and $pCLIP_f$-H2B constructs generated using $pSNAP_f$ and $pCLIP_f$ vectors. Cells were labeled with 3 µM SNAP-Cell TMR-Star (red) and 5 µM CLIP-Cell 505 (green) for 25 minutes and counterstained with Hoechst 33342 (blue) for nuclei.

Biotin Labels

For optimal flexibility with existing technologies, biotinylated labels are available for studies using streptavidin platforms. Cell-permeant (SNAP-Biotin and CLIP-Biotin) substrates are suitable for applications such as biotinylation of fusion proteins for detection with streptavidin fluorophore conjugates or labeling in solution for analysis by SDS-PAGE/Western blot. Biotin labels are also used for binding and protein interaction studies.

PRODUCT	NEB #	SIZE
SNAP-Biotin®	S9110S	50 nmol
CLIP-Biotin	S9221S	50 nmol

Purified Protein

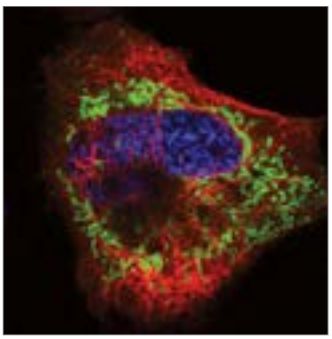
Purified protein can be used as a positive control for *in vitro* labeling with various SNAP-tag fluorescent substrates.

PRODUCT	NEB #	SIZE	CONC.	MOLECULAR WEIGHT
SNAP-tag Purified Protein	P9312S	50 µg	50 µM	19,694

Blocking Agents

Blocking agents are non-fluorescent substrates that block the reactivity of the SNAP-tag intracellularly (SNAP-Cell Block) or on the surface of cells (SNAP-Surface® Block). They can be used to generate inactive controls in live or fixed cell and *in vitro* labeling experiments performed with SNAP-tag fusion proteins. Their irreversible blocking makes them ideal for pulse-chase applications.

PRODUCT	NEB #	APPLICATION	SIZE
SNAP-Cell Block	S9106S	Block SNAP-tag inside live cells and *in vitro*	100 nmol
SNAP-Surface Block	S9143S	Block SNAP-tag on the surface of live cells and *in vitro*	200 nmol

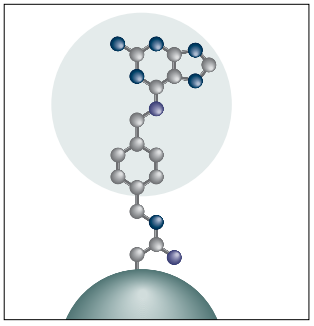


Live HeLa cell transfected with pSNAP$_f$-tubulin and pCLIP$_f$-Cox8A (mitochondrial cytochrome oxidase 8A). Cells were labeled with 3 µM SNAP-Cell TMR-Star (red) and 5 µM CLIP-Cell 505 (green) for 25 minutes and counterstained with Hoechst 33342 (blue) for nuclei.

SNAP-Capture

SNAP-Capture products are magnetic agarose beads coupled to a benzylguanine substrate, used to selectively capture and immobilize SNAP-tag fusion proteins from solution. These beads have a high loading capacity for SNAP-tag fusion proteins and show very low non-specific adsorption of proteins from a complex lysate, making them suitable for pull-down applications.

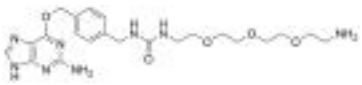
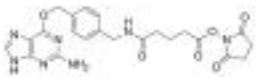
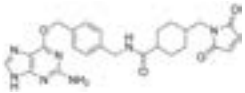
PRODUCT	NEB #	SIZE
SNAP-Capture Magnetic Beads	S9145S	2 ml



Substrate structure on SNAP-Capture magnetic beads

Building Blocks

For advanced users with novel probes interested in working with SNAP-tag labeling technologies, a complete line of building blocks is available for linkage of the core benzylguanine (BG) moieties to activated esters, primary amines and thiol groups. The variety of functional groups allows a choice of chemical coupling approaches to suit the molecule or surface to be coupled for the generation of custom substrates.

PRODUCT	NEB #	STRUCTURE	APPLICATION	SIZE
BG-PEG-NH2	S9150S		SNAP-tag substrate. PEG-linker gives superior flexibility. Particularly suited for immobilization on solid surfaces.	2 mg
BG-GLA-NHS	S9151S		SNAP-tag substrate. Activated as NHS ester. Reacts with primary amines.	2 mg
BG-Maleimide	S9153S		SNAP-tag substrate. Activated as maleimide. Reacts with thiols.	2 mg

Troubleshooting Guide: Labeling with SNAP-tag Technology

APPLICATION	PROBLEM	CAUSE	SOLUTION
Cellular Labeling	No labeling	Fusion protein not expressed	• Verify transfection • Check expression of fusion protein via Western blot or SDS-PAGE with fluorescent substrate.
	Weak labeling	Poor expression and/or insufficient exposure of fusion protein to substrate	• Increase substrate concentration • Increase incubation time
		Rapid turnover of fusion protein	• Analyze samples immediately or fix cells directly after labeling • Label at lower temperature (4°C or 16°C)
	High background	Non-specific binding of substrates	• Reduce substrate concentration and/or incubation time • Allow final wash step to proceed for up to 2 hours • Include fetal calf serum or BSA during labeling
	Signal strongly reduced after short time	Instability of fusion protein	• Fix cells • Switch tag from N-terminus to C-terminus or vice versa
		Photobleaching	• Add commercially available anti-fade reagent • Reduce illumination time and/or intensity
Labeling in Solution	Precipitation	Insoluble fusion	• Test from pH 5.0 to 10.0 • Optimize salt concentration [50 to 250 mM] • Add 0.05 to 0.1% Tween 20
	Weak or no labeling	Exhaustive labeling has not been achieved	• Increase incubation time to 2 hrs at 25°C or 24 hrs at 4°C • Reduce the volume of protein solution labeled • Check expression of fusion protein via SDS-PAGE with fluorescent substrate.
	Loss of activity	Instability of fusion protein	• Reduce labeling time • Decrease labeling temperature (4°C or 16°C)

FAQs

How does SNAP-tag labeling differ from using GFP fusion proteins?

GFP and SNAP-tag are both valuable technologies used to visualize proteins in live cells. GFP is an intrinsically fluorescent protein derived from *Aequorea victoria* while SNAP-tag is derived from hAGT, a human DNA repair protein. In contrast to GFP, the fluorescence of SNAP-tag fusions can be readily turned on with the addition of a variety of fluorescent probes added directly to the culture media. Substituting different fluorophores or other functionalities (biotin, magnetic beads, blocking agents) requires no new cloning or expression, merely incubation of the appropriate substrate with cells, cell lysates or recombinant proteins.

What is the difference between SNAP- and CLIP-tag?

SNAP-tag and CLIP-tag are both derived from O^6 -alkylguanine-DNA-alkyltransferase (hAGT). SNAP-tag recognizes O^6-labeled benzylguanine substrates while CLIP-tag recognizes O^2-labeled benzylcytosine substrates. Each tag transfers the label from the substrate to itself, resulting in specific covalent labeling. In creating the tags, hAGT has been engineered to no longer interact with DNA, but rather with derivatives of the free benzylguanine or benzylcytosine substrates. The tags exhibit no cross-reactivity with one another, enabling researchers to simultaneously label fusion proteins containing SNAP- and CLIP-tags with different fluorophores in live or fixed cells.

Can I clone my protein as a fusion to the N- or C-terminus of the tags?

Yes. SNAP- and CLIP-tags can be fused to either the N- or C-terminus of a protein of interest. However, to label surface proteins on the outside of cells the SNAP-tag or CLIP-tag must be cloned so that it is oriented to the extracellular surface of the plasma membrane. In this orientation, the tag is accessible to its fluorophore conjugated substrate.

How stable is the labeled protein in mammalian cells?

The stability of the tagged protein in the cell is dependent upon the stability of protein of interest. Labeled SNAP-tag fusion protein has been detected for up to 2 days in mammalian cells.

Are SNAP-tag substrates stable to fixation?

Yes. SNAP-tag substrates are derived from organic fluorophores which are stable to fixation. Fluorescently-labeled SNAP-tag fusion proteins do not lose signal intensity in contrast to some GFP spectral variants. After labeling the SNAP-tag fusion proteins, the cells can be fixed with standard fixation methods such as para-formaldehyde, ethanol, methanol, methanol/acetone etc. without loss of signal.

ADDITIONAL FAQS CAN BE FOUND AT WWW.NEB.COM

Reviews:

Lukinavicius, G. et al. (2015) Fluorescent labeling of SNAP-tagged proteins in cells. *Methods Mol. Biol.* 1266, 107–118.

Corrêa Jr., I. R. (2015) Considerations and protocols for the synthesis of custom protein labeling probes. *Methods Mol. Biol.* 1266, 55–79.

Corrêa Jr., I. R. (2014) Live-cell reporters for fluorescence imaging. *Curr. Opin. Chem. Biol.* 20, 36–45.

Single-Molecule Imaging:

Bosch, P. J. et al. (2014) Evaluation of fluorophores to label SNAP-tag fused proteins for multicolor single-molecule tracking microscopy in live cells. *Biophys. J.* 107, 803–814.

Smith, B. A. et al. (2013) Three-color single molecule imaging shows WASP detachment from Arp2/3 complex triggers actin filament branch formation. eLife 2, e01008.

Jaiswal, R. et al. (2013) The Formin Daam1 and Fascin Directly Collaborate to Promote Filopodia Formation. *Curr. Biol.* 23, 1373–1379.

Breitsprecher, D. et al. (2012) Rocket Launcher Mechanism of Collaborative Actin Assembly Defined by Single-Molecule Imaging. *Science*, 336, 1164–1168.

Hoskins, A. A. et al. (2011) Ordered and dynamic assembly of single spliceosomes. *Science*, 331, 1289–1295.

Super-Resolution Imaging:

Zhao, Z. W. et al. (2014) Spatial organization of RNA polymerase II inside a mammalian cell nucleus revealed by reflected light-sheet super resolution microscopy. *Proc. Natl. Acad. Sci. USA*, 111, 681–686.

Lukinavicius, G. et al. (2013) A near-infrared fluorophore for live-cell super-resolution microscopy of cellular proteins. *Nat Chem.* 5, 132–139.

Jones, S. A. et al. (2011) Fast, three-dimensional super-resolution imaging of live cells. *Nat. Methods*, 8, 499–505.

Klein, T. et al. (2011) Live-cell dSTORM with SNAP-tag fusion proteins. *Nat. Methods*, 8, 7–9.

Pellett, P. A. et al. (2011) Two-color STED microscopy in living cells. *Biomed. Opt. Expr.* 2, 2364–2371.

Hein, B. et al. (2010) Stimulated Emission Depletion Nanoscopy of Living Cells Using SNAP-Tag Fusion Proteins. *Biophys J.* 98, 158–163.

Tissue and Animal Imaging:

Yang, G. et al. (2015) Genetic targeting of chemical indicators *in vivo*. *Nat. Methods*, 12, 137–139.

Kohl, J. et al. (2014) Ultrafast tissue staining with chemical tags. *Proc. Natl. Acad. Sci. USA*, 111, E3805–E3814.

Ivanova, A. et al. (2013) Age-dependent labeling and imaging of insulin secretory granules. *Diabetes*, 62, 3687–3696.

Gong, H. et al. (2012) Near-Infrared Fluorescence Imaging of Mammalian Cells and Xenograft Tumors with SNAP-Tag. *PLoS ONE* 7(3): e34003.

Bojkowska K. et al. (2011) Measuring *in vivo* protein half-life. *Chem. Biol.* 18, 805–815.

Cell-Surface Protein Labeling and Internalization Analysis:

Bitsikas, V. et al. (2014) Clathrin-independent pathways do not contribute significantly to endocytic flux. *eLife* 3, e03970.

Jaensch, N. et al. (2014) Stable Cell Surface Expression of GPI-Anchored Proteins, but not Intracellular Transport, Depends on their Fatty Acid Structure. *Traffic*, 15, 1305–1329.

Cole, N. B. and Donaldson, J. G. (2012) Releasable SNAP-tag Probes for Studying Endocytosis and Recycling. *ACS Chem. Biol.* 7, 464–469.

Pulse-Chase Analysis:

Rošic, S. et al. (2014) Repetitive centromeric satellite RNA is essential for kinetochore formation and cell division. *J. Cell Biol.* 207, 335–349.

Stoops, E. H. et al. (2014) SNAP-Tag to Monitor Trafficking of Membrane Proteins in Polarized Epithelial Cells. *Methods Mol. Biol.* 1174, 171–182.

Bordor, D. L. et al. (2012) Analysis of Protein Turnover by Quantitative SNAP-Based Pulse-Chase Imaging. *Curr. Protoc. Cell Biol.* 55, 8.8.1–8.8.34.

Pull-Down Studies:

Register, A. C. et al. (2014) SH2-Catalytic Domain Linker Heterogeneity Influences Allosteric Coupling across the SFK Family. *Biochemistry*, 53, 6910–6923.

Shi, G. et al. (2012) SNAP-tag based proteomics approach for the study of the retrograde route. *Traffic*, 13, 914–925.

Bieling, P. et al. (2010) A minimal midzone protein module controls formation and length of antiparallel microtubule overlaps. *Cell*, 142, 420–432.

Protein-Protein and Protein-Ligand Interactions:

Griss, R. et al. (2014) Bioluminescent sensor proteins for point-of-care therapeutic drug monitoring. *Nat. Chem. Biol.* 10, 598–603.

Chidley, C. et al. (2011) A yeast-based screen reveals that sulfasalazine inhibits tetrahydrobiopterin biosynthesis. *Nat. Chem. Biol.* 7, 375–383.

Gautier A. et al. (2009) Selective Cross-Linking of Interacting Proteins using Self-Labeling Tags. *J. Am. Chem. Soc.* 131, 17954–17962.

Maurel D. et al. (2008) Cell-surface protein-protein interaction analysis with time-resolved FRET and SNAP-tag technologies: application to GPCR oligomerization. *Nat. Methods*, 5, 561–567.

USA
New England Biolabs, Inc.
Telephone (978) 927-5054
Toll Free (USA Orders) 1-800-632-5227
Toll Free (USA Tech) 1-800-632-7799
info@neb.com

Australia & New Zealand
New England Biolabs (Australia) PTY
Telephone: 1800 934 218 (AU)
info.au@neb.com
Telephone: 0800 437 209 (NZ)
info.nz@neb.com

Canada
New England Biolabs, Ltd.
Toll Free: 1-800-387-1095
info.ca@neb.com

China
New England Biolabs (Beijing), Ltd.
Telephone: 010-82378265/82378266
info@neb-china.com

France
New England Biolabs France
Telephone: 0800 100 632
info.fr@neb.com

Germany & Austria
New England Biolabs GmbH
Free Call: 0800/246 5227 (Germany)
Free Call: 00800/246 52277 (Austria)
info.de@neb.com

Japan
New England Biolabs Japan, Inc.
Telephone: +81 (0)3 5669 6191
info.jp@neb.com

Singapore
New England Biolabs, Pte. Ltd.
Telephone: +65 638 59623
sales.sg@neb.com

Republic of Korea
New England Biolabs Korea Ltd.
Toll Free: +82 (70) 47318478
info.kr@neb.com

United Kingdom
New England Biolabs (UK), Ltd.
Call Free: 0800 318486
info.uk@neb.com

www.neb.com

ISO 9001 Registered Quality Management
ISO 14001 Registered Environmental Management
ISO 13485 Registered Medical Devices
Certified B Corporation
SGP Sustainable Green Printing Partnership sgppartnership.org

CIA – Version 8.0 – 12/24

Did you know that many of these products can be purchased in large volumes and custom formats? Learn more at **www.neb.com/customizedsolutions**