

# MARCKS Redistribution<sup>®</sup> Assay

For High-Content Analysis

096-01.03

Number	Description
<b>R04-096-01</b>	Recombinant U2OS cells stably expressing human MARCKS (GenBank Acc. NM_002356) fused to the N-terminus of enhanced green fluorescent protein (EGFP). U2OS cells are adherent epithelial cells derived from human osteosarcoma. Expression of MARCKS-EGFP is controlled by a standard CMV promoter and continuous expression is maintained by addition of G418 to the culture medium.

**Quantity:** 2 cryo-vials each containing  $1.0 \times 10^6$  cells in a volume of 1.0 ml Cell Freezing Medium.

**Storage:** Immediately upon receipt store cells in liquid nitrogen (vapor phase).

**Warning:** Please completely read these instructions and the material safety data sheet for DMSO before using this product. This product is for research use only. Not intended for human or animal diagnostic or therapeutic uses. Handle as potentially biohazardous material under at least Biosafety Level 1 containment. Safety procedures and waste handling are in accordance with the local laboratory regulations.

**CAUTION:** This product contains Dimethyl Sulfoxide (DMSO), a hazardous material. Please review Material Safety Data Sheet before using this product.

## Introduction

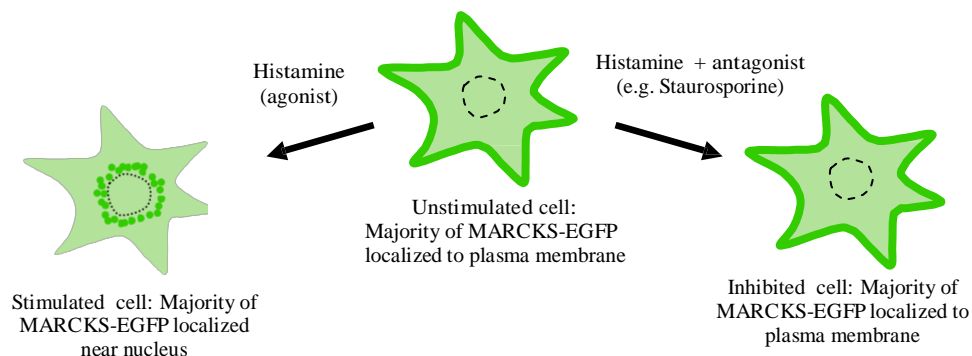
### The Redistribution<sup>®</sup> Technology

The Redistribution Technology monitors the cellular translocation of GFP-tagged proteins in response to drug compounds or other stimuli and allows easy acquisition of multiple readouts from the same cell in a single assay run. In addition to the primary readout, high content assays provide supplementary information about cell morphology, compound fluorescence, and cellular toxicity.

### The MARCKS Redistribution Assay

The protein MARCKS (myristoylated alanine-rich C kinase substrate) is a ubiquitous substrate of PKC. MARCKS is a cytoskeletal protein and has been implicated in regulation of cell spreading, adhesion, phagocytosis, and membrane trafficking [1-3]. MARCKS is localized at the plasma membrane with the N-terminal myristate inserted into the lipid bilayer, but upon activation by PKC it translocates to the cytosol [4].

The MARCKS Redistribution<sup>®</sup> Assay has been developed using histamine as reference agonist. Histamine activates endogenous H1 G-coupled receptors, which leads to  $\text{Ca}^{2+}$  release, PKC activation and ultimately MARCKS translocation from membrane to cytoplasm. Knockdown of endogenous H1 receptors abolishes the response to histamine.



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**Figure 1.** Illustration of the MARCKS translocation event

The assay has been developed both in agonist and antagonist format. In the agonist format, histamine is used as reference agonist. In the antagonist assay, the broad PKC inhibitor staurosporine is used as the reference compound and several additional PKC inhibitors have been tested for activity in this assay. GF 109203X, Go6983, and Ro 31-8220 (all broad isoform specificity) are able to antagonize MARCKS translocation in response of histamine, whereas Go6976 (conventional PKC specific) is not.

## Additional materials required

The following reagents and materials need to be supplied by the user.

- Dulbecco's Modified Eagle Medium (DMEM), high glucose, without L-Glutamine, Sodium Pyruvate (Thermo Scientific, Fisher Scientific cat.# SH30081)
- L-Glutamine supplement, 200 mM (Thermo Scientific, Fisher Scientific cat.# SH30034)
- Fetal Bovine Serum (FBS) (Thermo Scientific, Fisher Scientific cat.# SH30071)
- Penicillin/Streptomycin, 100X solution (Thermo Scientific, Fisher Scientific cat.# SV30010),
- Trypsin-EDTA, 0.05% (Thermo Scientific, Fisher Scientific cat.# SH30236)
- G418, 50mg/ml (Thermo Scientific, Fisher Scientific cat.# SC30069)
- Dimethylsulfoxide (DMSO) (Fisher Scientific, cat.# BP231)
- Dulbecco's Phosphate-Buffered Saline (PBS), w/o calcium, magnesium, or Phenol Red (Thermo Scientific, Fisher Scientific cat.# SH30028)
- Histamine (Sigma-Aldrich, cat.# H7125)
- Staurosporine from Streptomyces sp. (Sigma-Aldrich, cat.# S5921)  
Note: Staurosporine is only used in the antagonist mode of the assay.
- Hoechst 33258 (Fisher Scientific, cat.# AC22989)
- Triton X-100 (Fisher Scientific, cat.# AC21568)
- 10% formalin, neutral-buffered solution (approximately 4% formaldehyde) (Fisher Scientific, cat.# 23-305-510)  
Note: is not recommended to prepare this solution by diluting from a 37% formaldehyde solution.
- 96-well microplate with lid (cell plate) (e.g. Nunc 96-Well Optical Bottom Microplates, Thermo Scientific cat.# 165306)
- Black plate sealer
- Nunc EasYFlasks with Nunclon Delta Surface, T-25, T-75, T-175 (Thermo Scientific, cat.# 156367, 156499, 159910)

## Reagent preparation

The following reagents are required to be prepared by the user.

- Cell Culture Medium: DMEM supplemented with 2mM L-Glutamine, 1% Penicillin-Streptomycin, 0.5 mg/ml G418, and 10% FBS.
- Cell Freezing Medium: 90% Cell Culture Medium without G418 + 10% DMSO.
- Plate Seeding Medium: DMEM supplemented with 2mM L-Glutamine, 1% Penicillin-Streptomycin, 0.5 mg/ml G418, and 10% FBS.
- Assay Buffer: DMEM supplemented with 2mM L-Glutamine and 1% Penicillin-Streptomycin.
- Control Compound Stock (agonist mode): 100 mM histamine stock solution in deionized H<sub>2</sub>O. Prepare by dissolving 100 mg histamine (MW = 111.15) in 8997  $\mu$ l H<sub>2</sub>O. Store at -20 °C.
- Control Compound Stock (antagonist mode): 1 mM staurosporine stock solution in DMSO. Prepare by dissolving 0.5 mg staurosporine (MW = 466.53) in 1072  $\mu$ l DMSO. Store at -20°C.  
Note: Staurosporine is only used in the antagonist mode of the assay.
- Fixing Solution: 10% formalin, neutral-buffered solution (approximately 4% formaldehyde).  
Note: It is not recommended to prepare this solution by diluting from a 37% formaldehyde solution.
- Hoechst Stock: 10 mM stock solution is prepared in DMSO.
- Hoechst Staining Solution: 1  $\mu$ M Hoechst in PBS containing 0.5% Triton X-100. Prepare by dissolving 2.5 ml Triton X-100 with 500 ml PBS. Mix thoroughly on a magnetic stirrer. When Triton X-100 is dissolved add 50  $\mu$ l 10 mM Hoechst 33258. Store at 4°C for up to 1 month.

The following procedures have been optimized for this cell line. It is strongly recommended that an adequately sized cell bank is created containing cells at a low passage number.

### Cell thawing procedure

1. Rapidly thaw frozen cells by holding the cryovial in a 37°C water bath for 1-2 minutes. Do not thaw cells by hand, at room temperature, or for longer than 3 minutes, as this decreases viability.
2. Wipe the cryovial with 70% ethanol.
3. Transfer the vial content into a T75 tissue culture flask containing 25 ml Cell Culture Medium and place flask in a 37°C, 5% CO<sub>2</sub>, 95% humidity incubator.
4. Change the Cell Culture Medium the next day.

### Cell harvest and culturing procedure

For normal cell line maintenance, split 1:8 every 3-4 days. Maintain cells between 5% and 95% confluence. Passage cells when they reach 80-95% confluence. All reagents should be pre-warmed to 37°C.

1. Remove medium and wash cells once with PBS (10 ml per T75 flask and 12 ml per T175 flask).
2. Add trypsin-EDTA (2 ml per T75 flask and 4 ml per T175 flask) and swirl to ensure all cells are covered.
3. Incubate at 37°C for 3-5 minutes or until cells round up and begin to detach.
4. Tap the flask gently 1-2 times to dislodge the cells. Add Cell Culture Medium (6 ml per T75 flask and 8 ml per T175 flask) to inactivate trypsin and resuspend cells by gently pipetting to achieve a homogenous suspension.
5. Count cells using a cell counter or hemocytometer.
6. Transfer the desired number of cells into a new flask containing sufficient fresh Cell Culture Medium (total of 20 ml per T75 flask and 40 ml per T175 flask).
7. Incubate the culture flask in a 37°C, 5% CO<sub>2</sub>, 95% humidity incubator.

### Cell freezing procedure

1. Harvest the cells as described in the “Cell harvest and culturing procedure”, step 1 – 5.
2. Prepare a cell suspension containing  $1 \times 10^6$  cells per ml (5 cryogenic vials =  $5 \times 10^6$  cells).
3. Centrifuge the cells at 250g (approximately 1100 rpm) for 5 minutes. Aspirate the medium from the cells.
4. Resuspend the cells in Cell Freezing Medium at  $1 \times 10^6$  cells per ml until no cell aggregates remain in the suspension.
5. Dispense 1 ml of the cell suspension into cryogenic vials.
6. Place the vials in an insulated container or a cryo-freezing device (e.g. Nalgene "Mr. Frosty" Freezing Container, Thermo Scientific, Fisher Scientific cat.# 15-350-50) and store at -80°C for 16-24 hours.
7. Transfer the vials for long term storage in liquid nitrogen.

### Cell plating procedure

The cells should be seeded into 96-well plates 18-24 hours prior to running the assay. Do not allow the cells to reach over 95% confluence prior to seeding for an assay run. The assay has been validated with cells up to passage 22, split as described in the “Cell harvest and culturing procedure”.

1. Harvest the cells as described in the “Cell harvest and culturing procedure”, step 1-5 using Plate Seeding Medium instead of Cell Culture Medium.
2. Dilute the cell suspension to 30,000 cells/ml in Plate Seeding Medium.
3. Transfer 100 µl of the cell suspension to each well in a 96-well tissue culture plate (cell plate). This gives a cell density of 3000 cells/well.  
Note: At this step, be careful to keep the cells in a uniform suspension.
4. Incubate the cell plate on a level vibration-free table for 1 hour at room temperature (20-25°C). This ensures that the cells attach evenly within each well.
5. Incubate the cell plate for 18-24 hours in a 37°C, 5% CO<sub>2</sub>, 95% humidity incubator prior to starting the assay.

## Assay protocol - agonist mode

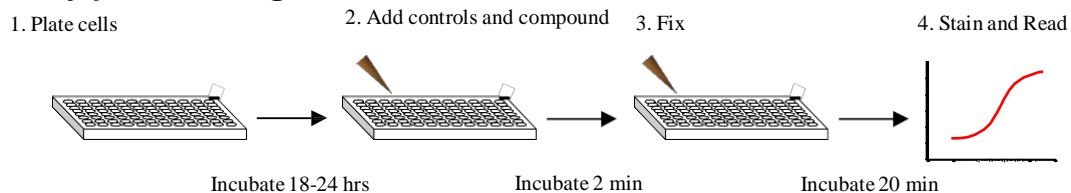


Figure 2: Quick assay workflow overview

The following protocol is based on 1x 96-well plate.

1. Before initiating the assay:

- Prepare Assay Buffer. Ensure Assay Buffer is pre-warmed to 20-37°C.

2. Prepare controls and test compounds

- Dilute controls and test compounds in Assay Buffer to a 2X final concentration. (Volumes and concentrations are indicated below). A final DMSO concentration of 0.25% is recommended, but the assay can tolerate up to 2% DMSO final concentration.
- Mix controls for 1x 96-well plate as indicated below:

	Assay Buffer	Control Stock	DMSO	2X concentration	Final assay concentration	Final DMSO concentration
Negative control	12 ml	----	60 µl	0.5% DMSO	----	0.25%
Positive control	12 ml	24 µl Histamine	60 µl	200 µM Histamine	100 µM Histamine	0.25%

3. Add 100 µl 2X concentrated control or compound solution in Assay Buffer to appropriate wells of the cell plate.
4. Incubate cell plate for 2 minutes in a 37°C, 5% CO<sub>2</sub>, 95% humidity incubator.
5. Fix cells by gently decanting the buffer and add 150 µl Fixing Solution per well.
6. Incubate cell plate at room temperature for 20 minutes.
7. Wash the cells 4 times with 200 µl PBS per well per wash.
8. Decant PBS from last wash and add 100 µl 1 µM Hoechst Staining Solution.
9. Seal plate with a black plate sealer. Incubate at room temperature for at least 30 minutes before imaging. The plate can be stored at 4°C for up to 3 days in the dark.

## Assay protocol - antagonist mode

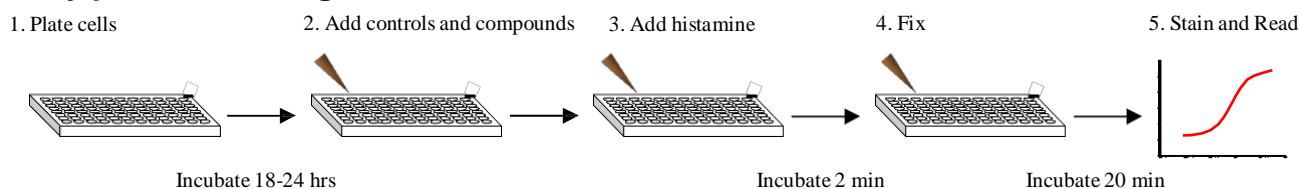


Figure 3: Quick assay workflow overview

The following protocol is based on 1x 96-well plate.

1. Before initiating the assay:
  - Prepare Assay Buffer. Ensure Assay Buffer is pre-warmed to 20-37°C.
2. Prepare controls and test compounds
  - Dilute controls and test compounds in Assay Buffer to a 4X final concentration. (Volumes and concentrations are indicated below). A final DMSO concentration of 0.25% is recommended, but the assay can tolerate up to 2% DMSO final concentration.
  - Mix controls for 1x 96-well plate as indicated below:

	Assay Buffer	Control Stock	DMSO	4X concentration	Final assay concentration	Final DMSO concentration
Negative control	6 ml	----	60 $\mu$ l	1% DMSO	----	0.25%
Positive control	6 ml	24 $\mu$ l Staurosporine	36 $\mu$ l	4 $\mu$ M Staurosporine	1 $\mu$ M Staurosporine	0.25%

3. Prepare 4X histamine Agonist Solution (400  $\mu$ M):
  - 400  $\mu$ M histamine Agonist Solution is prepared by diluting 24  $\mu$ l 100 mM histamine with 6 ml Assay Buffer. Use the histamine Agonist Solution within 20 minutes after preparation
4. Add 50  $\mu$ l 4X concentrated control or compound solution in Assay Buffer to appropriate wells of the cell plate.
5. Add 50  $\mu$ l 4X histamine Agonist Solution to appropriate wells of the cell plate.
6. Incubate cell plate for 2 minutes in a 37°C, 5% CO<sub>2</sub>, 95% humidity incubator.
7. Fix cells by gently decanting the buffer and add 150  $\mu$ l Fixing Solution per well.
8. Incubate cell plate at room temperature for 20 minutes.
9. Wash the cells 4 times with 200  $\mu$ l PBS per well per wash.
10. Decant PBS from last wash and add 100  $\mu$ l 1  $\mu$ M Hoechst Staining Solution.
11. Seal plate with a black plate sealer. Incubate at room temperature for at least 30 minutes before imaging. The plate can be stored at 4°C for up to 3 days in the dark.

## Imaging

The translocation of MARCKS-EGFP can be imaged on most HCS platforms and fluorescence microscopes. The filters should be set for Hoechst (350/461 nm) and GFP/FITC (488/509 nm) (wavelength for excitation and emission maxima). Consult the instrument manual for the correct filter settings.

The translocation can typically be analyzed on images taken with a 10x objective or higher magnification.

The primary output in the MARCKS Redistribution<sup>®</sup> assay is the formation of spots in the cytoplasm. The data analysis should therefore report an output that corresponds to number, area, or intensity of spots in the cytoplasm.

### Imaging on Thermo Scientific Arrayscan HCS Reader

This assay has been developed on the Thermo Scientific Arrayscan HCS Reader using a 10x objective (0.63X coupler), XF100 filter sets for Hoechst and FITC, and the SpotDetectorV3 BioApplication. The output parameter used was SpotTotalAreaPerObject. Two images were taken per well, corresponding to approximately 300 cells/well.

Other BioApplications that can be used for this assay include CompartmentalAnalysisV2 and ColocalizationV3.

### High Content Outputs

In addition to the primary readout, it is possible to extract secondary high content readouts from the Redistribution<sup>®</sup> assays. Such secondary readouts may be used to identify unwanted toxic effects of test compounds or false positives. In order to acquire this type of information, the cells should be stained with a whole cell dye which allows for a second analysis of the images for determination of secondary cell characteristics.

Examples of useful secondary high content outputs:

Nucleus size, shape, intensity:	Parameter used to identify DNA damage, effects on cell cycle and apoptosis.
Cell number, size, and shape:	Parameter for acute cytotoxicity and apoptosis.
Cell fluorescence intensity:	Parameter for compound cytotoxicity and fluorescence.

The thresholds for determining compound cytotoxicity or fluorescence must be determined empirically. Note that the primary translocation readout in some cases may affect the secondary outputs mentioned above.

## Representative Data Examples

The MARCKS Redistribution<sup>®</sup> Assay monitors the translocation of MARCKS-EGFP between the cytoplasm and the plasma membrane. Histamine is used as the reference compound in the agonist assay format. In the antagonist assay format, inhibition of histamine-induced MARCKS-EGFP translocation is measured, and staurosporine is used as the reference compounds. Example images are shown in Figure 4.

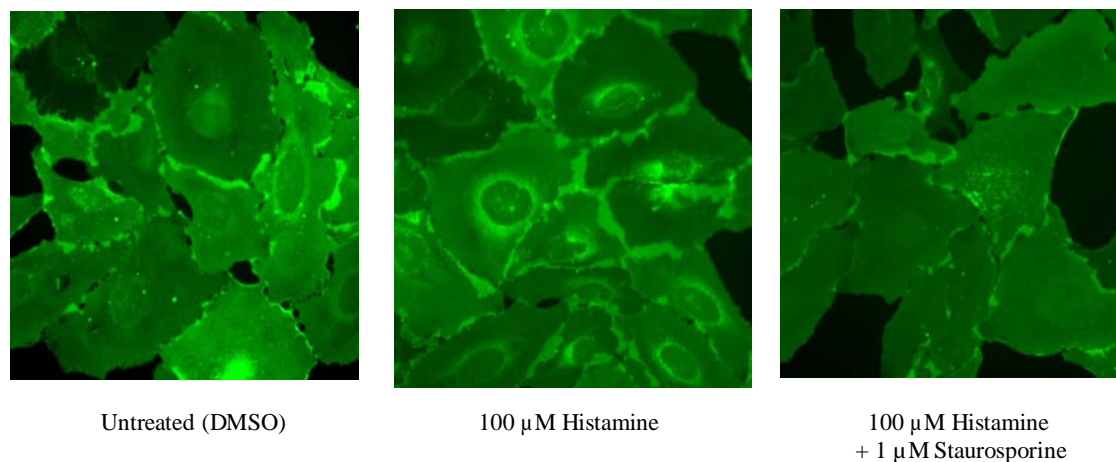


Figure 4. Translocation of MARCKS-EGFP in response to histamine. Cells were treated with 100  $\mu$ M histamine for 2 min in the presence or absence of the antagonist staurosporine. The MARCKS-EGFP translocation from the plasma membrane to perinuclear spots is detected by the image analysis algorithm.



Figure 5 shows a concentration response curve of the reference ligand histamine in the MARCKS Redistribution<sup>®</sup> agonist assay. The EC<sub>50</sub> of histamine is approximately 1  $\mu$ M. The assay can also be used to detect antagonists of histamine-induced translocation of MARCKS. The EC<sub>50</sub> of the broad PKC inhibitor staurosporine is ~90 nM

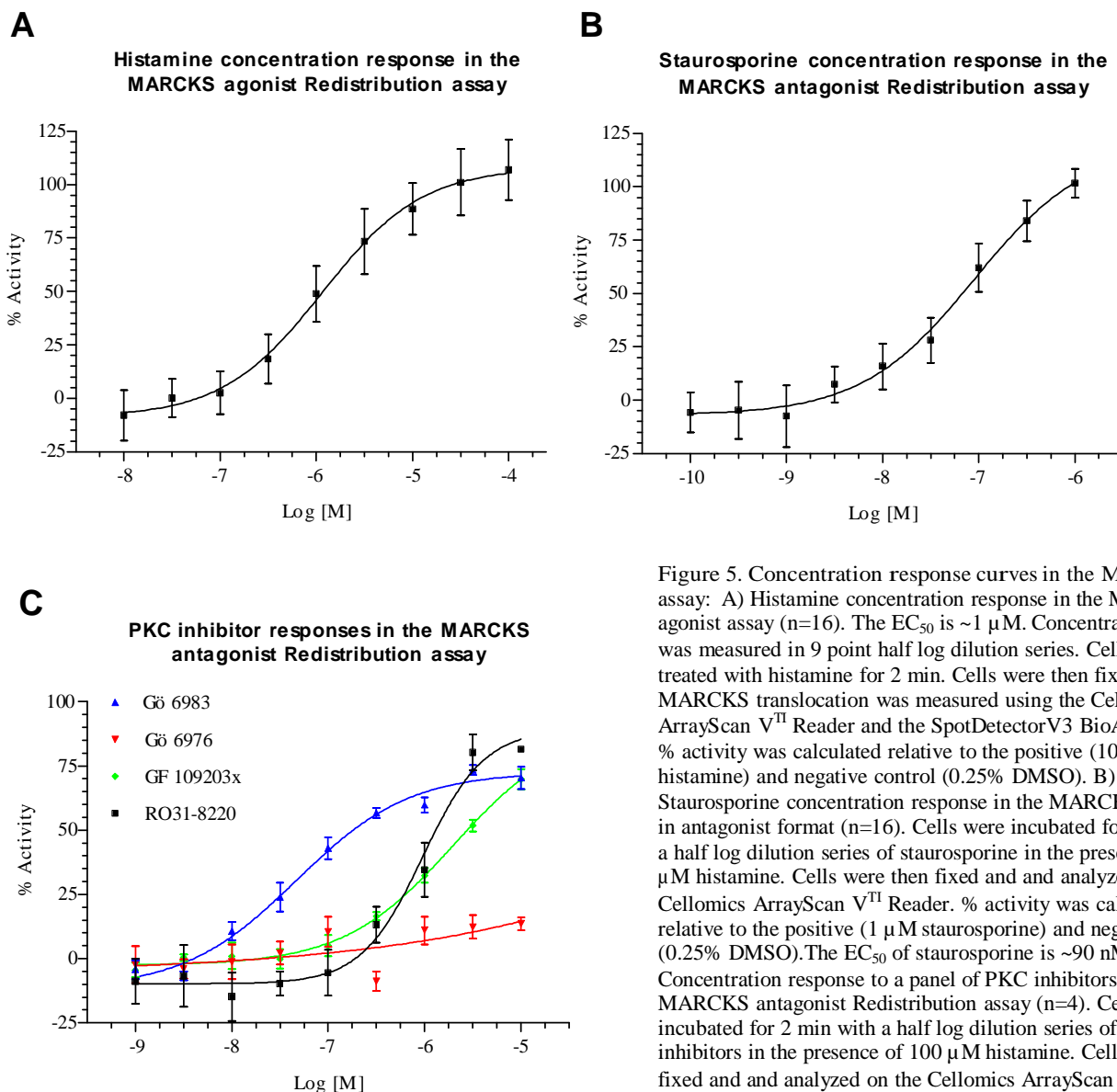


Figure 5. Concentration response curves in the MARCKS assay: A) Histamine concentration response in the MARCKS agonist assay (n=16). The EC<sub>50</sub> is ~1  $\mu$ M. Concentration response was measured in 9 point half log dilution series. Cells were treated with histamine for 2 min. Cells were then fixed and MARCKS translocation was measured using the Celloomics ArrayScan V<sup>TI</sup> Reader and the SpotDetectorV3 BioApplication. % activity was calculated relative to the positive (100  $\mu$ M histamine) and negative control (0.25% DMSO). B) Staurosporine concentration response in the MARCKS assay run in antagonist format (n=16). Cells were incubated for 2 min with a half log dilution series of staurosporine in the presence of 100  $\mu$ M histamine. Cells were then fixed and analyzed on the Celloomics ArrayScan V<sup>TI</sup> Reader. % activity was calculated relative to the positive (1  $\mu$ M staurosporine) and negative control (0.25% DMSO). The EC<sub>50</sub> of staurosporine is ~90 nM. C) Concentration response to a panel of PKC inhibitors in the MARCKS antagonist Redistribution assay (n=4). Cells were incubated for 2 min with a half log dilution series of the PKC inhibitors in the presence of 100  $\mu$ M histamine. Cells were then fixed and analyzed on the Celloomics ArrayScan V<sup>TI</sup> Reader. % activity was calculated relative to the positive (1  $\mu$ M staurosporine) and negative control (0.25% DMSO).

## Product qualification

Assay performance has been validated with an average Z' = 0.40 ± 0.09 in agonist mode and Z' = 0.52 ± 0.08 in antagonist mode. The cells have been tested for viability. The cells have been tested negative for mycoplasma and authenticated to be U2OS cells by DNA fingerprint STR analysis.



## Related Products

Product #	Type	Product description	Cell line
R04-098-01	Profiling & Screening	PKC $\beta$ Redistribution <sup>®</sup> Assay	U2OS
R04-099-01	Profiling & Screening	PKC $\epsilon$ Redistribution <sup>®</sup> Assay	U2OS
R04-017-02	Profiling & Screening	Gq-coupled GPCRs – NFATc1 Redistribution <sup>®</sup> Assay	U2OS
R04-045-02	Profiling & Screening	Gs/Gi-coupled GPCRs – PKA Redistribution <sup>®</sup> Assay	CHO-K1
R04-048-01	Profiling & Screening	NK1:NFATc1 Redistribution <sup>®</sup> Assay	U2OS

## References

1. Hartwig JH et al, Nature, 1992, Apr 16;356(6370):618-22.
2. Blackshear, JBC, 1993, 268 (3), Jan 25, 1501-1504
3. Aderem, A. Cell, 1992. 71, 713–716
4. Wang JK et al, PNAS, 1989, Apr; 86(7):2253-6

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For European customers:

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