SUMOylation of chromatin organization proteins

Lu, J., Matunis, MJ., May, B., Suske, G., Thibault, P., Yang, WC.

European Bioinformatics Institute, New York University Langone Medical Center, Ontario Institute for Cancer Research, Oregon Health and Science University.

The contents of this document may be freely copied and distributed in any media, provided the authors, plus the institutions, are credited, as stated under the terms of Creative Commons Attribution 4.0 International (CC BY 4.0) License. For more information see our license.

20/11/2021
Introduction

Reactome is open-source, open access, manually curated and peer-reviewed pathway database. Pathway annotations are authored by expert biologists, in collaboration with Reactome editorial staff and cross-referenced to many bioinformatics databases. A system of evidence tracking ensures that all assertions are backed up by the primary literature. Reactome is used by clinicians, geneticists, genomics researchers, and molecular biologists to interpret the results of high-throughput experimental studies, by bioinformaticians seeking to develop novel algorithms for mining knowledge from genomic studies, and by systems biologists building predictive models of normal and disease variant pathways.

The development of Reactome is supported by grants from the US National Institutes of Health (P41 HG003751), University of Toronto (CFREF Medicine by Design), European Union (EU STRP, EMI-CD), and the European Molecular Biology Laboratory (EBI Industry program).

Literature references


Reactome database release: 78

This document contains 1 pathway and 15 reactions (see Table of Contents)

https://reactome.org
SUMOylation of proteins involved in chromatin organization regulates gene expression in several ways: direct influence on catalytic activity of enzymes that modify chromatin, recruitment of proteins that form repressive (e.g. PRC1) or activating complexes on chromatin, recruitment of proteins to larger bodies (e.g. PML bodies) in the nucleus (reviewed in Cubenas-Potts and Matunis 2013).

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author/Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-13</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
PIAS1 SUMOylates L3MBTL2 with SUMO2

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-6804485

**Type:** transition

**Compartments:** nucleoplasm

PIAS1 and possibly other SUMO E3 ligases SUMOylates L3MBTL2 with SUMO2 at lysine-675 and lysine-700 near the C-terminus (Stielow et al. 2014, Tammsalu et al. 2014). SUMOylation of L3MBTL2 does not appear to affect its chromatin binding activity, however SUMOylation does enhance transcriptional repression of a subset of L3MBTL2-target genes, particularly those with low L3MBTL2 occupancy including pro-inflammatory genes (Stielow et al. 2014). SUMOylated L3MBTL2 appears to increase the level of local ubiquitinated histone H2A (Stielow et al. 2014).

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-10-10</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2015-10-10</td>
<td>Reviewed</td>
<td>Suske, G.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
PIAS1 SUMOylates SATB1 with SUMO1

**Location**: SUMOylation of chromatin organization proteins

**Stable identifier**: R-HSA-4615905

**Type**: transition

**Compartments**: nucleoplasm

PIAS1 SUMOylates SATB1 at lysine-744 with SUMO1 (Tan et al. 2008, Tan et al. 2010). SUMOylation targets SATB1 to PML bodies where it is cleaved by caspase.

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
PIAS1 SUMOylates SATB1 with SUMO2,3

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-4615839

**Type:** transition

**Compartments:** nucleoplasm

PIAS1 SUMOylates SATB1 at lysine-744 with SUMO2,3 (Tan et al. 2008, Tan et al. 2010, Tammsalu et al. 2014). SUMOylation targets SATB1 to PML bodies where it is cleaved by caspase.

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
PIAS1 SUMOylates SATB2 with SUMO3

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4615900

Type: transition

Compartments: nucleoplasm

PIAS1 SUMOylates SATB2 at lysine-233 and lysine-350 with SUMO3 (Dobreva et al. 2003, Lamoliatte et al. 2013, Lamoliatte et al. 2014). SUMOylation reduces binding of SATB2 to matrix attachment regions and reduces activation of transcription by SATB2. SUMOylated SATB2 is localized to the nuclear periphery.

Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Actions</th>
<th>Authors/Editors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-11</td>
<td>Edited, Reviewed</td>
<td>Thibault, P.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matonis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
PIAS2-2 SUMOylates SUZ12 with SUMO1

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4615873

Type: transition

Compartments: nucleoplasm

PIAS2-2 (PIASxbeta) SUMOylates SUZ12, a subunit of the Polycomb Repressive Complex 2 (PRC2), at lysine-75 with SUMO1 (Riising et al. 2008). SUMOylation does not affect the repression of transcription by PRC2. The effect of SUMOylation on PRC2 function is unknown. The EZH2 subunit of PRC2 can also be SUMOylated at multiple positions.

Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
RANBP2 SUMOylates HDAC4 with SUMO1

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4615872

Type: transition

Compartments: nuclear envelope, nucleoplasm


Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Author/Editor</th>
<th>Reviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
RANBP2 SUMOylates HDAC4 with SUMO2,3

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4615987

Type: transition

Compartments: nuclear envelope, nucleoplasm

RANBP2 SUMOylates HDAC4 at lysine-559 with SUMO2,3 (Kirsh et al. 2002). SUMOylation increases transcription repression by HDAC4.

Literature references

Dejean, A., Mathieu, M., Müller, S., Seeler, JS., Gast, A., Kirsh, O. et al. (2002). The SUMO E3 ligase RanBP2 promotes modification of the HDAC4 deacetylase. EMBO J., 21, 2682-91.

Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Author/Editor</th>
<th>Reviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
SUMOylation of HDAC1 with SUMO1

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4615889

Type: transition

Compartments: nucleoplasm

HDAC1 is SUMOylated at lysine-444 and lysine-476 with SUMO1 (Kirsh et al. 2002, David et al. 2002, Cheng et al. 2004, Citro et al. 2013). SUMOylation with SUMO1 enhances transcription repression by HDAC1 and promotes degradation of HDAC1 (Citro et al. 2013). HDAC1 can also be SUMOylated with SUMO2, which enhances stability of HDAC1 (Citro et al. 2013).

Literature references


Dejean, A., Mathieu, M., Müller, S., Seeler, JS., Gast, A., Kirsh, O. et al. (2002). The SUMO E3 ligase RanBP2 promotes modification of the HDAC4 deacetylase. EMBO J., 21, 2682-91.

Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Authors/Editors</th>
<th>Reviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
<td></td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matusis, MJ., Lu, J., Yang, WC.</td>
<td></td>
</tr>
</tbody>
</table>
SUMOylation of HDAC2 with SUMO1

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-4616015

**Type:** transition

**Compartments:** nucleoplasm

HDAC2 is SUMOylated at lysine-462 with SUMO1 (Brandl et al. 2012). SUMOylation of HDAC2 blocks TP53-dependent (p53-dependent) expression of genes but is required for induction of NF-kB-dependent gene expression (Wagner et al. 2015).

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
SUMOylation of Histone H4 with SUMO1

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4570496

Type: transition

Compartments: nucleoplasm

Histone H4 (HIST1H4) is SUMOylated at an unknown residue with SUMO1 (Shiio and Eisenman 2003). SUMOylated histone H4 is associated with repression of transcription.

Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author/Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-19</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
SUMOylation of Histone H4 with SUMO3

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4570485

Type: transition

Compartments: nucleoplasm

Histone H4 (HIST1H4) is SUMOylated at an unknown residue with SUMO3 (Shiio and Eisenman 2003). SUMOylation of histone H4 is associated with repression of transcription.

Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author/Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-19</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
CBX4 SUMOylates BMI1 in PRC1 with SUMO1

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-4551655

**Type:** transition

**Compartments:** nucleoplasm

CBX4 SUMOylates BMI1 in Polycomb Repressive Complex 1 (PRC1) at lysine-88 (Ismail et al. 2012). SUMOylation of BMI1 is necessary for its accumulation at sites of DNA damage. CBX4 directly binds poly(ADP-ribose) synthesized by PARP1 at sites of damage.

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-13</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
CBX4 SUMOylates CBX4 in PRC1 with SUMO1

Location: SUMOylation of chromatin organization proteins

Stable identifier: R-HSA-4551727

Type: transition

Compartments: nucleoplasm

CBX4 in Polycomb Repressive Complex 1 (PRC1) autoSUMOylates with SUMO1 (Kagey et al. 2005, Roscic et al. 2006, Merrill et al. 2010). As inferred from mouse homologs, SUMOylation of CBX4 appears to be essential for recruitment of the PRC1 complex to histone H3 trimethylated at lysine-27 (H3K27me3) (Kang et al. 2010).

Literature references


Editions

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-13</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
**SUMOylation of CBX5 with SUMO1**

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-4615933

**Type:** transition

**Compartments:** nucleoplasm

**Inferred from:** Sumoylation of Cbx5 with Sumo1 (Mus musculus)

As inferred from mouse homologs, CBX5 (HP1 alpha) is SUMOylated at lysine-84 and other lysine residues with SUMO1. SUMOylated CBX5 associates with long non-coding transcripts in pericentric heterochromatin and SUMOylation is required for initial targeting of CBX5 to pericentric domains.

**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author/Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-09-21</td>
<td>Authored, Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ., Lu, J., Yang, WC.</td>
</tr>
</tbody>
</table>
ZBED1 (DREF) SUMOylates CHD3 with SUMO1

**Location:** SUMOylation of chromatin organization proteins

**Stable identifier:** R-HSA-8956365

**Type:** transition

**Compartments:** nucleoplasm

ZBED1 (hDREF) SUMOylates CHD3 (Mi2alpha) at lysine-1971 with SUMO1 (Yamashita et al. 2016). SUMOylation leads to dissociation of CHD3 from chromatin and suppresses transcriptional repression by CHD3.

**Literature references**


**Editions**

<table>
<thead>
<tr>
<th>Date</th>
<th>Action</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-01-22</td>
<td>Authored</td>
<td>Lu, J.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Reviewed</td>
<td>Matunis, MJ.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Edited</td>
<td>May, B.</td>
</tr>
<tr>
<td>2017-01-22</td>
<td>Authored</td>
<td>Yang, WC.</td>
</tr>
</tbody>
</table>
Table of Contents

Introduction

SUMOylation of chromatin organization proteins

- PIAS1 SUMOylates L3MBTL2 with SUMO2
- PIAS1 SUMOylates SATB1 with SUMO1
- PIAS1 SUMOylates SATB1 with SUMO2,3
- PIAS1 SUMOylates SATB2 with SUMO3
- PIAS2-2 SUMOylates SUZ12 with SUMO1
- RANBP2 SUMOylates HDAC4 with SUMO1
- RANBP2 SUMOylates HDAC4 with SUMO2,3
- SUMOylation of HDAC1 with SUMO1
- SUMOylation of HDAC2 with SUMO1
- SUMOylation of Histone H4 with SUMO1
- SUMOylation of Histone H4 with SUMO3
- CBX4 SUMOylates BMI1 in PRC1 with SUMO1
- CBX4 SUMOylates CBX4 in PRC1 with SUMO1
- SUMOylation of CBX5 with SUMO1
- ZBED1 (DREF) SUMOylates CHD3 with SUMO1

Table of Contents