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Snapshot: Nonmotor Proteins in Spindle Assembly

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Chromosome segregation during cell division depends on the highly ordered bipolar microtubule structure known as the mitotic spindle. Organization of microtubules into this highly ordered structure relies on both motor and nonmotor proteins. Nonmotor spindle proteins fulfill diverse roles including nucleation and organization of microtubules, regulation of spindle shape and size, regulation of motor activity and microtubule dynamics, as well as control of chromosome segregation and cell-cycle progression. Many nonmotor spindle proteins display distinct localization patterns in mitosis, and several contribute to more than one functional activity within the spindle. Given this complexity, it is not surprising that nonmotor proteins frequently show altered expression patterns in cancer or mutations in human diseases.

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Abbreviations

APC	Adenomatosis Polyposis Coli
Astrin	Aster-associated protein
CLASP1/2	Cytoplasmic Linker-Associated Protein
CLIP170	CAP-GLY Domain-Containing Linker Protein
DDA3	Differential Display Activated by p53
DGT	Dim γ -tubulin
HURP/DLG7	Hepatoma Upregulated Protein
INCENP	INner CENtromere Protein
Lis1	Lissencephaly 1
MAPRE1/Eb1	Microtubule-Associated Protein, RP/EB family, member 1
NuMA	Nuclear Mitotic Apparatus
NuSAP	Nucleolar Spindle-Associated Protein
Op18/Stathmin	Oncoprotein 18
Prc1	Protein Regulator of Cytokinesis
RHAMM/HMMR	Receptor of Hyaluronan-Mediated Motility
TACC 1-3	Transforming Acidic Coiled-Coil
Tankyrase	TRF1-interacting Ankyrin-Related ADP-ribose
TD60	Telophase Disk 60kDa

TOGp	Tumor Overexpressed Gene
TPX2	Targeting Protein for Xklp2
Vkl	Vegetative Interaction with Kar3

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	Protein name	Species	Localization	Function in Spindle Assembly
Microtubule Nucleation/Stabilization	DGT/augmin complex	Human, fly	Spindle microtubules	Boosts microtubule number by regulating γ -tubulin
	NuSAP	Human, mouse, frog	Central spindle	Nucleation, stabilization, and bundling of microtubules near chromosomes
	* RHAMM/HMMR	Human, mouse, frog (XRHAMM)	Centrosomes, spindle poles, spindle midbody	Nucleates and stabilizes microtubules at spindle poles; influences cyclin B1 activity
	* TACC 1-3	Human, mouse, fly (D-TACC), worm (TACC-1), frog (Maskin), Sp (Alp7)	Centrosomes, spindle poles	Promotes microtubule nucleation and stabilization at spindle poles
	* TOGp	Human, mouse, fly (Minispindles/Msps), worm (ZYG-9), frog (XMAP215/Dis1), Sc (Stu2), Sp (Dis1/Alp14)	Centrosomes, spindle poles	Promotes centrosome and spindle pole stability; promotes plus-end microtubule dynamics
Microtubule Crosslinking/Stabilization	Astrin	Human, mouse (Spag5)	Spindle poles, kinetochores	Crosslinks and stabilizes microtubules at spindle poles and kinetochores; stabilizes cohesin
	* HURP/DLG7	Human, mouse, fly, worm, frog, Sc	Kinetochores fibers, most intense near kinetochores	Stabilizes kinetochores fiber; influences chromosome alignment
	* NuMA	Human, mouse, fly (Mud/Asp1), frog	Spindle poles	Formation/maintenance of spindle poles; inhibits APC/C at spindle poles
	* Prc1	Human, mouse, fly (Fascetto/Feo), worm (SPD-1), frog, Sc (Ase1), Sp (Ase1)	Central spindle, spindle midbody	Stabilizes anaphase spindle elongation by crosslinking antiparallel spindle midzone microtubules
	Tektin 2	Human, mouse, fly, worm, frog,	Centrosomes, midbody	Bundles microtubules of the midbody to allow cytokinesis
	* TPX2	Human, mouse, fly (Asp1), worm (TPXL-1), frog	Spindle poles, spindle midbody	Promotes microtubule nucleation and centrosome integrity; activates Aurora

	Protein name	Species	Localization	Function in Spindle Assembly
				A; crosslinks microtubules at spindle poles
Microtubule Severance/Destabilization	* DDA3	Human, mouse	Spindle microtubules, midbody	Bundles microtubules; regulates the spindle pole localized microtubule depolymerase Kif2a
	Fidgetin	Human, mouse (Fign1), fly (Fign1), worm (FIGL-1), frog (Fign1)	Centrosomes	Catalyzes turnover of γ -tubulin; contributes to microtubule depolymerization and chromosome movement
	Katanin	Human, mouse (Katan1), fly, worm (MEI), frog, Sc	Centrosomes, chromatin	Promotes microtubule plus-end depolymerization; contributes to pole-ward chromosome movement
	* Op18/Stathmin	Human, mouse (Stathmin), fly (Stathmin), frog (Stathmin)	Centrosomes, spindle poles	Regulates microtubule dynamics by promoting depolymerization and sequestering of tubulin dimers
	* Spastin	Human, mouse, fly (D-Spastin), worm, frog	Spindle poles, spindle midbody	Catalyzes turnover of γ -tubulin; contributes to microtubule depolymerization and chromosome movement
+ Tip Trackers	* APC	Human, mouse, fly, worm (APR-1), frog, Sc (Kar9)	Growing microtubule plus ends	Stabilizes microtubule plus ends; influences chromosome alignment
	CLASP1, 2	Human, mouse, fly (MAST/Orbit), worm (CLS-2) Sp (Peg1)	Growing microtubule plus ends	Stabilizes plus-end microtubule dynamics; influences spindle formation and chromosome alignment
	CLIP170	Human, mouse, fly, frog, Sc (Bik1), Sp (Tip1)	Growing microtubule plus ends	Regulates plus-end microtubule dynamics by promoting rescue of depolymerization
	* Lis1	Human, mouse, fly, worm, frog, Sc (Pac1)	Growing microtubule plus ends	Recruits dynein to microtubule plus ends

	Protein name	Species	Localization	Function in Spindle Assembly
	* MAPRE1/Eb1	Human, mouse, fly, worm, frog, Sc (Bim1), Sp (Mal3)	Growing microtubule plus ends	Regulates growth of microtubule plus ends by suppressing depolymerization; influences chromosome alignment
Chromosomal Passenger Complex	* Aurora B	Human, mouse (AIM-1), fly (Lal), worm (AIR-2) frog, Sc (Ipl1), Sp (ARK1)	Inner centromeres in metaphase, central spindle/ midbody in anaphase	Regulates spindle structure, kinetochore-microtubule attachment, and error correction; mitotic progression, cytokinesis
	* Borealin	Human, mouse, fly (Borr), worm (CSC-1), frog (Dasra)	Inner centromeres in metaphase, central spindle/ midbody in anaphase	Controls the localization and activity of Aurora B
	INCENP	Human, mouse, fly, worm (ICP-1), frog, Sc (Sli15), Sp (Plc1)	Inner centromeres in metaphase, central spindle/ midbody in anaphase	Controls the localization and activity of Aurora B
	* Survivin	Human, mouse, fly (Deterin), frog, worm (BIR-1), Sc (Bir1), Sp (Bir1/Cut17)	Inner centromeres in metaphase, central spindle/ midbody in anaphase	Controls the localization and activity of Aurora B; protects against apoptosis
	TD60	Human, mouse, fly, frog	Inner centromeres in metaphase, central spindle/ midbody in anaphase	Activates the kinase activity of Aurora B
Others	CHICA	Human	Spindle microtubules	Polar ejection in cooperation with the chromokinesin Kid
	Chromator	Fly	Fusiform spindle shape around spindle microtubules	Forms a microtubule-independent fusiform spindle; influences bipolar spindle formation; putative spindle matrix protein
	* Dynactin	Human, mouse, fly, worm, frog, Sc, Sp	Spindle poles, kinetochores, spindle midbody	Coactivator of dynein, required for dynein functions including spindle pole focusing and chromosome movement
	* Lamin B	Human, mouse, fly, worm, frog	Spindle microtubules	Promotes microtubule assembly and organization; putative spindle matrix protein
	Megator	Fly	Fusiform spindle shape around spindle microtubules	Forms complex with Skeletor/

	Protein name	Species	Localization	Function in Spindle Assembly
				Chromator; forms microtubule-independent fusiform spindle; putative spindle matrix protein
	Skeletor	Fly	Fusiform spindle shape around spindle microtubules	Forms a microtubule-independent fusiform spindle; putative spindle matrix protein
	* Tankyrase	Human, mouse, fly, worm (PME-5), frog	Spindle poles	Contributes to spindle pole focusing; putative spindle matrix protein
	Vik1	Sc	Spindle pole body	Influences microtubule stability by regulation of the kinesin Kar3

Sp, *Schizosaccharomyces pombe*

Sc, *Saccharomyces cerevisiae*

* overexpression or mutation linked to human cancer or other diseases