Supplemental Materials

Molecular Biology of the Cell

Moser et al.

SUPPLEMENTAL MATERIALS

Ccq1-Tpz1^{TPP1} interaction facilitates telomerase and SHREC association with telomeres in fission yeast

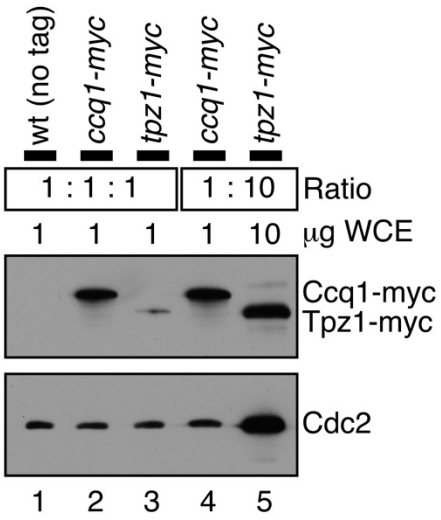
Bettina A. Moser[a], Olga N. Raguimova[a], and Toru M. Nakamura[a]

[a]Department of Biochemistry and Molecular Genetics, College of Medicine, University of Illinois at Chicago, Chicago, Illinois, USA.

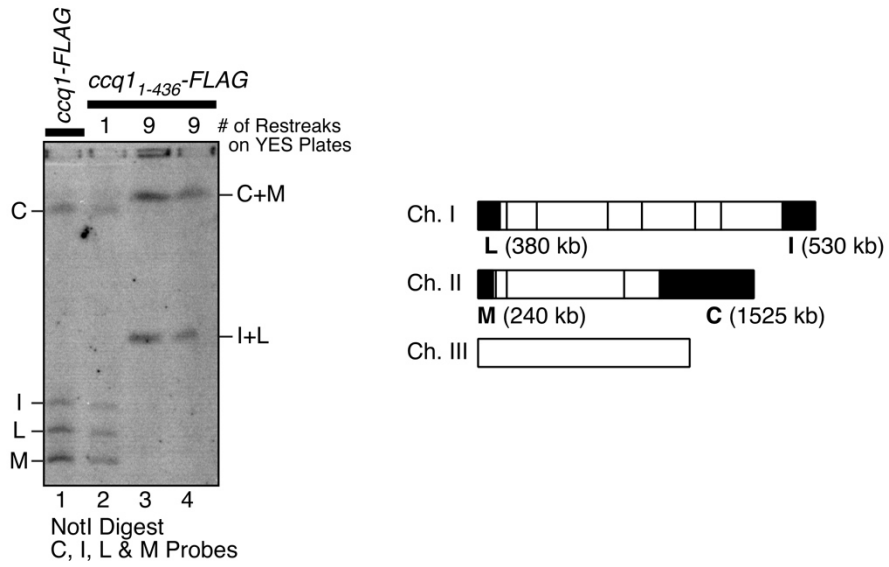
Supplemental Figures S1-S4

Supplemental Tables S1-S4

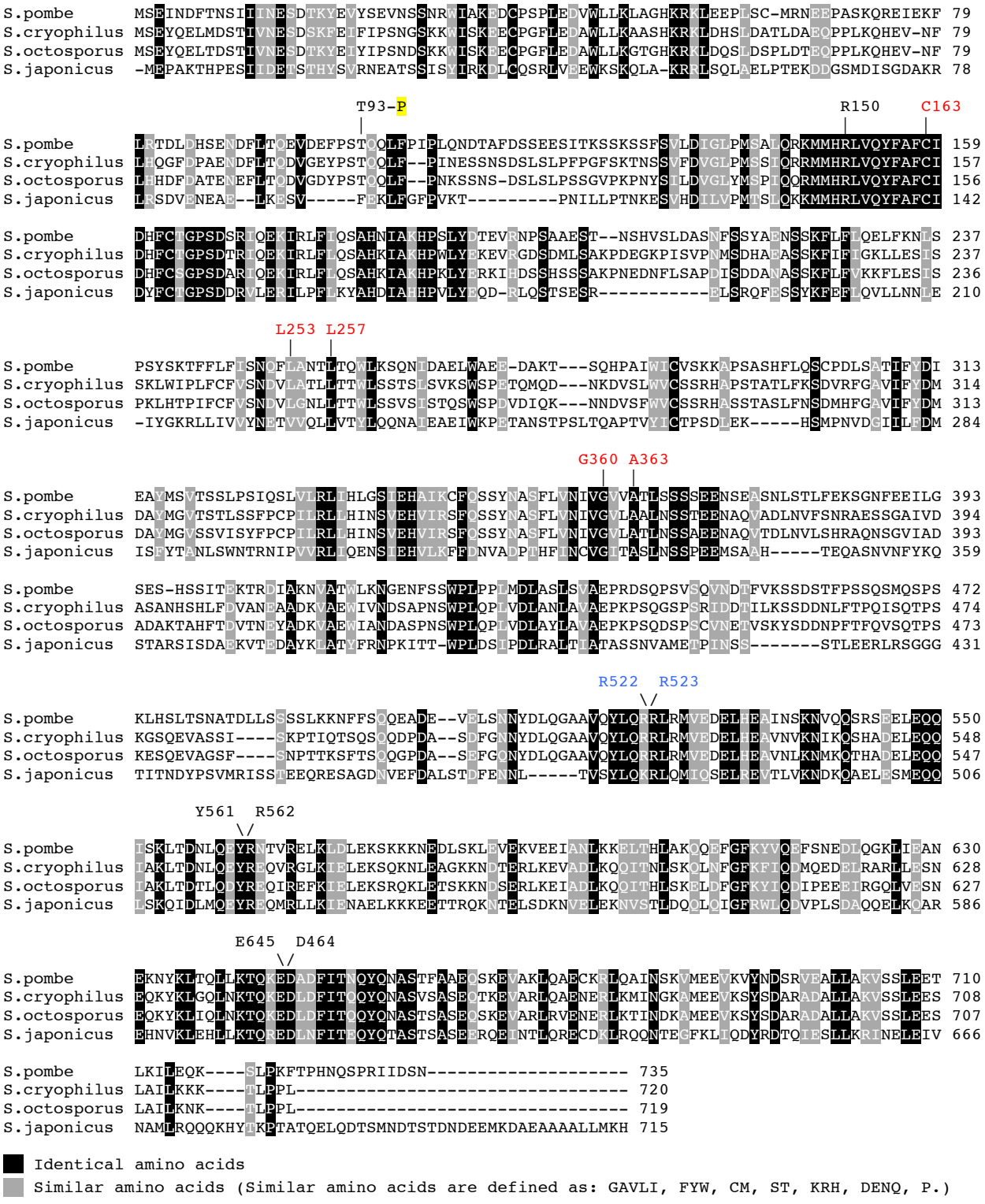
Supplemental References



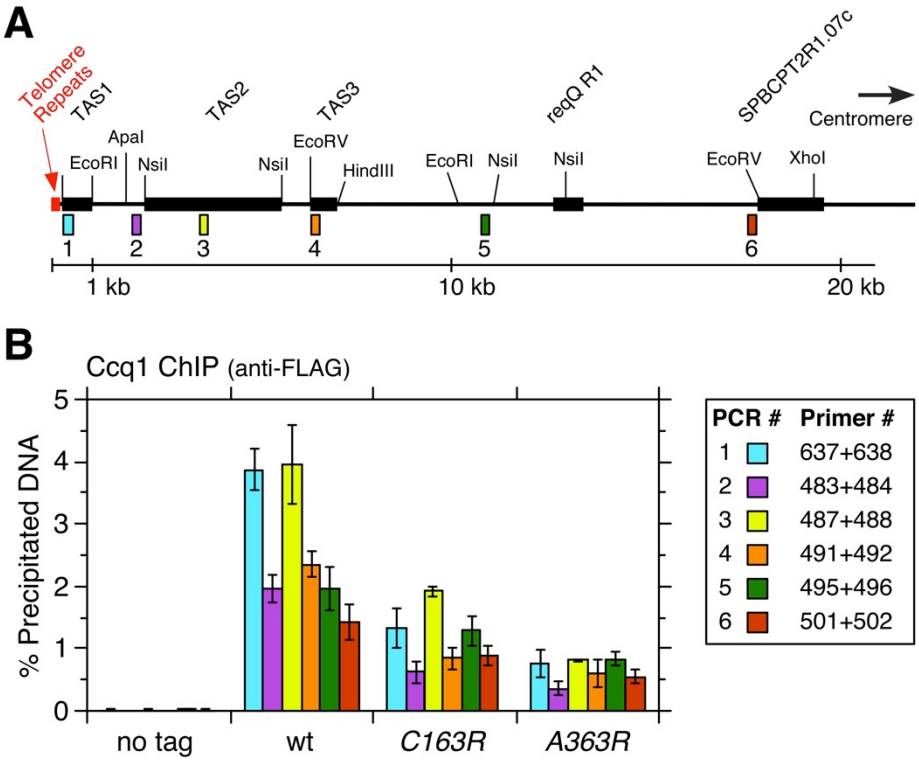
Supplemental Figure S1. Comparison of expression levels for Ccq1 and Tpz1^{TPP1}. The indicated amounts of whole cell extracts from strains that carry either myc-tagged Ccq1 or Tpz1^{TPP1} were analyzed by anti-myc western blot analysis. Analysis indicated that Ccq1 expression level is at least 10-fold greater than Tpz1^{TPP1} expression level.



Supplemental Figure S2. Characterization of chromosome structure for *ccq1$_{1-436}$* cells. Pulsed-field gel analysis found that after successive restreaks on YES plates, *ccq1$_{1-436}$* cells survive by circularizing chromosomes. Samples were prepared from early (1x) or extensively restreaked (9x) samples as indicated. A NotI restriction map of *S. pombe* chromosomes is also shown to the right. Telomeric NotI fragments (C, I, L, and M) are indicated with black boxes.



Supplemental Figure S3. Sequence alignment of Ccq1 from closely related fission yeast species. Ccq1 sequences from *S. pombe*, *S. cryophilus*, *S. octosporus*, and *S. japonicus* (Rhind *et al.*, 2011) were aligned using MUSCLE (MUltiple Sequence Comparison by Log-Expectation) program (Edgar, 2004). Amino acid residues mutated in the current study, and Ccq1 Thr93 phosphorylation site are indicated.



Supplemental Figure S4. Ccq1 binding distribution at sub-telomere regions for wild-type and Ccq1-Tpz1^{TPP1} interaction disruption mutants of Ccq1. (**A**) A schematic map of telomere and sub-telomere regions based on the *S. pombe* genome sequencing project (Wood *et al.*, 2002) and our own sequencing of sub-telomere regions. Main features are indicated above. Colored bars marked with numbers indicate locations of PCR products for ChIP analysis shown in (B). (**B**) Ccq1 ChIP analysis for sub-telomere regions. Results are ordered from boxes 1 to 6, and color-coded as in the map shown in (A), and primer numbers for PCR are given. Primer sequences used in ChIP are summarized in Supplemental Table S3. Error bars represent standard error of the mean from at least three experimental replicates.

Table S1 Fission yeast strains used in this study.

Figure		Strain		Full Genotype[a]
1C	1	TN2411	*ccq1*$^+$ (no tag)	*h*$^-$ *his3-D1*
	2	YTC6732	*ccq1-FLAG*	*h*$^-$ *his3-D1 ccq1*$^+$*::5FLAG-kanMX6*
	3-5	TN13162, BAM13523, BAM13524	*ccq1*$_{1-632}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-632)}$*::5FLAG-kanMX6* (13162 1x; 13523 4x; 13524 9x)
	6-8	TN13160, BAM13521, BAM13522	*ccq1*$_{1-583}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-583)}$*::5FLAG-kanMX6* (13160 1x; 13521 4x; 13522 9x)
	9-11	TN13158, BAM13519, BAM13520	*ccq1*$_{1-500}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-500)}$*::5FLAG-kanMX6* (13158 1x; 13519 4x; 13520 9x)
	12-14	TN13156, BAM13511, BAM31512	*ccq1*$_{1-436}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-436)}$*::5FLAG-kanMX6* (13156 1x; 13511 4x; 13512 9x)
1D	1	TN2411	*ccq1*$^+$ (no tag)	*h*$^-$ *his3-D1*
	2-4	YTC6732	*ccq1-FLAG*	*h*$^-$ *his3-D1 ccq1*$^+$*::5FLAG-kanMX6*
	5	TN13162	*ccq1*$_{1-632}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-632)}$*::5FLAG-kanMX6*
	6	TN13160	*ccq1*$_{1-583}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-583)}$*::5FLAG-kanMX6*
	7	TN13158	*ccq1*$_{1-500}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-500)}$*::5FLAG-kanMX6*
	8	TN13156	*ccq1*$_{1-436}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-436)}$*::5FLAG-kanMX6*
1E	1	TN13162	*ccq1*$_{1-632}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-632)}$*::5FLAG-kanMX6*
	2	TN13340	*ccq1*$_{1-632}$*-FLAG tpz1-myc*	*h*$^-$ *his3-D1 tpz1*$^+$*::13myc-hphMX6 ccq1*$_{(1-632)}$*::5FLAG-kanMX6*
	3	TN13160	*ccq1*$_{1-583}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-583)}$*::5FLAG-kanMX6*
	4	TN13336	*ccq1*$_{1-583}$*-FLAG tpz1-myc*	*h*$^-$ *his3-D1 tpz1*$^+$*::13myc-hphMX6 ccq1*$_{(1-583)}$*::5FLAG-kanMX6*
	5	TN13156	*ccq1*$_{1-436}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-436)}$*::5FLAG-kanMX6*
	6	TN13328	*ccq1*$_{1-436}$*-FLAG tpz1-myc*	*h*$^-$ *his3-D1 tpz1*$^+$*::13myc-hphMX6 ccq1*$_{(1-436)}$*::5FLAG-kanMX6*
	7	TN13158	*ccq1*$_{1-500}$*-FLAG*	*h*$^+$ *his3-D1 ccq1*$_{(1-500)}$*::5FLAG-kanMX6*
	8	TN13332	*ccq1*$_{1-500}$*-FLAG tpz1-myc*	*h*$^-$ *his3-D1 tpz1*$^+$*::13myc-hphMX6 ccq1*$_{(1-500)}$*::5FLAG-kanMX6*
1F		TN2411	*his*$^-$	*h*$^-$ *his3-D1*
		TN3784	*his+*	*h*$^-$
		CF52	telomere (1L)::*his3*$^+$ *ccq1*$^+$ (wt)	*h*^{90} *ura4-DS/E ade6-M210 his3-D1 his3*$^+$*::tel(1L)*
		TN13459	telomere (1L)::*his3*$^+$ *ccq1*$_{1-632}$	*h*$^-$ *ura4-DS/E or ura4-D18 his3-D1 ccq1*$_{(1-632)}$*::5FLAG-kanMX6 his3*$^+$*::tel(1L)*
		TN13455	telomere (1L)::*his3*$^+$ *ccq1*$_{1-583}$	*h*$^-$ *his3-D1 ccq1*$_{(1-583)}$*::5FLAG-kanMX6 his3*$^+$*::tel(1L)*
		TN13399	telomere (1L)::*his3*$^+$ *ccq1*$_{1-500}$	*h*$^-$ *his3-D1 ccq1*$_{(1-500)}$*::5FLAG-kanMX6 his3*$^+$*::tel(1L)*
		TN13395	telomere (1L)::*his3*$^+$ *ccq1*$_{1-436}$	*h*$^-$ *his3-D1 ccq1*$_{(1-436)}$*::5FLAG-kanMX6 his3*$^+$*::tel(1L)*
		TN9133	telomere (1L)::*his3*$^+$ *ccq1Δ*	*h*$^-$ *his3-D1 ccq1Δ::hphMX his3*$^+$*::tel(1L)*
2B	1,19	TN2411	*ccq1*$^+$ (no tag)	*h*$^-$ *his3-D1*
	2,18,20	YTC6732	*ccq1-FLAG*	*h*$^-$ *his3-D1 ccq1*$^+$*::5FLAG-kanMX6*
	3-5	OR11529, OR11749	*ccq1-R150A-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-R150A::5FLAG-kanMX6* (11529 1x; 11749 9x; did not keep 5x stock)
	6-8	TN10611, TN10613	*ccq1-C163R-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6* (10611 1x; 10613 9x; did not keep 5x stock)
	9-11	OR11530, OR11750	*ccq1-L253R-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-L253R::5FLAG-kanMX6* (11530 1x; 11750 9x; did not keep 5x stock)
	12-14	OR11531, OR11752	*ccq1-L257R-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-L257R::5FLAG-kanMX6* (11531 1x; 11752 9x; did not keep 5x stock)
	15-17	OR11532, OR11754	*ccq1-G360R-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-G360R::5FLAG-kanMX6* (11532 1x; 11754 9x; did not keep 5x stock)
	21-23	TB11538, OR11760	*ccq1-A363R-FLAG*	*h*$^-$ *ade6-M216 his3-D1 ccq1-A363R::5FLAG-kanMX6* (11538 1x; 11760 9x; did not keep 5x stock)
	24-26	OR11533, OR11756	*ccq1-R522A,R523A-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-R522A,R523A::5FLAG-kanMX6* (11533 1x; 11756 9x; did not keep 5x stock)
	27-29	OR11534, OR11758	*ccq1-Y561A,R562A-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-Y561A,R562A::5FLAG-kanMX6* (11534 1x; 11758 9x; did not keep 5x stock)
	30-32	OR11535, OR11759	*ccq1-E645A,D646A-FLAG*	*h*$^-$ *ade6-M210 his3-D1 ccq1-E645A,D646A::5FLAG-kanMX6* (11535 1x; 11759 9x; did not keep 5x stock)
2C	1,7	TN7506	*ccq1-FLAG* (wt)	*h*$^-$ *his3-D1 tpz1*$^+$*::13myc-kanMX6 ccq1*$^+$*::5FLAG-kanMX6*
	2	BAM10855	*ccq1-T93A-FLAG*	*h*$^+$ *his3-D1 tpz1*$^+$*::13myc-kanMX6 ccq1-T93A::5FLAG-kanMX6*
	3	TN11914	*ccq1-R150A-FLAG*	*h*$^+$ *ade6-M210 his3-D1 tpz1*$^+$*::13myc-hphMX6 ccq1-R150A::5FLAG-kanMX6*

	4	TN10675	*ccq1-C163R-FLAG*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-kanMX6 ccq1-C163R::5FLAG-kanMX6*
	5	TN11917	*ccq1-L253R-FLAG*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-L253R::5FLAG-kanMX6*
	6	TN11919	*ccq1-L257R-FLAG*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-L257R::5FLAG-kanMX6*
	8	TN11920	*ccq1-G360R-FLAG*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-G360R::5FLAG-kanMX6*
	9	TN11922	*ccq1-A363R-FLAG*	*h$^+$ ade6-M216 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-A363R::5FLAG-kanMX6*
	10	TN11925	*ccq1-R522A,R523A-FLAG*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-R522A,R523A::5FLAG-kanMX6*
	11	TN11926	*ccq1-Y561A,R562A-FLAG*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-Y561A,R562A::5FLAG-kanMX6*
	12	TN11928	*ccq1-E645A,D646A-FLAG*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-E645A,D646A::5FLAG-kanMX6*
2D	1	YTC6732	*ccq1-FLAG*	*h$^-$ his3-D1 ccq1$^+$::5FLAG-kanMX6*
	2	TN7506	*ccq1-FLAG* (wt) *tpz1-myc*	*h$^-$ his3-D1 tpz1$^+$::13myc-kanMX6 ccq1$^+$::5FLAG-kanMX6*
	3	BAM10855	*ccq1-T93A-FLAG tpz1-myc*	*h$^+$ his3-D1 tpz1$^+$::13myc-kanMX6 ccq1-T93A::5FLAG-kanMX6*
	4	TN11914	*ccq1-R150A-FLAG tpz1-myc*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-R150A::5FLAG-kanMX6*
	5	TN10675	*ccq1-C163R-FLAG tpz1-myc*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-kanMX6 ccq1-C163R::5FLAG-kanMX6*
	6	TN11917	*ccq1-L253R-FLAG tpz1-myc*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-L253R::5FLAG-kanMX6*
	7	TN11919	*ccq1-L257R-FLAG tpz1-myc*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-L257R::5FLAG-kanMX6*
	8	TN11920	*ccq1-G360R-FLAG tpz1-myc*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-G360R::5FLAG-kanMX6*
	9	TN11922	*ccq1-A363R-FLAG tpz1-myc*	*h$^+$ ade6-M216 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-A363R::5FLAG-kanMX6*
	10	TN11925	*ccq1-R522A,R523A-FLAG tpz1-myc*	*h$^-$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-R522A,R523A::5FLAG-kanMX6*
	11	TN11926	*ccq1-Y561A,R562A-FLAG tpz1-myc*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-Y561A,R562A::5FLAG-kanMX6*
	12	TN11928	*ccq1-E645A,D646A-FLAG tpz1-myc*	*h$^+$ ade6-M210 his3-D1 tpz1$^+$::13myc-hphMX6 ccq1-E645A,D646A::5FLAG-kanMX6*
3A	1,18	TN2411	*ccq1$^+$* (no tag)	*h$^-$ his3-D1*
	2,17	YTC6732	*ccq1-FLAG*	*h$^-$ his3-D1 ccq1$^+$::5FLAG-kanMX6*
	3	TN9258	*ccq1Δ*	*h$^-$ his3-D1 ccq1Δ::hphMX* (linear chromosomes)
	4	TN9259	*ccq1Δ*	*h$^-$ his3-D1 ccq1Δ::hphMX* (circular chromosomes)
	5-8	TN10611, TN10612, TN10613, TN13532	*ccq1-C163R-FLAG*	*h$^-$ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6* (10611 1x; 10612 3x; 10613 8x; 13532 16x)
	9-11	BAM13533, BAM13534, BAM13535	*ccq1-C163R-FLAG*	*h$^+$ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6* (derived from dissection of diploid 11526) (13533 1x; 13534 5x small colonies; 13535 5x large colonies)
	12-14		*ccq1-C163R-FLAG*	*h$^?$ ade6-M210/M216 his3-D1 ccq1-C163R::5FLAG-kanMX6* (derived from dissection of diploid 11526 but did not create entries in our strain collection) (lane #12 1x; lane #13 5x small colonies; lane #14 5x large colonies)
	15	TN11930	*ccq1-C163R-FLAG poz1Δ*	*h$^+$ his3-D1 poz1Δ::natMX6 ccq1-C163R::5FLAG-kanMX6*
	16	TN11931	*ccq1-C163R-FLAG poz1Δ*	*h$^-$ ade6-M210 his3-D1 poz1Δ::natMX6 ccq1-C163R::5FLAG-kanMX6*
		TN11526	*ccq1-C163R-FLAG/ccq1$^+$*	*h$^+$/h^{90} ade6-M210/ade6-M216 his3-D1/his3-D1 ccq1-C163R::5FLAG-kanMX6/ccq1$^+$*
3C	1	YTC6732	*ccq1-FLAG*	*h$^-$ his3-D1 ccq1$^+$::5FLAG-kanMX6*
	2	TN9258	*ccq1Δ*	*h$^-$ his3-D1 ccq1Δ::hphMX* (linear chromosomes)
	3	TN9259	*ccq1Δ*	*h$^-$ his3-D1 ccq1Δ::hphMX* (circular chromosomes)
	4-7	TN10611, TN10612, TN10613, TN13532	*ccq1-C163R-FLAG*	*h$^-$ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6* (10611 1x; 10612 3x; 10613 8x; 13532 16x)
	8-10	BAM13533, BAM13534, BAM13535	*ccq1-C163R-FLAG*	*h$^+$ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6* (derived from dissection of diploid 11526) (13533 1x; 13534 5x small colonies; 13535 5x large colonies)
	11-13		*ccq1-C163R-FLAG*	*h$^?$ ade6-M210/M216 his3-D1 ccq1-C163R::5FLAG-kanMX6* (derived from dissection of diploid 11526 but did not create entries in our strain collection) (lane #12 1x; lane #13 5x small colonies; lane #14 5x large colonies)
3D	1	YTC8354	*poz1Δ*	*h$^-$ ade6-M216 his3-D1 poz1Δ::natMX6*
	2	YTC6732	*ccq1-FLAG*	*h$^-$ his3-D1 ccq1$^+$::5FLAG-kanMX6*
	3	TN10611	*ccq1-C163R-FLAG*	*h$^-$ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6*
	4	TN10531	*ccq1-FLAG poz1Δ*	*h$^-$ his3-D1 poz1Δ::natMX6 ccq1-5FLAG:kanMX6*
	5	TN11930	*ccq1-C163R-FLAG poz1Δ*	*h$^+$ his3-D1 poz1Δ::natMX6 ccq1-C163R::5FLAG-kanMX6*
	6	TN11931	*ccq1-C163R-FLAG poz1Δ*	*h$^-$ ade6-M210 his3-D1 poz1Δ::natMX6 ccq1-C163R::5FLAG-kanMX6*

4A		TN9496	*ccq1-C163R*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::natMX*
		TN9542	*ccq1-L253R*	*h⁻ ade6-M210 his3-D1 ccq1-L253R::natMX*
		TN9547	*ccq1-L257R*	*h⁻ ade6-M210 his3-D1 ccq1-L257R::natMX*
		TN9462	*ccq1-G360R*	*h⁺ ade6-M210 his3-D1 ccq1-G360R::natMX*
		TN9551	*ccq1-A363R*	*h⁻ ade6-M216 his3-D1 ccq1-A363R::natMX*
		TN6584	*ccq1Δ*	*h⁻ ade6-M210 his3-D1 ccq1Δ::hphMX*
		CF199	*ccq1⁺*	*h⁻ ade6-M210 his3-D1*
4B	1	TN11335	*chk1-myc ccq1-C163R*	*h⁻ ade6-M216 his3-D1 ccq1-C163R::5FLAG-kanMX6 chk1+::9myc-2HA-6His-ura4⁺*
	2	TN6591	*chk1-myc ccq1-L253R*	*h⁻ ade6-M216 his3-D1 ccq1-L253R::5FLAG-kanMX6 chk1+::9myc-2HA-6His-ura4⁺*
	3	TN6593	*chk1-myc ccq1-L257R*	*h⁻ ade6-M216 his3-D1 ccq1-L257R::5FLAG-:kanMX6 chk1+::9myc-2HA-6His-ura4⁺*
	4	TN6595	*chk1-myc ccq1-G360R*	*h⁻ ade6-M216 his3-D1 ccq1-G360R::-5FLAG-kanMX6 chk1+::9myc-2HA-6His-ura4⁺*
	5	TN6597	*chk1-myc ccq1-A363R*	*h⁻ ade6-M216 his3-D1 ccq1-A363R::5FLAG-kanMX6 chk1+::9myc-2HA-6His-ura4⁺*
	6	TN11330	*chk1-myc ccq1Δ*	*h⁻ ade6-M216 his3-D1 ccq1Δ::hphMX chk1+::9myc-2HA-6His-ura4⁺*
	7,8	TN890	*chk1-myc ccq1⁺*	*h⁻ ade6-M216 his3-D1 chk1+::9myc-2HA-6His-ura4⁺*
4C		TN2411	*rad26⁺* (no tag) *ccq1⁺*	*h⁻ his3-D1*
		TN12428, TN12429	*myc-rad26 ccq1⁺*	*his3-D1 ccq1⁺::natMX 9myc-rad26⁺::hphMX6* (12428 *h⁺*; 12429 *h⁻*)
		TN12439, TN12440	*myc-rad26 ccq1-C163R*	*ade6-M210 his3-D1 ccq1-C163R::natMX6 9myc-rad26⁺::hphMX6* (12439 *h⁻*; 12440 *h⁺*)
		TN12443, TN12444	*myc-rad26 ccq1-A363R*	*h⁻ ade6-M216 his3-D1 ccq1-A363R::natMX 9myc-rad26⁺::hphMX6*
		TN12435, TN12436	*myc-rad26 ccq1Δ*	*his3-D1 ccq1Δ::hphMX 9myc-rad26⁺::hphMX6* (12435 *h⁻ ade6-M216*; 12436 *h⁺*)
5A		TN2411	*ccq1⁺* (no tag)	*h⁻ his3-D1*
		YTC6732	*ccq1-FLAG*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6*
		TN10611	*ccq1-C163R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6*
		OR11530	*ccq1-L253R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-L253R::5FLAG-kanMX6*
		OR11531	*ccq1-L257R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-L257R::5FLAG-kanMX6*
		OR11532	*ccq1-G360R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-G360R::5FLAG-kanMX6*
		TB11538	*ccq1-A363R-FLAG*	*h⁻ ade6-M216 his3-D1 ccq1-A363R::5FLAG-kanMX6*
5B		TN2411	*trt1⁺* (no tag) *ccq1⁺*	*h⁻ his3-D1*
		TN7706, TN7707	*trt1-myc ccq1⁺*	*h⁻ his3-D1 trt1+::G8-13myc-kanMX6*
		TN12852, TN12853	*trt1-myc ccq1-C163R*	*h⁻ his3-D1 trt1+::G8-13myc-kanMX6 ccq1-C163R::natMX*
		TN12856, TN12857	*trt1-myc ccq1-A363R*	*h⁻ his3-D1 trt1+::G8-13myc-kanMX6 ccq1-A363R::natMX*
		TN8960, TN8963	*trt1-myc ccq1Δ*	*his3-D1 trt1⁺::G8-13myc-kanMX6 ccq1Δ::hphMX (8960 h⁺; 8963 h⁻)*
5C	1	TN7506	*ccq1-FLAG*	*h⁻ his3-D1 tpz1⁺::13myc-kanMX6 ccq1⁺::5FLAG-kanMX6*
	2	YTC10106	*ccq1-FLAG rap1Δ*	*h⁻ his3-D1 rap1Δ::ura4⁺ tpz1⁺::13myc-kanMX6 ccq1⁺::5FLAG-kanMX6*
	3	TN10675	*ccq1-C163R-FLAG*	*h⁺ ade6-M210 his3-D1 tpz1⁺::13myc-kanMX6 ccq1-C163R::5FLAG-kanMX6*
	4	TN10686	*ccq1-C163R-FLAG rap1Δ*	*h⁻ ade6-M210 his3-D1 rap1Δ::ura4⁺ tpz1⁺::13myc-kanMX6 ccq1-C163R::5FLAG-kanMX6*
	5	TN11922	*ccq1-A363R-FLAG tpz1⁺*	*h⁺ ade6-M216 his3-D1 tpz1⁺::13myc-hphpMX6 ccq1-A363R::5FLAG-kanMX6*
	6	TN12794	*ccq1-A363R-FLAG tpz1⁺ rap1Δ*	*h⁻ ade6-M216 his3-D1 rap1Δ::ura4⁺ tpz1⁺::13myc-hphpMX6 ccq1-A363R::5FLAG-kanMX6*
	7	BAM10855	*ccq1-T93A-FLAG*	*h⁺ his3-D1 tpz1⁺::13myc-kanMX6 ccq1-T93A::5FLAG-kanMX6*
	8	BAM10857	*ccq1-T93A-FLAG rap1Δ*	*h⁻ ade6-M210 his3-D1 rap1Δ::ura4⁺ tpz1⁺::13myc-kanMX6 ccq1-T93A::5FLAG-kanMX6*
	9	TN9011	*ccq1Δ*	*h⁻ his3-D1 tpz1⁺::13myc-kanMX6 ccq1Δ::hphMX*
	10	LK9883	*ccq1Δ rap1Δ*	*h⁻ his3-D1 rap1Δ::ura4⁺ tpz1⁺::13myc-kanMX6 ccq1Δ::hphMX*
	11	JH11174	*ccq1-FLAG tpz1-L449R*	*h⁻ tpz1-L449R::13myc-kanMX6 ccq1⁺::5FLAG-kanMX6*
	12	JH11544	*ccq1-FLAG tpz1-L449R rap1Δ*	*h⁻ his3-D1 rap1Δ::ura4⁺ tpz1-L449R::13myc-kanMX6 ccq1⁺::5FLAG-kanMX6*

6A		TN2411	*his⁻*	*h⁻ his3-D1*
		TN3784	*his+*	*h⁻*
		TN9125	telomere (1L)::*his3⁺ ccq1⁺* (wt)	*h⁻ ade6-M210 his3-D1 his3⁺::tel(1L)*
		TN9658	telomere (1L)::*his3⁺ ccq1-R150R*	*h⁻ ade6-M210 his3-D1 ccq1-R150A::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9666	telomere (1L)::*his3⁺ ccq1-C163R*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9668	telomere (1L)::*his3⁺ ccq1-L253R*	*h⁻ ade6-M210 his3-D1 ccq1-L253R::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9670	telomere (1L)::*his3⁺ ccq1-L257R*	*h⁻ ade6-M210 his3-D1 ccq1-L257R::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9672	telomere (1L)::*his3⁺ ccq1-G360R*	*h⁻ ade6-M210 his3-D1 ccq1-G360R::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9673	telomere (1L)::*his3⁺ ccq1-A363R*	*h⁺ ade6-M216 his3-D1 ccq1-A363R::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9660	telomere (1L)::*his3⁺ ccq1-R522A,R523A*	*h⁻ ade6-M210 his3-D1 ccq1-R522A,R523A::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9662	telomere (1L)::*his3⁺ ccq1-Y561A,R562A*	*h⁻ ade6-M210 his3-D1 ccq1-Y561A,R562A::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9664	telomere (1L)::*his3⁺ ccq1-E645A,D646A*	*h⁻ ade6-M210 his3-D1 ccq1-E645A,D646A::5FLAG-kanMX6 his3⁺::tel(1L)*
		TN9133	telomere (1L)::*his3⁺ ccq1Δ*	*h⁻ his3-D1 ccq1Δ::hphMX his3⁺::tel(1L)*
6B		TN2411	*ccq1⁺* (no tag)	*h⁻ his3-D1*
		YTC6732	*ccq1-FLAG*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6*
		TN10611	*ccq1-C163R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6*
		BAM12467	*ccq1-FLAG clr3Δ*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6 clr3Δ::natMX*
		BAM12470	*ccq1-C163R-FLAG clr3Δ*	*h⁺ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6 clr3Δ::natMX*
		TN13103	*ccq1-FLAG clr4Δ*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6 clr4Δ::kanMX6*
		TN13106	*ccq1-C163R-FLAG clr4Δ*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6 clr4Δ::kanMX6*
6C		TN2411	*clr3⁺* (no tag)	*h⁻ his3-D1*
		TN7084	*clr3-FLAG*	*h⁺ ura4-DS/E or ura4-D18 his3-D1 ccq1⁺::natMX clr3⁺::3FLAG-kanMX*
		TN12452	*clr3-FLAG ccq1-C163R*	*h⁺ ura4-DS/E or ura4-D18 ade6-M210 his3-D1 ccq1-C163R::natMX clr3⁺::3FLAG-kanMX*
		TN12457	*clr3-FLAG ccq1-A363R*	*h⁻ ura4-DS/E or ura4-D18 ade6-M216 his3-D1 ccq1-A363R::natMX clr3⁺::3FLAG-kanMX*
		TN12448	*clr3-FLAG ccq1Δ*	*h⁻ ura4-DS/E or ura4-D18 ade6-M210 his3-D1 ccq1Δ::hphMX clr3⁺::3FLAG-kanMX*
		TN13101, TN13102	*clr3-FLAG clr4Δ*	*ura4-DS/E or ura4-D18 ade6-M210 his3-D1 clr3⁺::3FLAG-kanMX clr4Δ::kanMX6* (13101 *h⁻*; 13102 *h⁺*)
6D	1	BAM11596	*clr3-FLAG ccq1⁺*	*h⁻ ura4-DS/E ade6-M210 his3-D1 clr3⁺::3FLAG-kanMX*
	2	BAM11592	*clr3-FLAG ccq1-myc*	*h⁺ his3-D1 ccq1⁺::13myc-kanMX6 clr3⁺::3FLAG-kanMX*
	3	TN12844	*clr3-FLAG ccq1-C163R-myc*	*h⁺ ura4-DS/E or ura4-D18 ade6-M216 his3-D1 ccq1-C163R::13myc-hphMX clr3⁺::3FLAG-kanMX*
	4	TN12848	*clr3-FLAG ccq1-A363R-myc*	*h⁺ ura4-DS/E or ura4-D18 ade6-M210 his3-D1 ccq1-A363R::13myc-hphMX clr3⁺::3FLAG-kanMX*
S1	1	TN2411	wt (no tag)	*h⁻ his3-D1*
	2,4	TN7217	*ccq1-myc*	*h- his3-D1 ccq1+::13myc-kanMX6*
	3,5	TN7196	*tpz1-myc*	*h- his3-D1 tpz1+::13myc-kanMX6*
S2	1	YTC6732	*ccq1-FLAG*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6*
	2-4	TN13156, BAM13512, BAM13514	*ccq1$_{1-436}$-FLAG*	*h⁺ his3-D1 ccq1$_{(1-436)}$::5FLAG-kanMX6* (13156 1x; 13512 9x; 13514 9x)
S4B		TN2411	wt (no tag)	*h⁻ his3-D1*
		YTC6732	*ccq1-FLAG*	*h⁻ his3-D1 ccq1⁺::5FLAG-kanMX6*
		TN10611	*ccq1-C163R-FLAG*	*h⁻ ade6-M210 his3-D1 ccq1-C163R::5FLAG-kanMX6*
		TB11538	*ccq1-A363R-FLAG*	*h⁻ ade6-M216 his3-D1 ccq1-A363R::5FLAG-kanMX6*

[1]All strains are *leu1-32 ura4-D18* (haploid) or *leu1-32/leu1-32 ura4-D18/ura4-D18* (diploid) unless different genotypes are indicated.

Table S2 Yeast 2/3-hybrid Plasmids used in this study.

Plasmid (Lab stock #)	Description
pGBKT7 (356)	Empty vector
pGBKT7-Tpz1 (495)	Tpz1-FL (full length)
pGBKT7-Tpz1-[421-485] (651)	Tpz1-[421-485]
pGADT7 (352)	Empty vector
pGAD-GH-Ccq1 (549)	Ccq1-FL (full length)
pGAD-GH-Ccq1-R150A (721)	Ccq1-R150A
pGAD-GH-Ccq1-C163R (646)	Ccq1-C163R
pGAD-GH-Ccq1-L253R (723)	Ccq1-L253R
pGAD-GH-Ccq1-L257R (725)	Ccq1-L257R
pGAD-GH-Ccq1-G360R (727)	Ccq1-G360R
pGAD-GH-Ccq1-A363R (729)	Ccq1-A363R
pGAD-GH-Ccq1-R522A,R523A (730)	Ccq1-R522A,R523A
pGAD-GH-Ccq1-Y561A,R562A (732)	Ccq1-Y561A,R562A
pGAD-GH-Ccq1-E645A,D646A (733)	Ccq1-E645A,D646A
pGBKT7-Clr3 (710)	DBD-Clr3
pGAD-GH-Tpz1 (461)	GAD-Tpz1
pGAD-GH-Tpz1+Ccq1 (1034)	GAD-Tpz1 and Ccq1 (no tag)
pGAD-GH-Tpz1-L449R+Ccq1 (1086)	GAD-Tpz1-L449R and Ccq1 (no tag)

Table S3 PCR primers used in telomere and sub-telomere ChIP assays

PCR #	Primer #	Sequences (5' to 3')
1	637	TATTTCTTTATTCAACTTACCGCACTTC
	638	CAGTAGTGCAGTGTATTATGATAATTAAAATGG
2	483	CTACTTACTGCACCCTAACGCACTCAAG
	484	ACAGTTGTGGAGCGTACTATGGTAATGA
3	487	CGATTACTCGCTTTACTGCTCGTTACCC
	488	GGGATGTAGTGCAATATGGCGAATGAGG
4	491	TATCTATTACTGTCTTTACCTCTGA
	492	ATAAACTAATATGGTTACGGT
5	495	CATCGTATGTGCGTTTATGACCACGACG
	496	CTAGTACTACGCCAGTGTCTTTGTCGGA
6	501	TGGTGTTGCTCCAAAGTGTAGTGGA
	502	GACAGTTGCCTCCGGTAAATGGATTC

Table S4 Statistical analysis of ChIP data by 2-tailed Student's t-test.

Figure	Genotypes and p-values[1]					
4C	no tag	*myc-rad26*	*myc-rad26 ccq1-C163R*	*myc-rad26 ccq1-A363R*		
myc-rad26	6.3×10^{-3}					
myc-rad26 ccq1-C163R	0.011	9.2×10^{-4}				
myc-rad26 ccq1-A363R	0.016	3.7×10^{-3}	0.11			
myc-rad26 ccq1Δ	5.9×10^{-5}	3.4×10^{-6}	0.17	0.14		
5A	no tag	*ccq-FLAG*	*ccq1-C163R -FLAG*	*ccq1-L253R -FLAG*	*ccq1-L257R -FLAG*	*ccq1-G360R -FLAG*
ccq1-FLAG	1.7×10^{-7}					
ccq1-C163R-FLAG	7.5×10^{-4}	4.3×10^{-5}				
ccq1-L253R-FLAG	8.5×10^{-4}	1.8×10^{-5}	0.033			
ccq1-L257R-FLAG	0.038	9.2×10^{-6}	7.8×10^{-3}	0.024		
ccq1-G360R-FLAG	6.2×10^{-6}	1.1×10^{-4}	0.83	3.3×10^{-3}	2.9×10^{-4}	
ccq1-A363R-FLAG	2.5×10^{-4}	1.6×10^{-4}	0.81	0.022	4.1×10^{-3}	0.96
5B	no tag	*trt1-myc*	*trt1-myc ccq1-C163R*	*trt1-myc ccq1-A363R*		
trt1-myc	4.3×10^{-3}					
trt1-myc ccq1-C163R	0.20	1.9×10^{-3}				
trt1-myc ccq1-A363R	0.20	3.2×10^{-3}	0.74			
trt1-myc ccq1Δ	0.39	2.7×10^{-5}	5.0×10^{-3}	8.7×10^{-3}		
6B	no tag	*ccq1-FLAG*	*ccq1-C163R -FLAG*	*ccq1-FLAG clr3Δ*	*ccq1-C163R -FLAG clr3Δ*	*ccq1-FLAG clr4Δ*
ccq1-FLAG	1.7×10^{-7}					
ccq1-C163R-FLAG	7.5×10^{-4}	4.3×10^{-5}				
ccq1-FLAG clr3Δ	8.5×10^{-7}	0.040	2.3×10^{-3}			
ccq1-C163R-FLAG clr3Δ	2.7×10^{-7}	9.0×10^{-5}	0.76	7.3×10^{-4}		
ccq1-FLAG clr4Δ	8.1×10^{-8}	0.023	1.9×10^{-3}	0.80	1.9×10^{-4}	
ccq1-C163R-FLAG clr4Δ	7.0×10^{-4}	2.9×10^{-4}	0.99	5.3×10^{-3}	0.74	3.7×10^{-3}
6C	no tag	*clr3-FLAG*	*clr3-FLAG ccq1-C163R*	*clr3-FLAG ccq1-A363R*	*clr3-FLAG ccq1Δ*	
clr3-FLAG	5.1×10^{-8}					
clr3-FLAG ccq1-C163R	3.0×10^{-6}	1.1×10^{-3}				
clr3-FLAG ccq1-A363R	6.6×10^{-5}	2.3×10^{-4}	9.1×10^{-3}			
clr3-FLAG ccq1Δ	5.8×10^{-3}	4.3×10^{-5}	1.2×10^{-4}	3.5×10^{-3}		
clr3-FLAG clr4Δ	9.0×10^{-7}	0.064	0.016	2.5×10^{-3}	3.9×10^{-4}	

[1]Statistically significant differences ($p\leq0.05$) are highlighted with red letters.

SUPPLEMENTAL REFERENCES

Edgar, R.C. (2004). MUSCLE: multiple sequence alignment with high accuracy and high throughput. Nucleic Acids Res *32*, 1792-1797.

Rhind, N., Chen, Z., Yassour, M., Thompson, D.A., Haas, B.J., Habib, N., Wapinski, I., Roy, S., Lin, M.F., Heiman, D.I., Young, S.K., Furuya, K., Guo, Y., Pidoux, A., Chen, H.M., Robbertse, B., Goldberg, J.M., Aoki, K., Bayne, E.H., Berlin, A.M., Desjardins, C.A., Dobbs, E., Dukaj, L., Fan, L., Fitzgerald, M.G., French, C., Gujja, S., Hansen, K., Keifenheim, D., Levin, J.Z., Mosher, R.A., Muller, C.A., Pfiffner, J., Priest, M., Russ, C., Smialowska, A., Swoboda, P., Sykes, S.M., Vaughn, M., Vengrova, S., Yoder, R., Zeng, Q., Allshire, R., Baulcombe, D., Birren, B.W., Brown, W., Ekwall, K., Kellis, M., Leatherwood, J., Levin, H., Margalit, H., Martienssen, R., Nieduszynski, C.A., Spatafora, J.W., Friedman, N., Dalgaard, J.Z., Baumann, P., Niki, H., Regev, A., and Nusbaum, C. (2011). Comparative Functional Genomics of the Fission Yeasts. Science *332*, 930-936.

Wood, V., Gwilliam, R., Rajandream, M.A., Lyne, M., Lyne, R., Stewart, A., Sgouros, J., Peat, N., Hayles, J., Baker, S., Basham, D., Bowman, S., Brooks, K., Brown, D., Brown, S., Chillingworth, T., Churcher, C., Collins, M., Connor, R., Cronin, A., Davis, P., Feltwell, T., Fraser, A., Gentles, S., Goble, A., Hamlin, N., Harris, D., Hidalgo, J., Hodgson, G., Holroyd, S., Hornsby, T., Howarth, S., Huckle, E.J., Hunt, S., Jagels, K., James, K., Jones, L., Jones, M., Leather, S., McDonald, S., McLean, J., Mooney, P., Moule, S., Mungall, K., Murphy, L., Niblett, D., Odell, C., Oliver, K., O'Neil, S., Pearson, D., Quail, M.A., Rabbinowitsch, E., Rutherford, K., Rutter, S., Saunders, D., Seeger, K., Sharp, S., Skelton, J., Simmonds, M., Squares, R., Squares, S., Stevens, K., Taylor, K., Taylor, R.G., Tivey, A., Walsh, S., Warren, T., Whitehead, S., Woodward, J., Volckaert, G., Aert, R., Robben, J., Grymonprez, B., Weltjens, I., Vanstreels, E., Rieger, M., Schafer, M., Muller-Auer, S., Gabel, C., Fuchs, M., Dusterhoft, A., Fritzc, C., Holzer, E., Moestl, D., Hilbert, H., Borzym, K., Langer, I., Beck, A., Lehrach, H., Reinhardt, R., Pohl, T.M., Eger, P., Zimmermann, W., Wedler, H., Wambutt, R., Purnelle, B., Goffeau, A., Cadieu, E., Dreano, S., Gloux, S., Lelaure, V., Mottier, S., Galibert, F., Aves, S.J., Xiang, Z., Hunt, C., Moore, K., Hurst, S.M., Lucas, M., Rochet, M., Gaillardin, C., Tallada, V.A., Garzon, A., Thode, G., Daga, R.R., Cruzado, L., Jimenez, J., Sanchez, M., del Rey, F., Benito, J., Dominguez, A., Revuelta, J.L., Moreno, S., Armstrong, J., Forsburg, S.L., Cerutti, L., Lowe, T., McCombie, W.R., Paulsen, I., Potashkin, J., Shpakovski, G.V., Ussery, D., Barrell, B.G., and Nurse, P. (2002). The genome sequence of *Schizosaccharomyces pombe*. Nature *415*, 871-880.