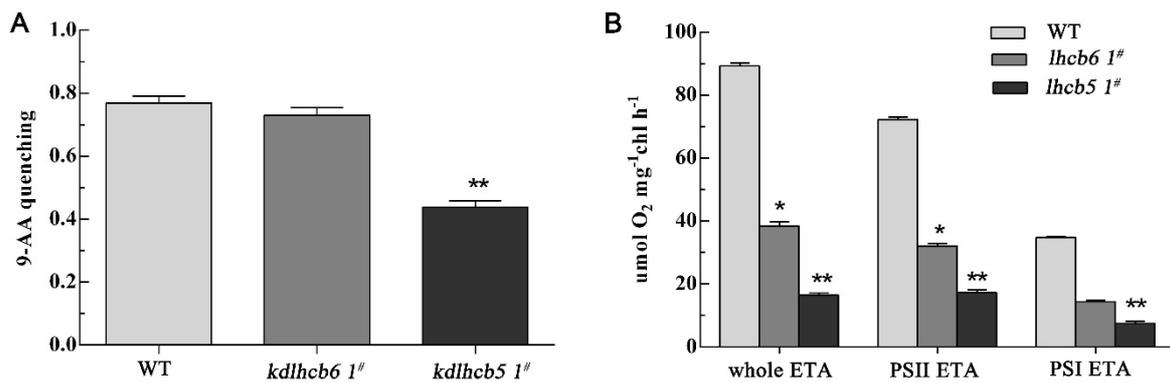
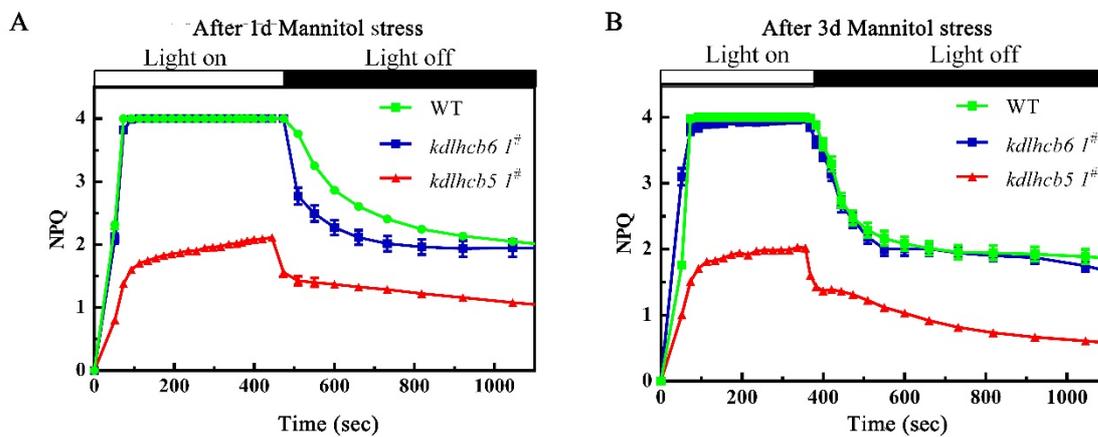


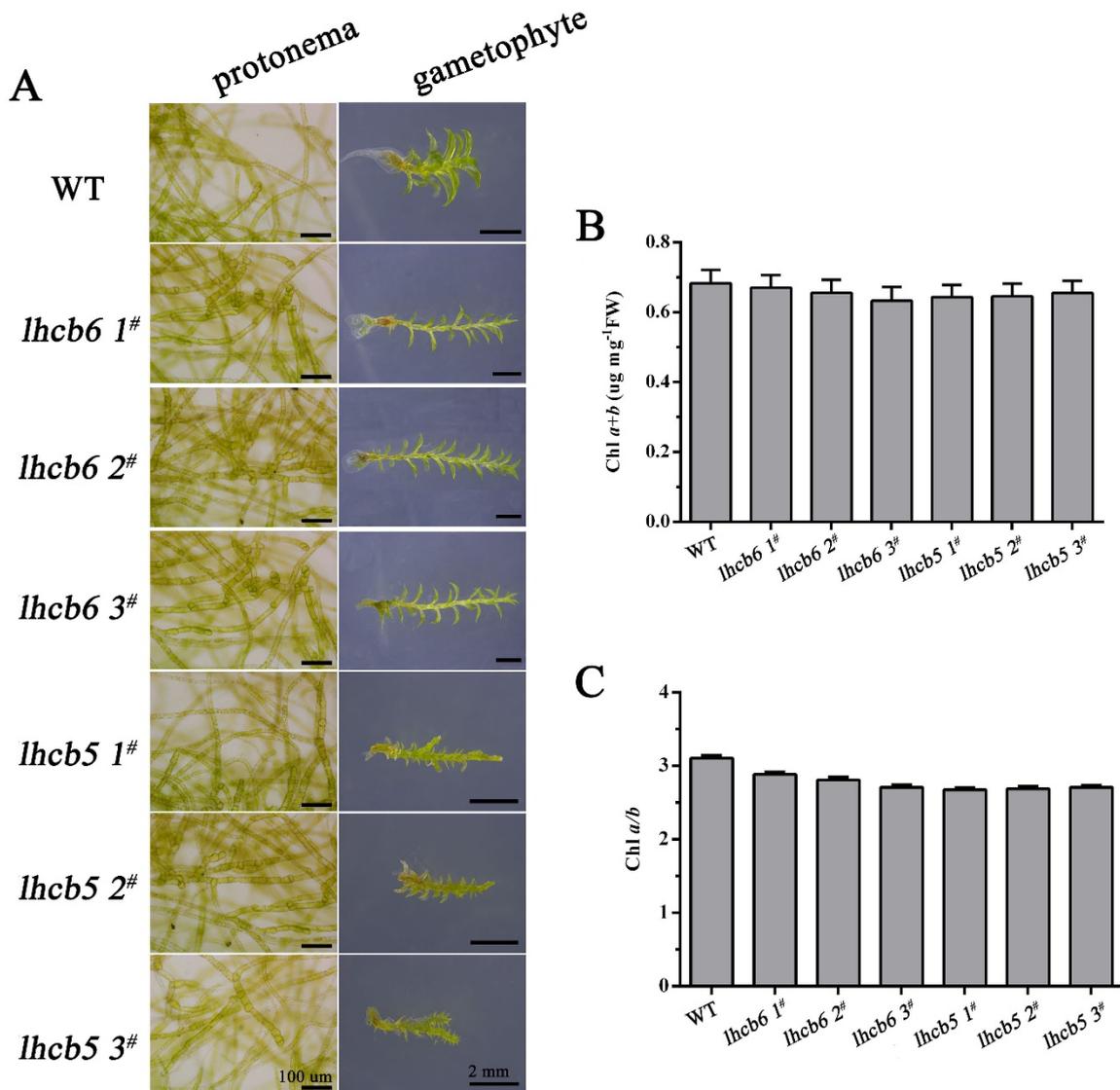
Supplementary Figure 1. Spectroscopic characterization of wild-type and mutants. The fluorescence emission spectra of thylakoid membranes were tested upon excitation 436 nm at room temperature. The data represent means \pm SD of three biological replicates.



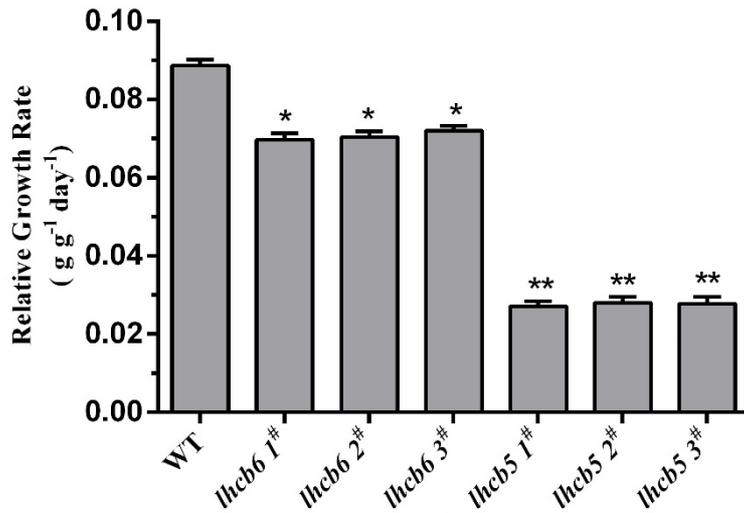
Supplementary Figure 2. Measurement of trans-thylakoid ΔpH and the activity of the electron transport chain in wild-type and mutants. (A) The fluorescence of 9-AA in intact chloroplasts was quantified as a measure for trans-thylakoid ΔpH . (B) The activity of the electron transport chain of mutants and wild-type thylakoids was mediated by indicator DCPIP. The data represent means \pm SD of three biological replicates. Statistical significance compared with the wild-type p is indicated by asterisks (** $P \leq 0.01$, * $P \leq 0.05$, student's t -test).



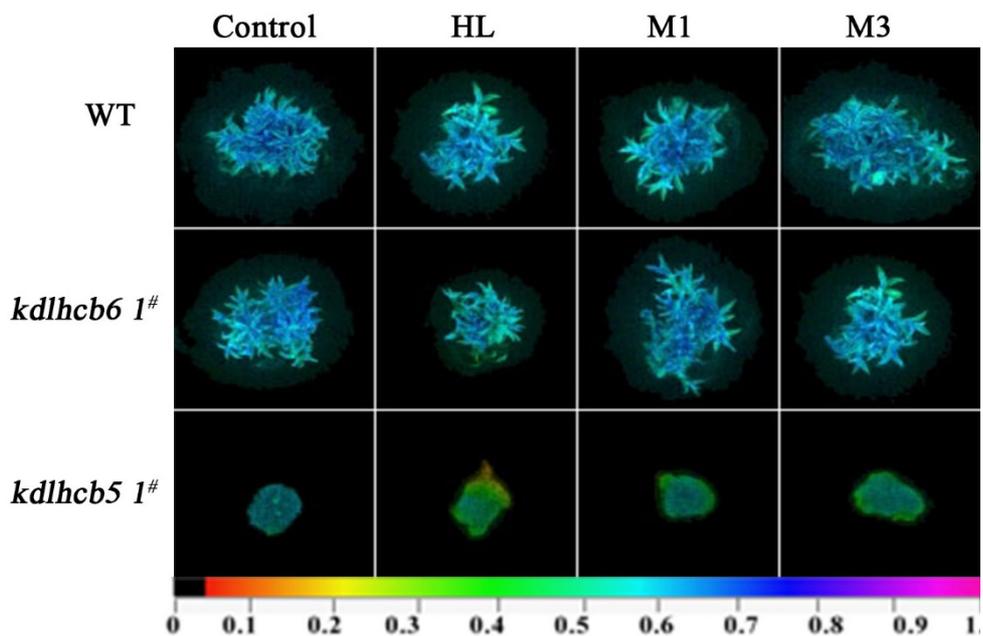
Supplementary Figure 3. Time courses for induction and relaxation of NPQ of wild-type and mutants under 500 mM mannitol for 1 and 3 days.



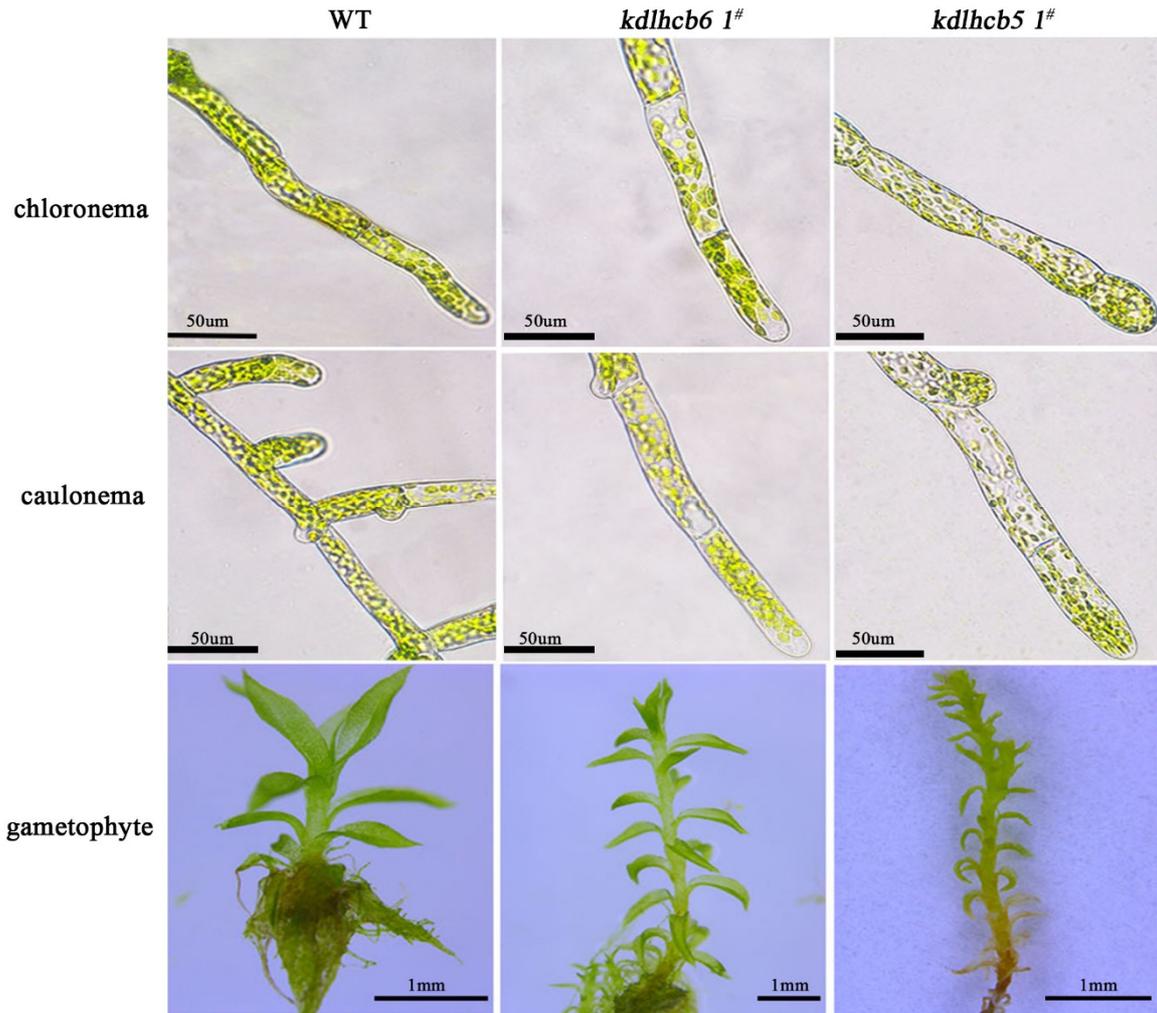
Supplementary Figure 4. The protonema and gametophyte tissues of wild-type and mutants. (A) Protonema filaments (left) and isolated leafy gametophyte (right) of *Physcomitrella*. The chlorophyll *a+b* content (B) and the ratio of chlorophyll *a/b* (C) of protonemal tissues in wild-type and mutants. FW, Fresh weight. The data represent the means \pm SD of three biological replicates. Statistical significance compared with the wild-type is indicated by asterisks (** $P \leq 0.01$, * $P \leq 0.05$, student's *t*-test).



Supplementary Figure 5. The relative growth rate (RGR) of wild-type and mutants. The data represent the means \pm SD of three biological replicates. Statistical significance compared with the wild-type p is indicated by asterisks (**P \leq 0.01, *P \leq 0.05, student's t-test).



Supplementary Figure 6. Chlorophyll fluorescence parameters of WT and mutants. The false color code depicted at the bottom of the image ranged from 0 (black) to 1.0 (purple). HL, high light. M1 and M3, mannitol stress for 1 and 3 days, respectively. .



Supplementary Figure 7. Micrographs of protonema (chloronema and caulonema) cells and gametophyte of WT and mutants.

Table 1. Primers used in this study.

Gene	Primer name	Sequence (5'-3')	Use
<i>PpLhcb6</i>	PpLhcb6 F-1 [#]	ACGGGGTACCATGGCCACCAAGAAGGTGTCG	pTN182 construct
	PpLhcb6 R-1 [#]	ACCCAAGCTTATGGAACGCCGCTCCATCCCT	pTN182 construct
	PpLhcb6 F-2 [#]	CTAGTCTAGAGCAGTCGGTAGAGTGGGCAAC	pTN182 construct
	PpLhcb6 R-2 [#]	ACGCGGATCCACAGACCCAAGGCACCGAGAG	pTN182 construct
	PpLhcb6 F-3 [#]	CCGCCTTGAAATGGTATAGAGA	mutant screening
	PpLhcb6 R-3 [#]	CTTGGAGAAGTCTGGCACGTAC	mutant screening
<i>PpLhcb5</i>	PpLhcb5 F-1 [#]	ACGGGGTACCACTCAACGGAACCTAAGGGAACA	pTN182 construct
	PpLhcb5 R-1 [#]	ACCCAAGCTTAAGGCGGCTAAGGGTCTATG	pTN182 construct
	PpLhcb5 F-2 [#]	CTAGTCTAGATTCCGATAAAGGCGTAGCAGT	pTN182 construct
	PpLhcb5 R-2 [#]	ACGCGGATCCGACCCACATTACATGAACAAGC	pTN182 construct
	PpLhcb5 F-3 [#]	TCGCCGAGGTGATTCTG	mutant screening
	PpLhcb5 R-3 [#]	TCTGCGGTCCCTGGAT	mutant screening
<i>PpLhcb4</i>	PpLhcb4 F	ATGCGTCGCCCAGTTGT	RT-PCR
	PpLhcb4 R	ATGCGTCGCCCAGTTGT	RT-PCR
<i>PpLhca3</i>	PpLhca3 F	TGCCTCCAAGCAAAGCC	RT-PCR

	PpLhca3 R	CGCCATCATCGCCAACC	RT-PCR
<i>PpLhcb9</i>	PpLhcb9 F	ACGGGAAGTCAGTGGCA	RT-PCR
	PpLhcb9 R	CTGGGTCGCTTGAGAAT	RT-PCR
<i>PpLhcsR</i>	PpLhcsR 1F	TTGGCTCCCGTATTTC	RT-PCR
	PpLhcsR 1R	TCGTCCCTCAAGGTGTT	RT-PCR
<i>PpPsbS</i>	PpPsbS F	CCTCGGCTTCGTTATTC	RT-PCR
	PpPsbS R	AGCACCTTCACTCCCT	RT-PCR
<i>Ppvde</i>	PpVDE F	GGTGCTGGAAGCGTTAG	RT-PCR
	PpVDE R	GAGACCGAGGCAGTTGT	RT-PCR
<i>PpEF1a</i>	PpEF1a F	GCCAAGAAGAAGTGAATAGTGCG	RT-PCR
	PpEF1a R	ACGTCTGCCTCGCTCTAGC	RT-PCR