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SUPPORTING INFORMATION

Figure S1. The phytochrome superfamily in Nostoc punctiforme. Jellybean domain architecture diagrams are shown for phytochromes and CBCRs of *N. punctiforme*. CBCR photocycles are color-coded as described in Note A and ref.⁶⁸.

	β1 notch	β2	Phe	Asp-motif
	1			11111
Cph2g2	DRVVLFKFNSQ-	-WSGQVVI	ESHNDFCRSIINDE	IDDPCFKGHY-LRLYREG
TePixJ	DRVIVYAFDDN-	-YVGTVVA	ESVAEGWPQARDQV:	IEDPCFREHW-VEAYRQG
Tlr0924	DRVLIYRFLGD-	-GSGIVAV	EATTLPQYSILGQV	IHDPCFTKET-ARRFLEG
NpF1883g3	DRVMIYSFNAN-	-WSGTVIA	ESVVLTYPKVLRAE	IEDPCFGQGY-VKEYQSG
NpR1597g1B	DRV <mark>G</mark> VFRLYPDL	AWEGE <mark>F</mark> IY	EDVATEWDSALAAK	LCDHCFSEEF-ASLYQQG
NpR5113g1B	DRV <mark>A</mark> VFQFDLEK	DWEGE <mark>F</mark> VS	SENVAPGWTSALKVK	/YDHCFGEQF-ASSYQQG
NpR5113g3	DRV <mark>A</mark> VFRFDPQK	DWEGE <mark>F</mark> IS	EDVVPECNSVIAEK	IYDYCFGENF-ASLYAQG
AnPixJg2	DRV <mark>A</mark> VYRFNPD-	-WSGE <mark>F</mark> VA	ESVGSGWVKLVGPD	IKTVWEDTHLQETQ-GGRYRHQ
NpR5113g2	DRV <mark>A</mark> IFSFNAD-	-WSGN <mark>F</mark> VA	ESFAEGWTPLVGIQ	PTIFDTYLQQTQ-GGRYVDN
NpR6012g4	DRV <mark>A</mark> VYRFNPN-	–WTGE <mark>F</mark> VA	ESVAHTWVKLVGPD	IKTVWEDTHLQETQ-GGRYAQG
	_			_
JSC1_41510	DRVFVYRFQPD-	-FSGIVVI	ESVGDNCVPVIDAQ	/EDQYEVETR-GEDYRQG
NpR3784	DRVFMYQFEPD-	-YSGVVVV	/ESVDDRWIAILNTQV	/QDTY <mark>F</mark> METR-GEEYSHG
Ava_3771	DRVFIYRFAPN-	-YSGCVVV	ESVGDNWRAVLNAQ	/EDTY <mark>F</mark> METH-GEKYRQG
Nos7524_2682	DRV <mark>F</mark> IYRFEAD-	-YSGVVVV	ESVDQRWISALNAH	/EDTY <mark>F</mark> METQ-GEEYRQG
Chro_3230	DRV <mark>F</mark> IYRFEPD-	-WGGVVIV	VESVAPEWTSILGSRI	?KDPSFAPTY-VELYKKG
Cyan7425_3771	DRV <mark>F</mark> IFRFLPD-	-WSGEVVA	ESVGAGWRSVLASK	/EDTY <mark>F</mark> QQTG-GEAYRQG
Glo7428_2205	ERV <mark>F</mark> IYRFEPD-	-WSGIVVV	ESVAPEWNSIAGKN	IKDTF <mark>F</mark> SHPGNRELYRQG
Scytonema	DRV <mark>F</mark> IYRFDPD-	-WSGTVVV	ESVAPGCNSVLGTV	IKDSF <mark>F</mark> QEPSHRQTYEQG
Cyan7822_5462	DRVIIYRLNPD-	-CSGIVVI	ESVAPGWLAIVNRE	ITDSY <mark>F</mark> VETE-AGNYHGG
Caloth_7103	ERV <mark>F</mark> IYRFEPD-	-WSGYVAV	ESVASGCSSILGTK	IKDSF <mark>F</mark> GEPLGRTLYQQG
PCC7424_1805	DRVIIYRLNPD-	-WSGIVVI	ESVAPKWIAILNME	ITDSY <mark>F</mark> VETE-GGDYHRG
Mic7113_2408	DRVIIFRLHPD-	-GSGVIVV	ESVDSGWRPISGIS	INDHH <mark>F</mark> AQAY-IKLYKQG
Nostoc9237/1	DRVIIYRFNPD-	-WSGVVVI	ESVAKGCQAILNME	ITETY <mark>F</mark> VETQ-AQFYQQN
Mic7113_0918	DRVLIFRLHAD-	-GSGVVVV	ESVGGEWIPMSGTV	INDHYLAQSY-IQLYQQG
MC7420_7957	DRVLVYQFAED-	-WSGEIVA	ESVGD-FPSVLGSQV	/RDAY <mark>F</mark> QETK-GADYLNG
MC7420_4951	DRVLVFRLYGD-	-GSGVVEV	ESVDVNWKPISGTV	INDRY <mark>F</mark> AEDY-IHLYQKG
010802	DRVLVYQFEAD-	-WTGTILA	ESVAG-FPPVLGTK	IR D SY <mark>F</mark> QQTK-GCEYLRG
	ß1 Phe			Asp-motif Phe
	p+ +			indp moorr rine
	prino			hep moorr the
СУ	ys ligated to	PCB	helix Phe	β6 His or Tyr
СУ	ys ligated to	PCB	helix Phe 	β6 His or Tyr
Cy	ys ligated to RVRAVSDIEKAD	PCB LAD C HKEI	helix Phe .LRHYQVKANLVVPVV	β6 His or Tyr /FNENLWGLLIAHEC
Cy Cph2g2 TePixJ	ys ligated to RVRAVSDIEKAD RIQATTDIFKAG	PCB LAD C HKEI LTE C HLNQ	helix Phe LRHYQVKANLVVPV LRPLKVRANLVVPM	β6 His or Tyr /FNENLWGLLIAHEC /IDDQLFGLLIAHQC
Cph2g2 TePixJ Tlr0924	ys ligated to RVRAVSDIEKAD RIQATTDIFKAG RTLSISDVNQAQ	PCB LADCHKEL LTECHLNQ LQDCYREL	helix Phe LRHYQVKANLVVPVV LRPLKVRANLVVPM LTRLQVQANLVVPLJ	β6 His or Tyr /FNENLWGLLIAHEC /IDDQLFGLLIAHQC LQGQHLWGLLIAHHC
Cph2g2 TePixJ Tlr0924 NpF1883g3	ys ligated to RVRAVSDIEKAD RIQATTDIFKAG RTLSISDVNQAQ RVLAINNIYEVG	PCB LADCHKEI LTECHLNQ LQDCYREI LADCHINI	helix Phe LHYQVKANLVVPVV LRPLKVRANLVVPM LITRLQVQANLVVPLJ LES <mark>F</mark> GVKANLVAPIJ	β6 His or Tyr /FNENLWGLLIAHEC /QQQHLWGLLIAHQC KDEQLFGLLIAHQC
Cph2g2 TePixJ Tlr0924 NpF1883g3 NpR1597g1B	ys ligated to RVRAVSDIEKAD RIQATTDIFKAG RTLSISDVNQAQ RVLAINNIYEVG RIRAIADIYQVN	PCB LADCHKEI LTECHLNQ LQDCYREI LADCHINI ASDCYIQI	helix Phe LRHYQVKANLVVPVV LRPLKVRANLVVPM LITRLQVQANLVVPL LESFGVKANLVAPI LESFGVKANLVAPI	β6 His or Tyr /FNENLWGLLIAHEC /QQHLWGLLIAHQC KDEQLFGLLIAHQC KGKNLWGLLCIHQC
Cph2g2 TePixJ Tlr0924 NpF1883g3 NpR1597g1B NpR5113g1B	ys ligated to RVRAVSDIEKAD RIQATTDIFKAG RTLSISDVNQAQ RVLAINNIYEVG RIRAIADIYQVN RVQAVADIYNAG	PCB LADCHKEI LTECHLNQ LQDCYREI LADCHINI ASDCYIQI LSDCHAAI	helix Phe LRHYQVKANLVVPV LRPLKVRANLVVPM LTRLQVQANLVVPL LESFGVKANLVAPL LERFQVKANLVVPL LERFQVKANLVVPL	β6 His or Tyr /FNENLWGLLIAHEC /QGQHLWGLLIAHQC LKGVLWGLLCIHQC KGKNLWGLLCIHQC
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Figure S2. Multiple sequence alignment of representative CBCRs. Representative DXCF (blue; teal-DXCF underlined) and red/green (red) CBCRs are aligned with known members of the NpR3784 group (brick red). The alignment spans the GAF β sheet, and the Asp-motif is highlighted in green. Key residues in the red/green CBCRs and NpR3784 group are highlighted (yellow and cyan, respectively). Accession details on members of the NpR3784 group are presented in Fig. 7.



Figure S3. Comparison of 15E photoproducts formed by NpR3784 variants. (A) Normalized absorption spectra are shown for the *15E* photostates of wild-type (dark blue) and $F_{66}V$ (pink) NpR3784. (B) Normalized absorption spectra are shown for the *15E* photostates of wild-type (dark blue) and $F_{135}L$ (pink) NpR3784. (C) Normalized absorption spectra are shown for the *15E* photostates of wild-type (dark blue) and $F_{100}L$ (pink) NpR3784. (D) Normalized absorption spectra are shown for the *15E* photostates of wild-type (dark blue), $F_{66}V$ $F_{135}L$ (pink), and $F_{66}V$ $F_{100}L$ $F_{135}L$ (brick red) NpR3784. Asterisks indicate noncovalently bound and/or incompletely converted covalently bound *15Z* species.



Figure S4. Denaturation analysis of Ava_3771. (A) Absorption spectra are shown for denatured Ava_3771 in the color scheme of Fig. 2. (B) Normalized photochemical difference spectra for denatured Ava_3771 (teal) and Mic7113_2408 (brick red) are shown. (C) To generate a denatured spectrum for the long-wavelength population of Ava_3771, the denatured difference spectra for Ava_3771 and Mic7113_2408 were used without normalization to calculate a scaling factor for the relative amounts of photochemically active PCB present in the two protein preparations. The absorption spectrum of denatured *15Z* Mic7113_2408 was scaled using this factor and subtracted from the absorption spectrum of Ava_3771 to generate a denatured spectrum for the long-wavelength population (dark blue; peaks at 372, 694 nm). The absorption spectrum for denatured *15Z* DrBphP (pink; peaks at 392, 708 nm) is shown for comparison.



Figure S5. Characterization of full-length JSC1-41510. (A) Absorption spectra are shown for full-length JSC1_41510 in the color scheme of Fig. 2. (B) Normalized photochemical difference spectra are shown for GAF-only (brown) and full-length (teal) JSC1_41510. (C) Absorption spectra are shown for full-length JSC1_41510 after scatter correction. (D) Normalized absorption spectra are shown for GAF-only (brown) and scatter-corrected full-length (sea foam green) JSC1_41510 in the *15Z* photostate.



Figure S6. Characterization of purified CBCRs. The indicated proteins were characterized by SDS-PAGE and transfer to PVDF membranes, followed by amido black staining (top) and zinc blotting (bottom).

Organism	GenBank Assembly ID
<i>Nostoc punctiforme</i> ATCC 29133 (= PCC 73102)	GCA_000020025.1
Nostoc sp. strain PCC 7524	GCA_000316645.1
<i>Nostoc</i> sp. 152 (= sp. strain PCC 9237/1) ¹	KC699835
Anabaena variabilis ATCC 29413	GCA_000204075.1
Cyanothece sp. strain PCC 7424	GCA_000021825.1
Cyanothece sp. strain PCC 7425	GCA_000022045.1
Cyanothece sp. strain PCC 7822	GCA_000147335.1
Chroococcidiopsis thermalis PCC 7203	GCA_000317125.1
Leptolyngbya sp. strain JSC-1	GCA_000733415.1
Gloeocapsa sp. strain PCC 7428	GCA_000317555.1
Coleofasciculus chthonoplastes PCC 7420	GCA_000155555.1
Microcoleus sp. strain PCC 7113	GCA_000317515.1
Scytonema hofmanni PCC 7110	GCA_000346485.1
Calothrix sp. strain PCC 7103	GCA_000331305.1
Oscillatoria sp. strain PCC 10802	GCA_000332335.1

Table S1: Known cyanobacterial genomes containing members of the NpR3784 group.

1. Accession for nucleotide fragment, not genome assembly.