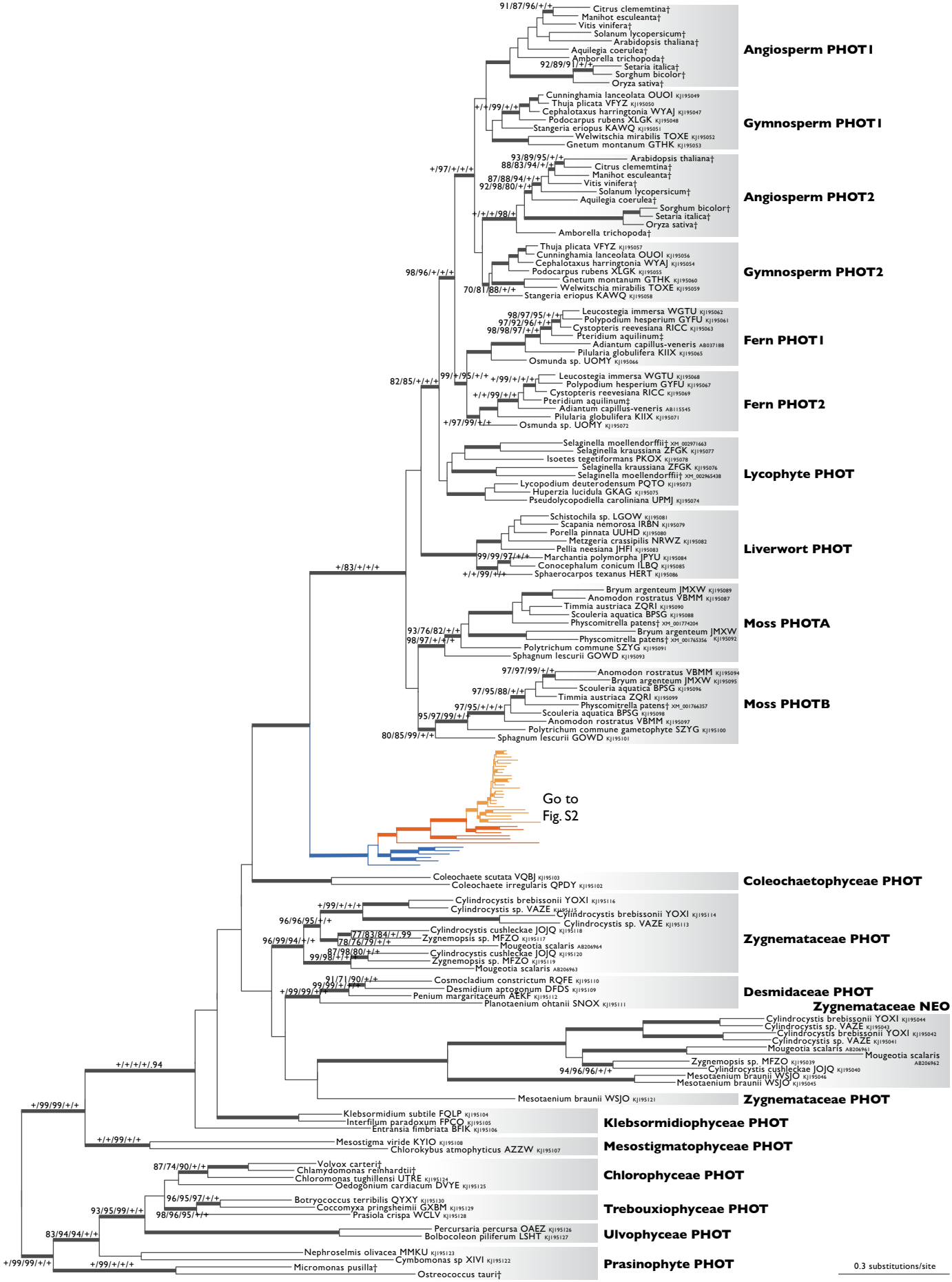

Fig. S1. Phylogenetic relationships of land plant and algal phototropin (PHOT) and the corresponding domains from hornwort, fern, and algal neochrome (NEO). Topology derived from the best maximum likelihood tree. The five support values associated with branches are maximum likelihood bootstrap values (BS) from Garli / BS from nhPhyML / aLRT supports under codon model (aLRT) / Bayesian posterior probabilities (PP) from MrBayes / PP from BEAST; these are only displayed (along with thickened branches) when BS > 70, aLRT > 70 and PP > 0.95. "+" denotes BS = 100, aLRT = 100 or PP = 1.00; thickened branches without numbers are "+/+/+/+/+". Alphanumeric codes following species names are the four-letter 1KP transcriptome identifiers, or Genbank accessions, or both; "†" indicates the sequence came from genome sequence data, and "‡" from *Pteridium aquilinum* transcriptome. The blue, orange and yellow branches represent hornwort phototropin, hornwort neochrome and fern neochrome, respectively.

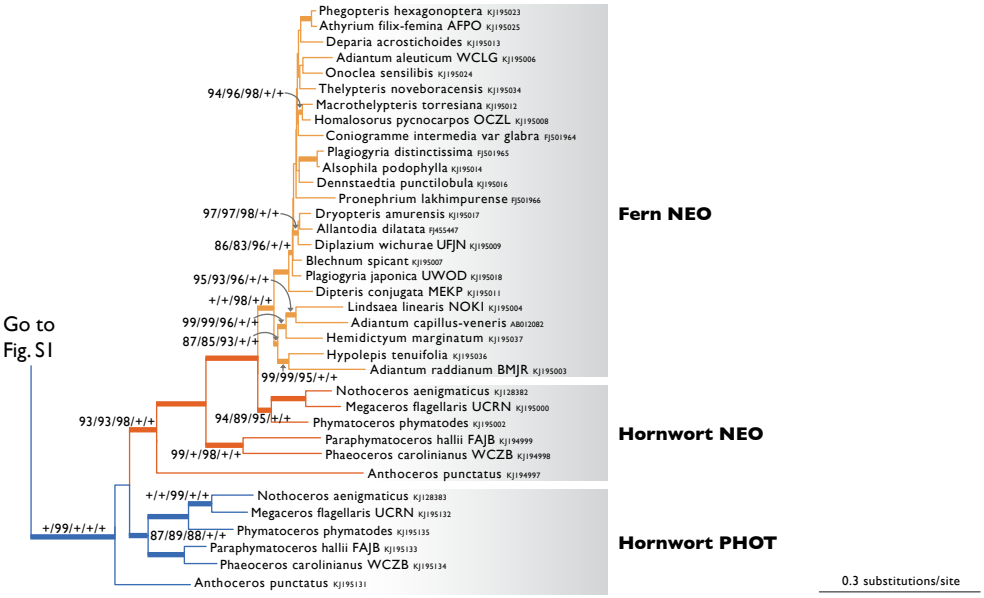

Fig. S2. Phylogenetic relationships of fern neochrome (NEO), hornwort neochrome and phototropin (PHOT). This figure is continued from Fig. S1 and follows the same conventions.

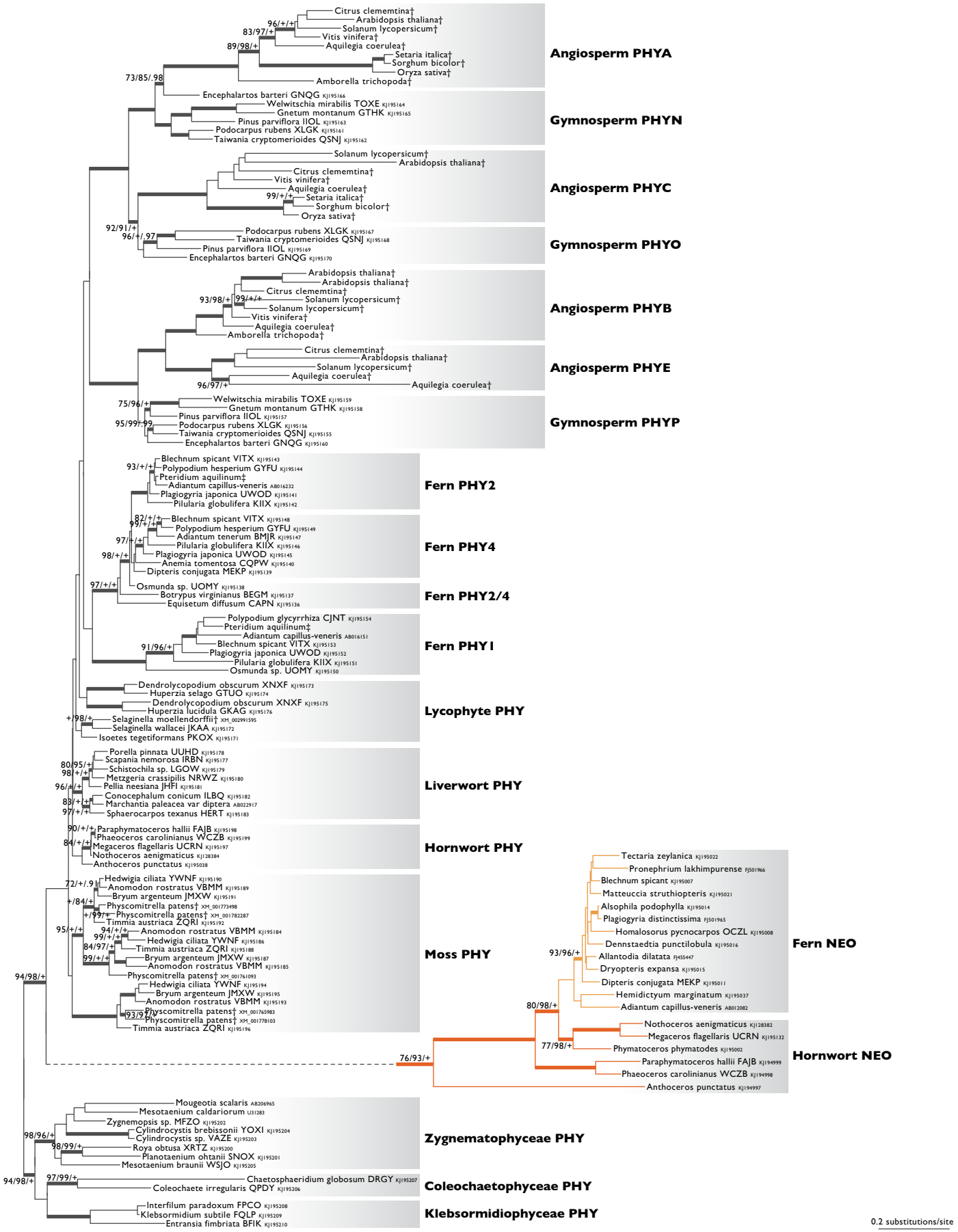

Fig. S3. Phylogenetic relationships of land plant and algal phytochrome (PHY) and the corresponding domains from hornwort and fern neochrome (NEO). Topology derived from the best maximum likelihood tree. The three support values associated with branches are maximum likelihood bootstrap values (BS) / aLRT supports under codon model (aLRT) / Bayesian posterior probabilities (PP) from MrBayes; these are only displayed (along with thickened branches) if BS > 70, aLRT > 0.95 and PP > 0.95. "+" denotes BS = 100, aLRT = 100 or PP = 1.00; thickened branches without numbers are "+/+/+". Alphanumeric codes following species names are the four-letter 1KP transcriptome identifiers, or Genbank accessions, or both; "†" indicates the sequence came from whole genome sequence data, and "‡" from *Pteridium aquilinum* transcriptome. For space considerations, the dashed line artificially extends the NEO clade and does not reflect true branch length. The orange and yellow branches represent hornwort neochrome and fern neochrome, respectively.

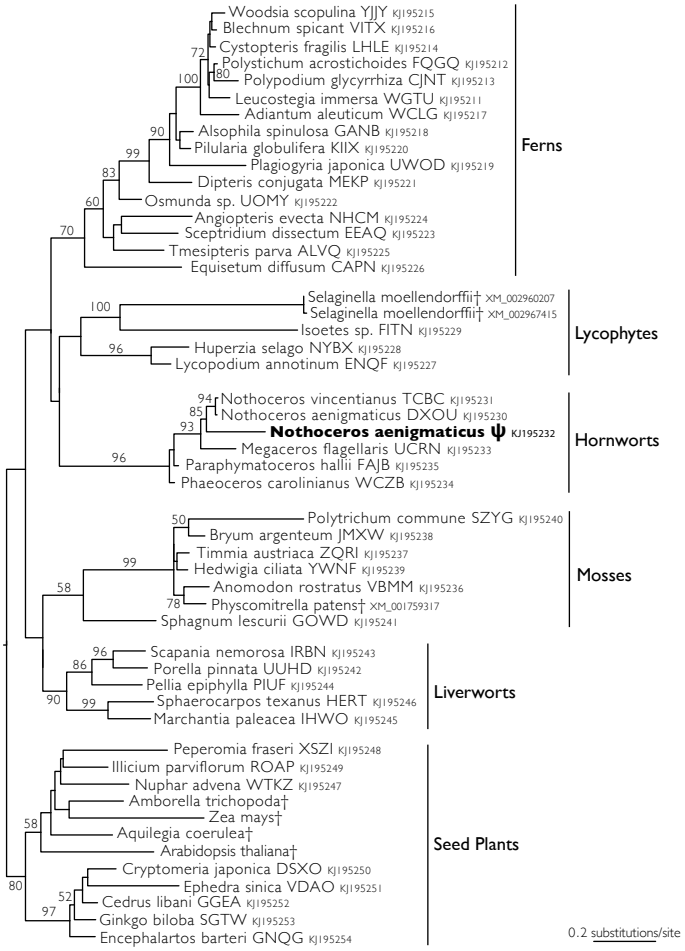

Fig. S4. Phylogenetic relationships of land plant imidazoleglycerol-phosphate dehydratase (IGPD). In the hornwort *Nothoceros aenigmaticus*, we conducted genome-walking downstream of neochrome and found a IGPD pseudogene (denoted by ψ). In a land plant phylogeny of IGPD our *N. aenigmaticus* pseudogene is most closely related to other hornwort IGPD. This relationship confirms that our hornwort neochrome sequence data were indeed derived from the hornwort genome, and not from symbiotic algae or fungi. Numbers associated with branches are maximum likelihood bootstrap support values. Alphanumeric codes following species names are the four-letter 1KP transcriptome identifiers, or Genbank accessions, or both; "†" indicates the sequence came from whole genome sequence data.

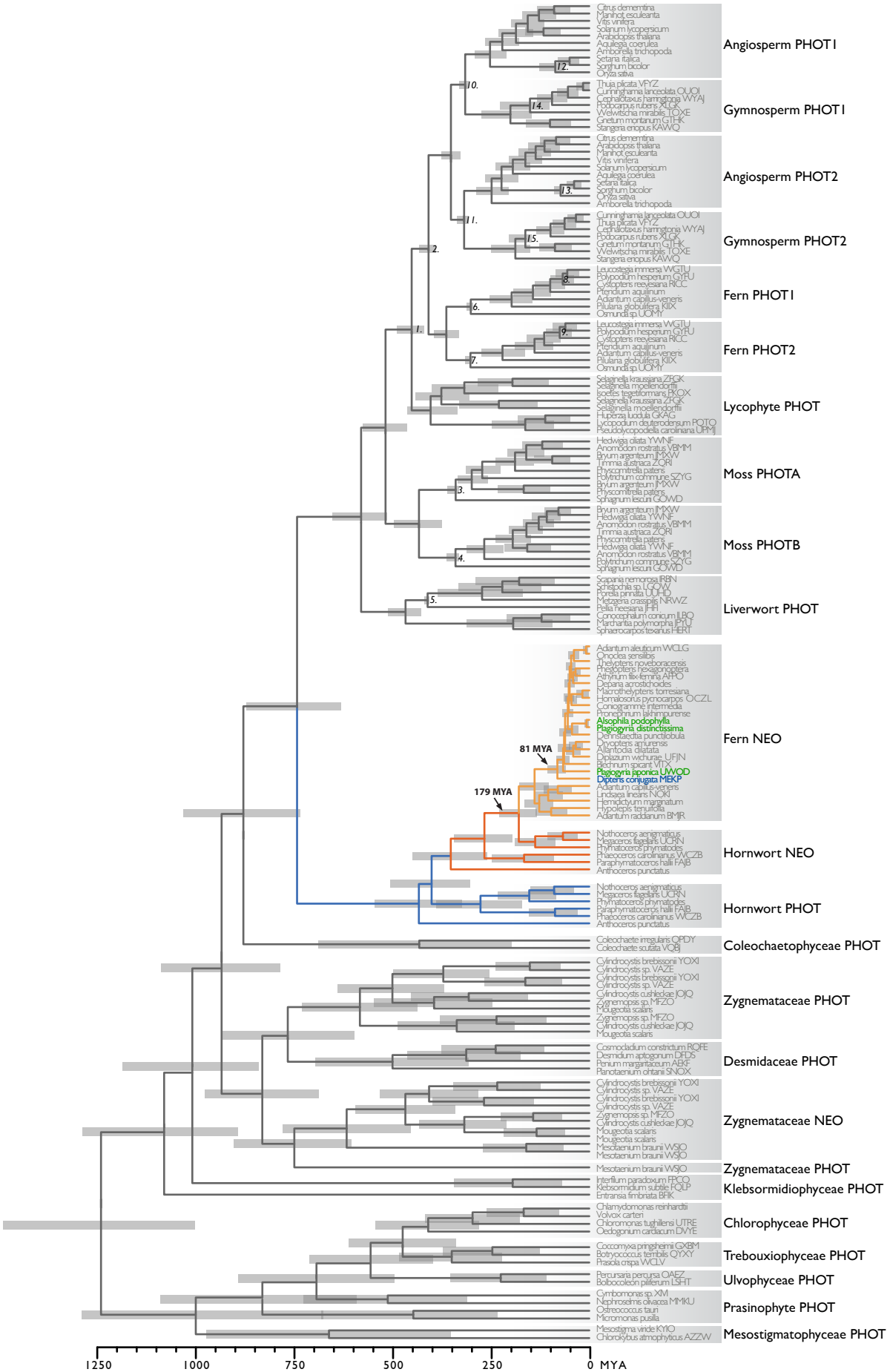

Fig. S5. Chronogram of land plant and algal phototropin (PHOT) and the corresponding domains from hornwort, fern, and algal neochrome (NEO). A simplified version of this figure is shown in Fig. 1B. Grey bars represent 95% highest posterior density intervals of the age estimates. Italicized numbers adjacent to nodes refer to the fossil or secondary time calibrations detailed in Table S2. Two divergence time estimates are highlighted: one marks the HGT event (179 MYA) and the other marks the split of Gleicheniales (blue taxon), Cyatheales (green taxa) and other neochromes (81 MYA).

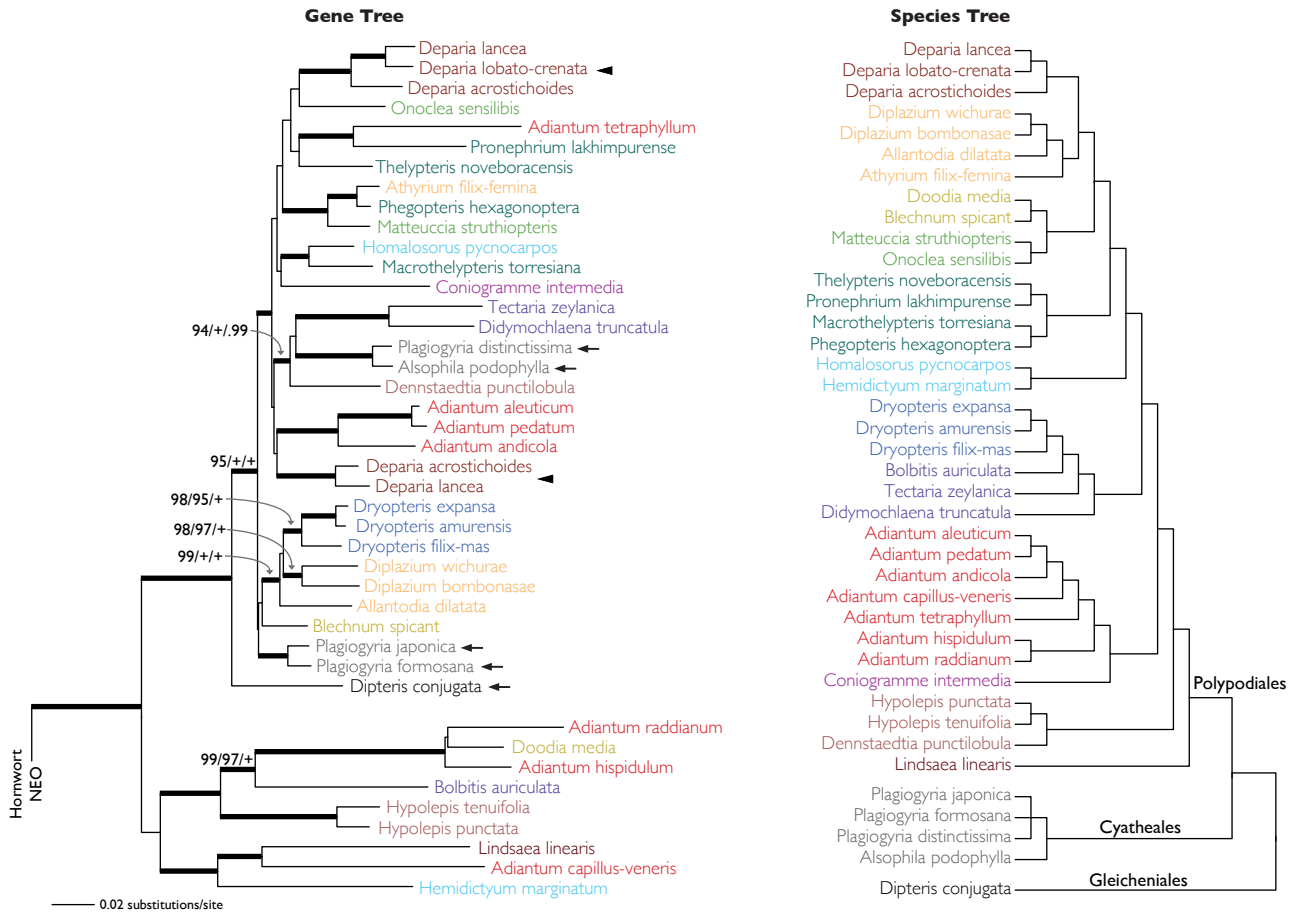

Fig. S6. Phylogenetic incongruence between fern neochrome gene tree and fern species tree. The gene tree topology is derived from the best maximum likelihood tree based on the nucleotide dataset, and the species tree summarized from Schuettpelz and Pryer (1), Kuo et al (2), Rothfels and Schuettpelz (3), and Rothfels et al (4). Tree inference based on codon models, 1st + 2nd and 3rd codon positions yielded similar topologies (Fig. S7). Closely related species/genera are coded with the same color. The neochrome gene tree is rooted with hornwort neochromes (not shown). Numbers above branches are maximum likelihood bootstrap values (BS) / aLRT supports under codon model (aLRT) / Bayesian posterior probabilities from MrBayes (PP), and are only displayed (along with thickened branches) if BS > 70, aLRT > 70 and PP > 0.95. "+" denotes BS = 100, aLRT = 100 or PP = 1.00; thickened branches without numbers are "+/+/+". Arrowheads point to the two divergent neochrome copies found in *Deparia* spp. Arrows point to neochromes from Gleicheniales and Cyatheales that appear nested among Polypodiales neochromes.

1. Schuettpelz E, Pryer KM (2007) Fern phylogeny inferred from 400 leptosporangiate species and three plastid genes. *Taxon* 56:1037–1050.
2. Kuo LY, Li FW, Chiou WL, Wang CN (2011) First insights into fern matK phylogeny. *Mol Phylogenet Evol* 59:556–566.
3. Rothfels CJ, Schuettpelz E (2013) Accelerated rate of molecular evolution for vittarioid ferns is strong but not driven by selection. *Syst Biol* 63:31–54.
4. Rothfels CJ et al. (2013) Transcriptome-mining for single-copy nuclear markers in ferns. *PLoS ONE* 8:e76957.

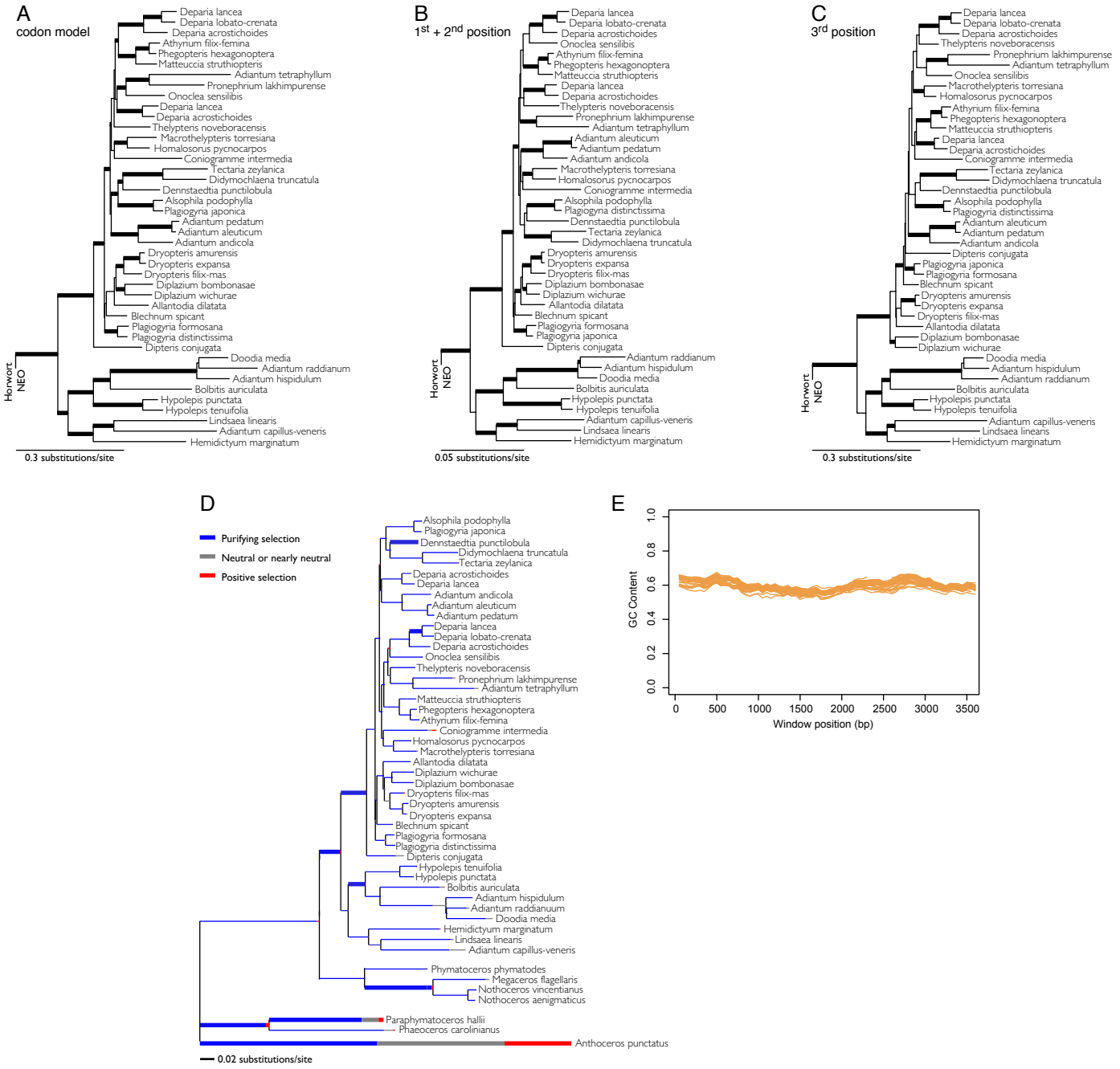

Fig. S7. Phylogeny, selection profile and GC content of fern neochromes. Maximum likelihood reconstructions of gene phylogeny based on (*A*) codon model, (*B*) first and second codon positions, and (*C*) third codon position. Thickened branches indicate aLRT supports (in *A*) or bootstrap supports (in *B*, *C*) > 70. (*D*) Selection profile displayed along phylogenetic branches for fern and hornwort neochromes. Tree topology derived from the best maximum likelihood tree (Fig. S6). The width of each color along a branch is proportional to the number of codon sites in the corresponding selection class. Thickened branches have experienced significant episodic positive selection ($P < 0.05$). (*E*) Sliding window analysis of GC content for fern neochrome. Each line displays the GC content for each neochrome sequence. None of the ferns in our study were deviant in base composition for neochrome. Each window is 400bp in size and the window slides every 50bp.

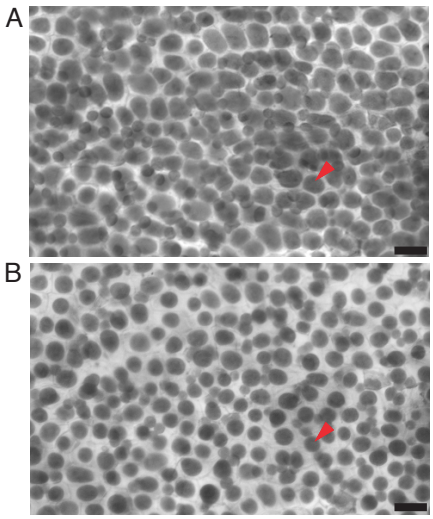

Fig. S8. Hornwort chloroplasts (arrowhead) contract under strong light. (*A*) Before irradiation, chloroplasts of *Nothoceros aenigmaticus* occupy most of the cellular space. (*B*) After irradiation of blue light (57 μmol m^{-2} s^{-1}) for 2 hours, chloroplasts evidently reduced in size. Scale bar = 40 μm.

Table S1. List of transcriptomes and genome sequences screened for neochrome, phototropin and phytochrome genes. All the transcriptomes were from 1KP (www.onekp.com), except for *Pteridium aquilium*. The four letter codes following species names are the 1KP transcriptome identifiers. Details of transcriptome tissue type and specimen voucher can be found at www.onekp.com. "*" denotes whole or draft genome sequences.

Angiosperms
- Amborella trichopoda*
- Aquilegia coerulea*
- Arabidopsis lyrata*
- Arabidopsis thaliana*
- Brachypodium distachyon*
- Capsella rubella*
- Carica papaya*
- Citrus clementina*
- Citrus sinensis*
- Cucumis sativus*
- Eucalyptus grandis*
- Fragaria vesca*
- Glycine max*
- Gossypium raimondii*
- Linum usitatissimum*
- Malus domestica*
- Manihot esculenta*
- Medicago truncatula*
- Mimulus guttatus*
- Oryza sativa*
- Panicum virgatum*
- Phaseolus vulgaris*
- Populus trichocarpa*
- Prunus persica*
- Ricinus communis*
- Setaria italica*
- Solanum lycopersicum*
- Solanum tuberosum*
- Sorghum bicolor*
- Theobroma cacao*
- Vitis vinifera*
- Zea mays*

Gymnosperms
- Austrotaxus spicata BTTS
- Callitris macleayana RMMV
- Cathaya agryrophylla NPRL
- Cedrus libani GGEA
- Cephalotaxus harringtonia WYAJ
- Cryptomeria japonica DSXO
- Cunninghamia lanceolata OUOI
- Cupressus dupreziana QNGJ
- Cycas micholitzii XZUY
- Dioon edule WLIC
- Encephalartos barteri GNQG
- Ephedra sinica VDAO
- Ginkgo biloba SGTW
- Glyptostrobus pensilis OXGJ
- Gnetum montanum GTHK
- Juniperus scopulorum XMGP
- Keteleeria evelyniana JUWL
- Larix speciosa WVWN
- Nothotsuga longibracteata AREG
- Phyllocladus hypohyllus JRNA
- Picea engelmanii AWQB
- Pinus jeffreyi MFTM
- Pinus parviflora IIOL
- Pinus ponderosa JBND
- Pinus radiata DZQM
- Podocarpus coriaceus SCEB
- Podocarpus rubens XLGK
- Pseudolarix amabilis AQFM
- Pseudotaxus chienii YLPM
- Pseudotsuga menziesii IOVS
- Sciadopitys verticillata YFZK
- Stangeria eriopus KAWQ
- Taiwania cryptomerioides QSNJ
- Taxus baccata WWSS
- Taxus cuspidata ZYAX
- Thuja plicata VFYZ
- Thujopsis dolabrata NKIN
- Torreya nucifera HQOM
- Torreya taxifolia EFMS
- Tsuga heterophylla GAMH
- Welwitschia mirabilis TOXE
- Widdringtonia cedarbergensis AUDE
- Wollemia nobilis RSCE

Ferns
- Adiantum aleuticum WCLG
- Adiantum raddianum BMJR
- Anemia tomentosa CQPW
- Angiopteris evecta NHCM
- Argyrochosma nivea XDDT
- Asplenium nidus PSKY
- Asplenium platyneuron KJZG
- Azolla caroliniana CVEG
- Athyrium filix-femina URCP
- Athyrium filix-femina AFPO
- Blechnum spicant VITX
- Bolbitis repanda JBLI
- Botrypus virginianus BEGM
- Cibotium glaucum ORJE
- Crepidomanes venosum TWFZ
- Cryptogramma acrostichoides WQML
- Culcita macrocarpa PNZO
- Cyathea spinulosa GANB
- Cystopteris fragilis XXHP
- Cystopteris fragilis LHLE
- Cystopteris protrusa YOWV
- Cystopteris reevesiana RICC
- Cystopteris utahensis HNDZ
- Davallia fejeensis OQWW
- Dennstaedtia davallioides MTGC
- Deparia lobato-crenata FCHS
- Didymochlaena truncatula RFRB
- Diplazium wichurae UFJN
- Dipteris conjugata MEKP
- Equisetum diffusum CAPN
- Equisetum hyemale JVSZ
- Gaga arizonica DCDT
- Gymnocarpium dryopteris HEGQ
- Hemionitis arifolia ZXJO
- Homalosorus pycnocarpos OCZL
- Hymenophyllum bivalve QIAD
- Hymenophyllum cupressiforme TRPJ
- Leucostegia immersa WGTU
- Lindsaea linearis NOKI
- Lindsaea microphylla YIXP
- Lygodium japonicum PBUU
- Marattia sp. UXCS
- Myriopteris eatonii GSXD
- Nephrolepis exaltata NWWI
- Notholaena montieliae YCKE
- Onoclea sensibilis HTFH
- Ophioglossum petiolatum QHVS
- Ophioglossum petiolatum WTJG
- Osmunda javanica VIBO
- Osmunda regalis YKSS
- Osmunda regalis UOMY
- Osmundastrum cinnamomeum BIVQ
- Pilularia globulifera KIIX
- Pityrogramma trifoliata UJTT
- Plagiogyria japonica UWOD
- Pleopeltis polypodioides UJWU
- Polypodium amorphum YLJA
- Polypodium glycyrrhiza CJNT
- Polypodium hesperium GYFU
- Polypodium hesperium IXLH
- Phlebodium pseudoaureum ZQYU
- Polystichum acrostichoides FQGQ
- Psilotum nudum QVMR
- Pteridium aquilinum[1]
- Pteris ensiformis FLTD
- Pteris vittata POPJ
- Sceptridium dissectum EEAQ
- Sticherus lobatus XDVM
- Thelypteris acuminata MROH
- Thyrsopteris elegans EWXK
- Tmesipteris parva ALVQ
- Vittaria appalachiana NDUV
- Vittaria lineata SKYV
- Woodsia ilvensis YQEC
- Woodsia scopulina YJJY

Lycophytes
- Dendrolycopodium obscurum XNXF
- Diphasiastrum digitatum WAFT
- Huperzia lucidula GKAG
- Huperzia myrisinites CBAE
- Huperzia selago GTUO
- Huperzia selago NYBX
- Huperzia squarrosa GAON
- Lycopodiella apressa ULKT
- Lycopodium annotinum ENQF
- Lycopodium deuterodensum PQTO
- Phylloglossum drummondii ZZEI
- Pseudolycopodiella caroliniana UPMJ
- Selaginella moellendorffii*
- Selaginella acanthonota ZYCD
- Selaginella apoda LGDQ
- Selaginella kraussiana ZFGK
- Selaginella lepidophylla ABIJ
- Selaginella selaginoides KUXM
- Selaginella stauntoniana ZZOL
- Selaginella wallacei JKAA
- Selaginella willdenowii KJYC
- Isoetes sp. PYHZ
- Isoetes sp. FITN
- Isoetes tegetiformans PKOX

Hornworts
- Anthoceros punctatus*[2]
- Megaceros flagellaris UCRN
- Nothoceros vincentianus TCBC
- Nothoceros aenigmaticus DXOU
- Paraphymatoceros hallii FAJB
- Phaeoceros carolinianus WCZB

Liverworts
- Bazzania trilobata WZYK
- Blasia sp. AEXY
- Calypogeia fissa RTMU
- Conocephalum conicum ILBQ
- Frullania sp. CHJJ
- Frullania sp. TGKW
- Lunularia cruciata TXVB
- Marchantia emarginata TFYI
- Marchantia paleacea IHWO
- Marchantia paleacea HMHL
- Marchantia polymorpha JPYU
- Metzgeria crassipilis NRWZ
- Odontoschisma prostratum YBQN
- Pallavicinia lyellii YFGP
- Pellia epiphylla PIUF
- Pellia neesiana JHFI
- Plagiochila asplenioides NWQC
- Porella navicularis KRUQ
- Porella pinnata UUHD
- Radula lindenbergia BNCU
- Riccia berychiana WJLO
- Scapania nemorosa IRBN
- Schistochila sp. LGOW
- Sphaerocarpos texanus HERT

Mosses
- Anomodon attenuatus QMWB
- Anomodon rostratus VBMM
- Atrichum angustatum ZTHV
- Aulacomnium heterostichum WNGH
- Bryum argenteum JMXW
- Buxbaumia aphylla HRWG
- Ceratodon purpureus FFPD
- Dicranum scoparium NGTD
- Funaria sp. XWHK
- Hedwigia ciliata YWNF
- Hypnum subimponens LNSF
- Leucobryum albidum VMXJ
- Leucobryum glaucum RGKI
- Leucodon sciuroides ZACW
- Neckera douglasii TMAJ
- Orthotrichum lyellii CMEQ
- Philonotis fontana ORKS
- Physcomitrella patens*
- Physcomitrium pyrimorfe YEPO
- Plagiomnium insigne BGXB
- Polytrichum commune SZYG
- Pseudotaxiphyllum elegans QKQO
- Racomitrium varium RDOO
- Rhynchostegium serrulatum JADL
- Rhytidiadelphus loreus WSPM
- Scouleria aquatica BPSG
- Schwetschkeopsis fabronia IGUH
- Sphagnum lescurii GOWD
- Sphagnum palustre RCBT
- Sphagnum recurvatum UHLI
- Syntrichia princeps GRKU
- Takakia lepidozioides SKQD
- Thuidium delicatulum EEMJ
- Timmia austriaca ZQRI

Charophytes
- Bambusina borreri QWFV
- Chaetosphaeridium globosum DRGY
- Chara vulgaris MWXT
- Chlorokybus atmophyticus AZZW
- Closterium lunula DRFX
- Coleochaete irregularis QPDY
- Coleochaete scutata VQBJ
- Cosmarium broomei HIDG
- Cosmarium granatum MNNM
- Cosmarium ochthodes HJVM
- Cosmarium ochthodes STKJ
- Cosmarium subtumidum WDGV
- Cosmarium tinctum BHBK
- Cosmocladium cf. constrictum RQFE
- Cylindrocystis brebissonii YOXI
- Cylindrocystis brebissonii RPGL
- Cylindrocystis cushleckae JOJQ
- Cylindrocystis sp. VAZE
- Desmidium aptogonum DFDS
- Entransia fimbriata BFIK
- Euastrum affine GYRP
- Gonatozygon kinahanii KEYW
- Interfilum paradoxum FPCO
- Klebsormidium subtile FQLP
- Mesostigma viride KYIO
- Mesotaenium braunii WSJO
- Mesotaenium caldariorum HKZW
- Mesotaenium endlicherianum WDCW
- Mesotaenium kramstei NBYP
- Micrasterias fimbriata MCHJ
- Mougeotia sp. ZRMT
- Netrium digitus FFGR
- Nucleotaenium eifelense KMNX
- Onychonema laeve GGWH
- Penium exiguum YSQT
- Penium margaritaceum AEKF
- Phymatodocis nordstedtiana RPQV
- Planotaenium ohtanii SNOX
- Pleurotaenium trabecula MOYY
- Roya obtusa XRTZ
- Spirogyra sp. HAOX
- Spirotaenia minuta NNHQ
- Spirotaenia sp. TPHT
- Staurastrum sebaldi ISHC
- Staurodesmus convergens WCQU
- Staurodesmus omearii RPRU
- Xanthidium antilopaeum GBGT
- Zygnemopsis sp. MFZO

Trebouxiophyceae
- Botryococcus braunii ETGN
- Botryococcus sudeticus VJDZ
- Botryococcus terribilis QYXY
- Chlorella minutissima MWAN
- Coccomyxa pringsheimii GXBM
- Eremosphaera viridis MNCB
- Geminella sp. PFUD
- Leptosira obovata ZNUM
- Microthamnion kuetzigianum DXNY
- Nannochloris atomus MFYC
- Parachlorella kessleri AKCR
- Pedinomonas minor RRSV
- Pedinomonas tuberculata PUAN
- Prasiola crispa WCLV
- Prototheca wickerhamii BILC
- Stichococcus bacillaris WXRI
- Trebouxia arboricola NKXU

Chlorophyceae
- Ankistrodesmus sp. OTQG
- Aphanochaete repens IJMT
- Asteromonas gracilis NTLE
- Brachiomonas submarina GUBD
- Carteria crucifera VIAU
- Carteria obtusa RUIF
- Chaetopeltis orbicularis BAZF
- Chlamydomonas reinhardtii*
- Chlamydomonas bilatus MULF
- Chlamydomonas cribrum BCYF
- Chlamydomonas moewusii JRGZ
- Chlamydomonas noctigama VALZ
- Chlamydomonas sp. TSBQ
- Chlamydomonas sp. AOUJ
- Chloromonas oogama IHOI
- Chloromonas perforata QRTH
- Chloromonas reticulata LBRP
- Chloromonas rosae AJUW
- Chloromonas subdivisa GFUR
- Chloromonas tughillensis UTRE
- Chlorosarcinopsis halophila KSFK
- Dunaliella salina RHVC
- Dunaliella tertiolecta ZDIZ
- Eudorina elegans RNAT
- Fritschiella tuberosa VFIV
- Golenkinia longispicula BZSH
- Gonium pectorale KUJU
- Haematococcus pluvialis ODXI
- Haematococcus pluvialis AGIO
- Hafniomonas reticulata FXHG
- Helicodictyon planctonicum AJAU
- Heterochlamydomonas inaequalis IRYH
- Lobochlamys segnis OFUE
- Lobomonas rostrata JKKI
- Microspora cf. tumidula FOYQ
- Neochloris oleoabundans EEJO
- Neochloris sp. GJIY
- Neochlorosarcina sp. USIX
- Oedogonium cardiacum DVYE
- Oedogonium foveolatum SDPC
- Oogamochlamys gigantea XDLL
- Pandorina morum RYJX
- Pediastrum duplex XKWQ
- Pediastrum duplex XTON
- Phacotus lenticularis ZIVZ
- Pirula salina NQYP
- Pleurastrum insigne PRIQ
- Pteromonas angulosa LNIL
- Pteromonas sp. ACRY
- Scenedesmus dimorphus PZIF
- Scourfieldia sp. EGNB
- Spermatozopsis exsultans MXDS
- Spermatozopsis similis ENAU
- Stephanosphaera pluvialis ZLQE
- Stigeoclonium helveticum JMUI
- Uronema sp. ISGT
- Uronema belkae RAWF
- Vitreochlamys sp. QWRA
- Volvox carteri*
- Volvox aureus JWGT
- Volvox aureus WRSL
- Volvox globator ISPU

Ulvophyceae
- Acrosiphonia sp. JIWJ
- Blastophysa cf. rhizopus VHIJ
- Bolbocoleon piliferum LSHT
- Bryopsis plumosa JTIG
- Cephaleuros virescens YDCQ
- Cladophora glomerata VBLH
- Codium fragile GYBH
- Cylindrocapsa geminella DZPJ
- Entocladia endozoica OQON
- Halochlorococcum marinum ALZF
- Ignatius tetrasporus KADG
- Ochlochaete sp. CQQP
- Oltmannsiellopsis viridis PZBH
- Oltmannsiellopsis viridis QJYX
- Percursaria percursa OAEZ
- Planophila laetevirens CBNG
- Planophila terrestris LETF
- Trentepohlia annulata NATT

Prasinophytes
- Bathycoccus prasinos MCPK
- Cymbomonas sp. XIVI
- Dolichomastix tenuilepis XOAL
- Mantoniella squamata QXSZ
- Micromonas pusilla*
- Monomastix opisthostigma BTFM
- Nephroselmis olivacea MMKU
- Nephroselmis pyriformis ISIM
- Ostreococcus tauri*
- Ostreococcus lucimarinus*
- Picocystis salinarum TGNL
- Prasinococcus capsulatus XMCL
- Prasinoderma coloniale HYHN
- Pseudoscourfieldia marina JMTE
- Pycnococcus provasolii MXEZ
- Pyramimonas parkeae TNAW
- Scherffelia dubia FMVB
- Tetraselmis chui HVNO
- Tetraselmis cordiformis DUMA
- Tetraselmis striata HHXJ
- coccoid prasinophyte XJGM

Glaucophyta
- Cyanophora paradoxa QFND
- Cyanophora paradoxa YTYU
- Cyanoptyche gloeocystis JKHA
- Glaucocystis cf. nostochinearum POOW
- Gloeochaete wittrockiana PQED

Red Algae
- Betaphycus gelatinae BWVJ
- Ceramium kondoi VZWX
- Chondrus crispus UGPM
- Chroodactylon ornatum LLXJ
- Dumontia simplex IEHF
- Eucheuma denticulatum JEBK
- Glaucosphaera vacuolata RSOF
- Gloeopeltis furcata SBLT
- Gracilaria asiatica VNAL
- Gracilaria blodgettii LJPN
- Gracilaria chouae FTRP
- Gracilaria lemaneiformi IKWM
- Grateloupia filicina ZJOJ
- Grateloupia livida IKIZ
- Grateloupia turuturu URSB
- Grateloupia chiangii PWKQ
- Gymnogongrus ftabelliformis CKXF
- Heterosiphonia pulchra YSBD
- Kappaphycus alvarezii IHJY
- Mazzaella japonica WEJN
- Polysiphonia japonica XAXW
- Porphyra yezoensis ZULJ
- Porphyridium cruentum OBUY
- Porphyridium purpureum PVGP
- Rhodella violacea RTLC
- Rhodochaete parvula JJZR
- Sinotubimorpha guangdongensis PYDB

Chromista
- Chroomonas sp. ROZZ
- Colpomenia sinuosa QLMZ
- Cryptomonas curvata BAKF
- Desmarestia viridis FSQE
- Dictyopteris undulata LIRF
- Hemiselmis virescens MJMQ
- Ishige okamurai APTP
- Isochrysis sp. BAJW
- Kjellmaniella crassifolia RAPY
- Laminaria japonica OGZM
- Laminaria japonica QDTV
- Mallomonas sp. BOGT
- Nannochloropsis oculata JQFK
- Ochromonas sp. EBWI
- Pavlova lutheri LLEN
- Pavlova lutheri NMAK
- Pavlova lutheri RFAD
- Petalonia fascia VRGZ
- Prorocentrum micans TZJQ
- Proteomonas sulcata IRZA
- Prymnesium parvum LXRN
- Punctaria latifolia ASZK
- Rhodomonas sp. IAYV
- Sargassum horneri RWXW
- Sargassum thunbergii YRMA
- Sargassum vachellianum HFIK
- Sargassum fusiforme LDRY
- Sargassum hemiphyllum VYER
- Sargassum henslowianum FIKG
- Sargassum integerrimum FOMH
- Sargassum muticum JGGD
- Scytosiphon lomentaria JCXF
- Scytosiphon dotyo ULXR
- Symphyocladia latiuscula UYFR
- Synura petersenii DBYD
- Synura sp. VKVG
- Undaria pinnatifida FIDQ

Excavata
- Euglena sp. UNBZ

[1]P.G. Wolf 923 (UTC); Norwich, UK.

[2]D.G. Long s.n. (OXF); Edinburgh, UK

Table S2. The calibrations used in dating the divergences within the phototropin gene family.

No.	Clade	Calibration	Date (MYA)	Prior	Reference	Justification
1	Tracheophyta	*Zosterophyllum sp.*	416	lognormal (mean: 3.5, STD: 1, offset: 416)	70, 74	Oldest unequivocal record of total group of lycoposid; see Ref. 72 for detailed justifications
2	Euphyllophyta	*Ibyka sp.*	388.2	lognormal (mean: 3.5, STD: 1, offset: 388.2)	70, 75	Oldest unequivocal record of monilophyte based on protoxylem morphology; see Ref. 72 for detailed justifications
3	Bryophyta PHOTA	"type III" fragment	330.9-346.7	lognormal (mean: 1.5, STD: 1, offset: 330.9)	71	Oldest unequivocal record of crown Bryophyta; the fibrils and pores similar to those of *Sphagnum* water-storage cells
4	Bryophyta PHOTB	"type III" fragment	330.9-346.7	lognormal (mean: 1.5, STD: 1, offset: 330.9)	71	Oldest unequivocal record of crown Bryophyta; the fibrils and pores similar to those of *Sphagnum* water-storage cells
5	Jungermanniopsida	*Riccardiothallus devonicus*	407-411	lognormal (mean: 1.5, STD: 1, offset: 407)	72	Oldest unequivocal record of crown Jungermanniopsida; gross morphology similar to the extant *Riccardia* species
6	Polypodiopsida PHOT1	*Rastropteris pirtgquanensis*	296	lognormal (mean: 1.5, STD: 1, offset: 296)	8, 76	Oldest unequivocal record of Osmundaceae stem; see Ref. 8 for detailed justifications
7	Polypodiopsida PHOT2	*Rastropteris pirtgquanensis*	296	lognormal (mean: 1.5, STD: 1, offset: 296)	8, 76	Oldest unequivocal record of Osmundaceae stem; see Ref. 8 for detailed justifications
8	Eupolypod PHOT1	imported secondary date	116.7	Normal (mean: 116.7, STD: 35.01)	8	A well-established time estimate for the divergence of Eupolypods
9	Eupolypod PHOT2	imported secondary date	116.7	Normal (mean: 116.7, STD: 35.01)	8	A well-established time estimate for the divergence of Eupolypods
10	Spermatophyta PHOT1	*Cordaixylon iowensis*	306.2	lognormal (mean: 2.5, STD: 1, offset: 306.2)	70, 77	Oldest unequivocal record of Acrogymnospermae; see Ref. 72 for detailed justifications
11	Spermatophyta PHOT2	*Cordaixylon iowensis*	306.2	lognormal (mean: 2.5, STD: 1, offset: 306.2)	70, 77	Oldest unequivocal record of Acrogymnospermae; see Ref. 72 for detailed justifications
12	Grass PHOT1	phytoliths in dinosaur coprolites	65-67	lognormal (mean: 1.5, STD: 1, offset: 65)	73	Oldest unequivocal record of PACMAD or BEP of grass; phytoliths morphology similar to subclades in PACMAD or in BEP
13	Grass PHOT2	phytoliths in dinosaur coprolites	65-67	lognormal (mean: 1.5, STD: 1, offset: 65)	73	Oldest unequivocal record of PACMAD or BEP of grass; phytoliths morphology similar to subclades in PACMAD or in BEP
14	Coniferae PHOT1	*Araucaria mirabilis*	147	lognormal (mean: 1.5, STD: 1, offset: 147)	70	Oldest unequivocal record of Cupressophyta crown; see Ref. 72 for detailed justifications
15	Coniferae PHOT2	*Araucaria mirabilis*	147	lognormal (mean: 1.5, STD: 1, offset: 147)	70	Oldest unequivocal record of Cupressophyta crown; see Ref. 72 for detailed justifications

Table S3. The primers and PCR protocols used in this study. See Table S4 for primer sequences.

Taxa	Gene	Primary PCR primers	Secondary PCR primers[1]	PCR program[2]	Specimen voucher
Hornworts:					
Phymatoceros phymatodes	neochrome	neoF65 + neoR2818	neoF430 + neoR2776	a/a	J. Pittermann s.n. (DUKE)
Phymatoceros phymatodes	neochrome	neoF65 + neoR4110	neoF2367 + neoR3456	a/a	J. Pittermann s.n. (DUKE)
Phymatoceros phymatodes	neochrome	neoF65 + neoR4110	neoF3230 + neoR4110	a/a	J. Pittermann s.n. (DUKE)
Phymatoceros phymatodes	phototropin	neoF65 + neoR4110	neoF2367 + neoR3456	a/a	J. Pittermann s.n. (DUKE)
Phymatoceros phymatodes	phototropin	photF1856 + photR2508	photF1970 + photR2245	a/a	J. Pittermann s.n. (DUKE)
Phymatoceros phymatodes	phototropin	photF2774 + photR4339	-	a	J. Pittermann s.n. (DUKE)
Megaceros flagellaris	neochrome	neoF65 + neoR902	-	b	B. Crandall-Stotler s.n. (ABSH)
Megaceros flagellaris	neochrome	neoF649 + neoR1950	-	b	B. Crandall-Stotler s.n. (ABSH)
Megaceros flagellaris	neochrome	neoF1844 + neoR2361	-	c	B. Crandall-Stotler s.n. (ABSH)
Megaceros flagellaris	neochrome	neoF2239 + neoR3300	-	b	B. Crandall-Stotler s.n. (ABSH)
Megaceros flagellaris	neochrome	neoF2361 + neoR4110	-	c	B. Crandall-Stotler s.n. (ABSH)
Megaceros flagellaris	phototropin	photF1856 + photR4339	photF1970 + photR4339	a/a	B. Crandall-Stotler s.n. (ABSH)
Nothoceros aenigmaticus	neochrome	F5 + R1_T1	F565 + R1_T1	d/d	F.W. Li 1291 (DUKE)
Nothoceros aenigmaticus	neochrome[3]	neoF4018 + AP1	neoF4110 + AP2	e/f	F.W. Li 1569 (DUKE)
Nothoceros aenigmaticus	neochrome[3]	neoR429 + AP1	R3re_phyN + AP2	e/f	F.W. Li 1569 (DUKE)
Nothoceros aenigmaticus	neochrome[3]	NaNEO_3-1_GM1 + AP1	NaNEO_3-1_GM2 + AP2	e/f	F.W. Li 1569 (DUKE)
Nothoceros aenigmaticus	phototropin	5upF1 + R7	5upF2 + R7	c/g	F.W. Li 1291 (DUKE)
Nothoceros aenigmaticus	phototropin[4]	F565 + I_R1	I_F2 + I_R2	d/d	F.W. Li 1291 (DUKE)
Nothoceros aenigmaticus	phytochrome	F-200_Maphy + R4850_Maphy	F-3_Maphy + R4450_Maphy	h/h	F.W. Li 1291 (DUKE)
Phaeoceros carolinianus	neochrome	neoF65 + neoR877	-	c	B. Crandall-Stotler s.n. (ABSH)
Phaeoceros carolinianus	neochrome	neoF649 + neoR1950	-	b	B. Crandall-Stotler s.n. (ABSH)
Phaeoceros carolinianus	neochrome	neoF1576 + neoR4104	-	a	B. Crandall-Stotler s.n. (ABSH)
Anthoceros punctatus	neochrome	neoF67 + neoR832	-	c	D. Chamberlain s.n. (E)
Anthoceros punctatus	neochrome	neoF428 + neoR3049	neoF812 + neoR2938	a/g	D. Chamberlain s.n. (E)
Anthoceros punctatus	neochrome	neoF2938 + neoR4104-2	neoF3049 + neoR4104-2	a/a	D. Chamberlain s.n. (E)
Ferns:					
Adiantum andicola	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	C.J. Rothfels 2641, DB5549[5] (DUKE)
Adiantum hispidulum	neochrome	neoF58 + neoR4238	neoF651 + neoR3718	c/c	L. Huiet s.n., DB9529 (DUKE)
Adiantum hispidulum	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	L. Huiet s.n., DB9529 (DUKE)
Adiantum pedatum	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	C.J.Rothfels 3839, DB7517 (DUKE)
Adiantum pedatum	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	C.J.Rothfels 3839, DB7517 (DUKE)
Adiantum tetraphyllum	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	L. Huiet 105, DB2505 (UC)
Adiantum tetraphyllum	neochrome	neoF20 + neoR4242	neoF20 + neoR2236	i/c	L. Huiet 105, DB2505 (UC)
Adiantum tetraphyllum	neochrome	neoF1108 + neoR3065	-	k	L. Huiet 105, DB2505 (UC)
Alsophila podophylla	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/l	E. Schuettpelz 1201A, DB4948 (DUKE)
Alsophila podophylla	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/l	E. Schuettpelz 1201A, DB4948 (DUKE)
Alsophila podophylla	neochrome	neoF20 + neoR4242	neoF538 + neoR4000	i/l	E. Schuettpelz 1201A, DB4948 (DUKE)
Bolbitis auriculata	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	F. Rakotondrainibe, DB3504 (P)
Dennstaedtia punctilobula	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	C.J. Rothfels 4167, DB8975 (DUKE)
Dennstaedtia punctilobula	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/l	C.J. Rothfels 4167, DB8975 (DUKE)
Dennstaedtia punctilobula	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/l	C.J. Rothfels 4167, DB8975 (DUKE)
Deparia acrostichoides	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	C.J. Rothfels 3894, DB7797 (DUKE)
Deparia acrostichoides	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	C.J. Rothfels 3894, DB7797 (DUKE)
Deparia acrostichoides	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	C.J. Rothfels 3894, DB7797 (DUKE)
Deparia lancea	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	E. Schuettpelz 298, DB2558 (DUKE)
Deparia lancea	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	E. Schuettpelz 298, DB2558 (DUKE)
Didymochlaena truncatula	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	E. Schuettpelz 267, DB2435 (DULE)
Diplazium bombonasae	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	R.C. Moran 7493, DB3764 (DUKE)
Doodia media	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	E. Schuettpelz 295, DB2555 (DUKE)
Dryopteris amurensis	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	A. Uchida 1392, DB7982 (TNS)
Dryopteris amurensis	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	A. Uchida 1392, DB7982 (TNS)
Dryopteris expansa	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	A. Ebihara TH2007-507, DB7977 (TNS)
Dryopteris expansa	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	A. Ebihara TH2007-507, DB7977 (TNS)
Hemidictyum marginatum	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/j	M. Christenhusz 2476, DB3054 (CAY)
Hemidictyum marginatum	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/j	M. Christenhusz 2476, DB3054 (CAY)
Hemidictyum marginatum	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/j	M. Christenhusz 2476, DB3054 (CAY)
Hemidictyum marginatum	neochrome	neoF1108 + neoR3065	-	k	M. Christenhusz 2476, DB3054 (CAY)
Hypolepis tenuifolia	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	E. Schuettpelz 286, DB2574 (DUKE)
Macrothelypteris torresiana	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	Schuettpelz 335, DB2980 (DUKE)
Macrothelypteris torresiana	neochrome	neoF20 + neoR4242	neoF20 + neoR2336	i/c	Schuettpelz 335, DB2980 (DUKE)
Macrothelypteris torresiana	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	Schuettpelz 335, DB2980 (DUKE)
Matteuccia struthiopteris	neochrome	neoF20 + neoR786	-	b	A. Larsson 258, DB7946 (DUKE)
Matteuccia struthiopteris	neochrome	neoF649 + neoR1950	-	b	A. Larsson 258, DB7946 (DUKE)
Matteuccia struthiopteris	neochrome	neoF1530 + neoR2300	-	m	A. Larsson 258, DB7946 (DUKE)
Matteuccia struthiopteris	neochrome	neoF2239 + neoR3300	-	m	A. Larsson 258, DB7946 (DUKE)
Matteuccia struthiopteris	neochrome	neoF2935 + neoR3720	-	m	A. Larsson 258, DB7946 (DUKE)
Matteuccia struthiopteris	neochrome	neoF58 + neoR4238	neoF651 + neoR3718	c/c	A. Larsson 258, DB7946 (DUKE)
Onoclea sensilibis	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	E. Schuettpelz 353, DB2998 (DUKE)
Onoclea sensilibis	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	E. Schuettpelz 353, DB2998 (DUKE)
Phegopteris hexagonoptera	neochrome	neoF20 + neoR4242	neoF651 + neoR3718	i/c	M. Christenhusz 3844, DB2731 (TUR)
Phegopteris hexagonoptera	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/c	M. Christenhusz 3844, DB2731 (TUR)
Plagiogyria formosana	neochrome	neoF20 + neoR786	-	b	E. Schuettpelz 1083A, DB4826 (DUKE)
Plagiogyria formosana	neochrome	neoF649 + neoR1950	-	b	E. Schuettpelz 1083A, DB4826 (DUKE)
Plagiogyria formosana	neochrome	neoF1530 + neoR2300	-	m	E. Schuettpelz 1083A, DB4826 (DUKE)
Plagiogyria formosana	neochrome	neoF2935 + neoR3720	-	m	E. Schuettpelz 1083A, DB4826 (DUKE)
Tectaria zeylanica	neochrome	neoF20 + neoR4242	-	i	E. Schuettpelz 514, DB3569 (GOET)
Thelypteris noveboracensis	neochrome	neoF20 + neoR4242	neoF2115 + neoR4242	i/l	C.J. Rothfels 4164, DB8972 (DUKE)

[1]The primer pair for secondary PCR in nested PCR reaction. "-" indicates no nested PCR was conducted.

[2]The PCR program used (primary PCR/secondary PCR, if nested PCR was used).

[3]Genome walking using Clontech Genome Walker kit.

[4]Genome walking using Inverse PCR.

[5]Fern DNA Database number (http://fernlab.biology.duke.edu).

a 98:30s, (98:10s, 70:30s,72:90s)x35, 72:600s
b 98:30s, (98:10s, 60:30s,72:90s)x35, 72:600s
c 98:30s, (98:10s, 72:120s)x35, 72:600s
d 98:30s, (98:10s, 72:180s)x35, 72:600s
e (94:25s, 72:180s)x7, (94:25s, 67:180s)x32, 67:420s
f (94:25s, 72:180s)x5, (94:25s, 67:180s)x20, 67:420s
g 98:30s, (98:10s, 67:30s,72:90s)x35, 72:600s
h 98:30s, (98:10s, 67:30s,72:150s)x35, 72:600s
i 98:30s, (98:10s, 68:30s,72:120s)x35, 72:600s
j 94:300s, (94:60s, 60:60,72:120s)x35, 72:600s
k 94:300s, (94:60s, 56:60,72:240s)x35, 72:600s
l 98:30s, (98:10s, 70:30s,72:120s)x35, 72:600s
m 98:30s, (98:10s, 55:30s,72:90s)x35, 72:600s

Table S4. The primer sequences.

Primer	Sequence (5'-3')
5upF1	ATTCACAAATGTTGCCCGATGTGC
5upF2	CTGCACTCCTACTCGTTACCG
AP1	GTAATACGACTCACTATAGGGC
AP2	ACTATAGGGCACGCGTGGT
F-200_Maphy	AGCGTGTAGCCTTGTCCTGTAC
F-3_Maphy	GCGACAGCGGCAAAGTTGAAG
F5	GCGGCAGGCTGCTCAACTACAG
F565	TACACCGAAGGCTACAAGGCTAATG
I_F2	CAAGTGCAATCCAATGATGCCGC
I_R1	TTCTGTAGTTGAGCAGCCTGCC
I_R2	GAGGAGTAGCCGGTCATGGTGAAG
NaNEO_3-1_GM1	TGTGGAACAAAGGCAACTTGGGACGAA
NaNEO_3-1_GM2	ATGTGAAGCCTCAAGCAAATGTTACAAGT
neoF1108	GTGCAGCTCAACATKGAGCTGGA
neoF1530	TCBTRTTTTGGTTYAGGTCRCAYACTGC
neoF1576	CTGGACAGGGACGACGACTCTCG
neoF1844	CATTGAGGGACAAGGAGGAGTTACCAGG
neoF20	CCAAGACGAAGCACAGCGTG
neoF2115	GGAGGTGATTGGAGSCAACTGC
neoF2239	AGGAAAGATGGYAGCWRYTTYTGGAA
neoF2300	GCTRGAGGTDASCAAGTACACDGAGGG
neoF2361	CGGCACCAGGACAAGGTTTCTG
neoF2367	CAGTCSCTCATCAAGTACGAYGT
neoF2935	GTKCAGCTYATCCGAGATGCAGT
neoF2938	CTGTCCCTGGAGATCGTGAACTACACC
neoF3049	CAACAGAAGGTGGCGGATTATGTTCC
neoF3230	CAGACCATCTATGGGTGCGGCATTC
neoF4018	ATCTTGCTCTACGAGATGCTCTATGGC
neoF4110	TACATTCCCAACCAGCATCCCAGTGAG
neoF428	GYACGGATSTGCGGATGCTCTTCAC
neoF430	ACGGATSTGCGGATGCTCTTCAC
neoF58	AGBGCNGATGCMAGRCTYCATGC
neoF649	GATCGDGTGATGGCBTACAARTTYCA
neoF649	GATCGDGTGATGGCBTACAARTTYCA
neoF65	ATGCGAGGCTKAATGCGGCGTTTGAG
neoF651	TCGGGTGATGGCCTACAAGTTCCA
neoF67	GCGAGGCTGMATGCGGYGTTYGAG
neoF812	ACAAGTTYCAYGAGGACGAGCACG
neoR1950	CCYCGAAYNGCYTCCATCCAYTCCTG
neoR2236	AGAAGYTGCTGCCRTCTTTCCTGTA
neoR2361	CRGAAACCTTGTCCTGGTGCCG
neoR2776	GCGAAGATGATGGGGTTGTCCG
neoR2818	GCACCTCCTCCCTGCTGTACTCTGTCAG
neoR2938	GGTGTAGTTCACGATCTCCAGGGACAG
neoR3049	GGAACATAATCCGCCACCTTCTGTTG
neoR3065	CTGHACTCCGATGAAGTACTGGA
neoR3300	GYARCCTSGGATCTGWGATCAC
neoR3456	AGCATCATSGCCTTGTCCATG
neoR3718	TGACVCCCATGCAGTGGAGGTACTC
neoR3720	GTTCTCBGGCTTSAGRTCBCGGTAGATG
neoR4104	ATGCTGGTKGGGAATGTRAGCTCCTTG
neoR4104-2	AYGCTGSTSGGGAAKGTGAGCTCCTTG
neoR4110	AGGCTCACTGGGATGCTGGTTGGG
neoR4238	CGGATRAGAGGCCAGTYGATKYCTYGGA
neoR4242	CGGATGAGAGGCCAGTCGATKYCT
neoR429	GAGTGAACAGCATCCGCACATCCGTG
neoR786	GGTARTGCARGCCVAGRTAHGGCTCC
neoR832	GAGGCTGATCGGCTGGTGGAGC
neoR877	ATGTACTGCGTGTGGCAACCGTGC
neoR902	GACGAGACGGAGCCCATGTTGC
photF1856	CTGGTGSTCAAGGAGGAGCTGG
photF1970	GCTCTCCWCCTTCCAGCAGACG
photF2645	CTTCGCCTCYGACCAYTTCCTGG
photF2774	GGAGAGACGGGACATCACTGTGC
photR2508	AGCAGCGACAGAAATCCCGAGGAC
photR2901	GCTCGTACTCGCTSCCRTCCAG
photR4102	ATGCTGSTSGGRAATGTGAGCTCCTTGTT
photR4339	TCYKCCTCGTCCCACTCCAGRTC
R1_T1	ACCCAGGATCAAAACACATCGCTG
R3re	GACGCATTCTCGCTCATTGCCAGGAT
R4450_Maphy	CCATCCACCACAGGTTCTGAACAC
R4850_Maphy	AAAATGTCCAGGACCGTCAGGTTC
R7	AGAGTGGTGGCCAAGTCAATTCC