

Supplementary Table S1. A) Biogeobears model test results for habitat and ecoregion. Columns from left to right: model tested; log of the likelihood value (LnL), number of parameters included in the model, dispersal, extinction, founder or jump dispersal event, corrected Akaike Information Criterion, weighted corrected Akaike Information Criterion (AICc). DEC+J was most well-supported for our dataset on habitat, and BAYAREALIKE+J was most well-supported for our dataset on ecoregions.

Ranges scored by habitat

Model	LnL	numparams	d	e	j	AICc	AICc_wt
DEC	-174	2	0.004	0.0029	0	352.1	5.30E-13
DEC+J	-145.5	3	0.001	1.00E-12	0.018	297.2	0.45
DIVALIKE	-172.4	2	0.0047	0.0019	0	348.8	2.80E-12
DIVALIKE+J	-145.6	3	0.0012	1.00E-12	0.017	297.4	0.42
BAYAREALIKE	-216.5	2	0.0026	0.034	0	437	2.00E-31
BAYAREALIKE+J	-146.7	3	0.0005	0.0007	0.02	299.6	0.14

Ranges scored by ecoregion

Model	LnL	numparams	d	e	j	AIC	AICc	AIC_wt
DEC	-228	2	0.0061	0.095	0	460.1	460.2	2.60E-08
DEC+J	-274.7	3	0.0003	0.0019	0.058	555.4	555.5	5.40E-29
DIVALIKE	-244.1	2	0.0038	0.0005	0	492.1	492.2	2.90E-15
DIVALIKE+J	-223.6	3	0.0019	1.00E-12	0.01	453.2	453.4	8.20E-07
BAYAREALIKE	-360.9	2	0.01	0.01	0	725.8	725.8	5.40E-66
BAYAREALIKE+J	-209.6	3	0.0007	1.00E-07	0.014	425.2	425.3	1

Section S1

Supplementary Section S1. Accessions used in our phylogenomic analyses; species included in previous analyses are given with the associated citation. Datasets and trees used in our analyses are deposited on Figshare (10.6084/m9.figshare.22211935).

Cactaceae: Opuntioideae: Cyllindropuntieae — *Cyllindropuntia acanthocarpa* (Majure et al. 2019), *Cyllindropuntia alcahes* (Majure et al. 2019), *Cyllindropuntia bigelovii* (Majure et al. 2019), *Cyllindropuntia bigelovii* (Majure et al. 2019), *Cyllindropuntia californica* (Majure et al. 2019), *Cyllindropuntia cholla* (Majure et al. 2019), *Cyllindropuntia ciribe* (Majure et al. 2019),

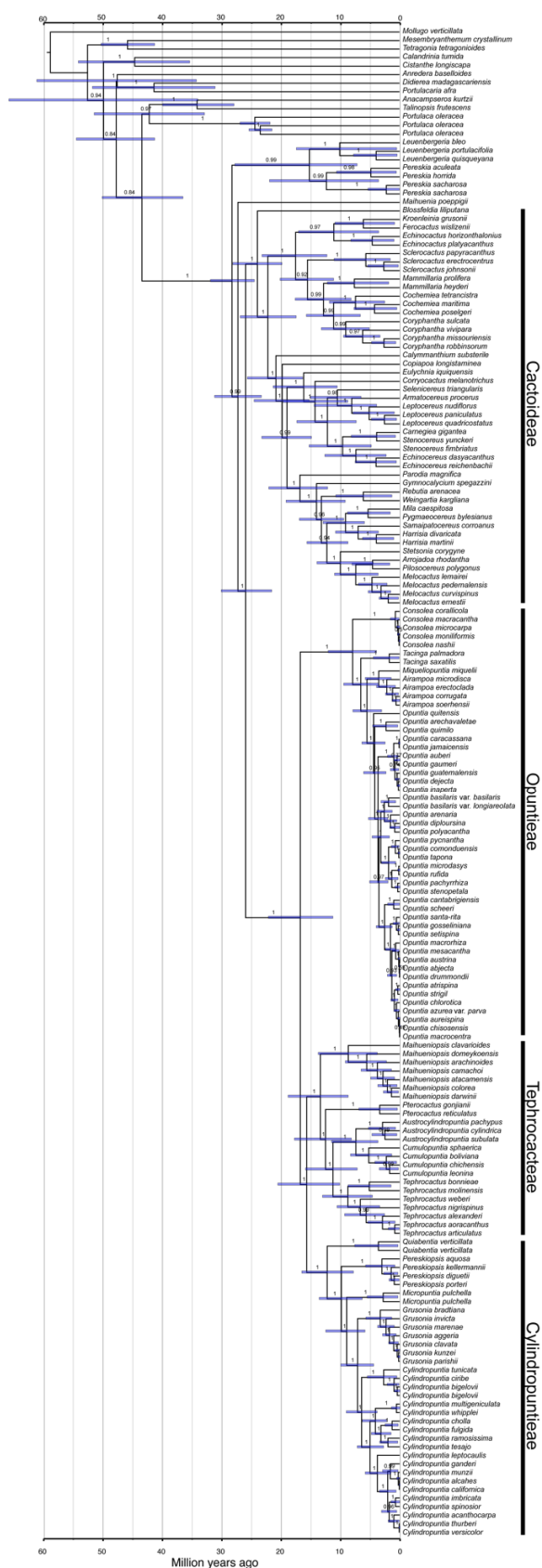
Cylindropuntia fulgida (Majure et al. 2019), *Cylindropuntia ganderi* (Majure et al. 2019), *Cylindropuntia imbricata* (Majure et al. 2019), *Cylindropuntia leptocaulis* (Majure et al. 2019), *Cylindropuntia multigeniculata* (Majure et al. 2019), *Cylindropuntia munzii* (Majure et al. 2019), *Cylindropuntia ramosissima* (Majure et al. 2019), *Cylindropuntia spinosior* (Majure et al. 2019), *Cylindropuntia tesajo* (Majure et al. 2019), *Cylindropuntia thurberi* (Majure et al. 2019), *Cylindropuntia tunicata* (Majure et al. 2019), *Cylindropuntia versicolor* (Majure et al. 2019), *Cylindropuntia whipplei* (Majure et al. 2019), *Grusonia aggeria* (Majure et al. 2019), *Grusonia bradtiana* (Majure et al. 2019), *Grusonia clavata* (Majure et al. 2019), *Grusonia invicta* (Majure et al. 2019), *Grusonia kunzei* (Majure et al. 2019), *Grusonia marenae* (Majure et al. 2019), *Grusonia parishii* (Majure et al. 2019), *Micropuntia pulchella* (Majure et al. 2019), *Micropuntia pulchella* (Majure et al. 2019), *Pereskiopsis aquosa* (Majure et al. 2019), *Pereskiopsis diguettii* (Majure et al. 2019), *Pereskiopsis kellermannii* (Majure et al. 2019), *Pereskiopsis porteri* (Majure et al. 2019), *Quiabentia verticillata* (Majure et al. 2019), *Quiabentia verticillata* (Majure et al. 2019). **Opuntieae** — *Consolea corallicola* (Majure et al. 2021a), *Consolea macracantha* (Majure et al. 2021a), *Consolea picardae* (Majure et al. 2021a), *Consolea moniliformis* (Majure et al. 2021a), *Consolea nashii* (Majure et al. 2021a), *Miqueliopuntia miquelii* (Köhler et al., 2020), *Opuntia abjecta* Majure 3908 (FLAS), *Opuntia arechavaletae* (Majure et al. 2021a), *Opuntia arenaria* Moore 2911 (FLAS), *Opuntia atrispina* Majure 5636 (DES, FLAS), *Opuntia auberi* DBG 1990 (DES), *Opuntia aureispina* Majure 5657 (DES), *Opuntia austrina* (Majure et al. 2021a), *Opuntia azurea* var. *parva* Majure 5649 (DES), *Opuntia basilaris* var. *basilaris* Majure 5753 (DES, FLAS), *Opuntia basilaris* var. *longiareolata* DBG 1952 (DES), *Opuntia cantabrigiensis* DBG 1987 (DES), *Opuntia caracassana* DBG 1997 (DES), *Opuntia chisosensis* Majure 5669 (DES), *Opuntia chlorotica* Majure 5497 (DES), *Opuntia comonduensis* DBG 2011 (DES), *Opuntia dejecta* Majure 7064 (DES), *Opuntia diploursina* Stock 1869 (UT), *Opuntia drummondii* Majure 756 (MISSA), *Opuntia gaumeri* DBG 1999 0027 (DES), *Opuntia gosseliniana* DBG 2003 (DES), *Opuntia guatemalensis* Majure 7117 (FLAS), *Opuntia inaperta* (Majure et al. 2021a), *Opuntia jamaicensis* Majure 9083 (FLAS), *Opuntia macrocentra* Majure 5673 (DES), *Opuntia macrorhiza* Snow 2089 (FLAS), *Opuntia mesacantha* Majure 4231 (FLAS), *Opuntia microdasys* DBG 1987 (DES), *Opuntia pachyrrhiza* Puente 601 (ASU), *Opuntia polyacantha* DBG 2013 (DES), *Opuntia pycnantha* DBG 1968 (DES), *Opuntia quimilo* DBG 2011 (DES), *Opuntia quitensis* Majure 3848 (FLAS), *Opuntia rufida* Majure 5655 (DES),

Opuntia santa-rita DBG 2001 (DES), *Opuntia scheeri* Puente 4727 (DES), *Opuntia setispina* Puente s.n. (DES), *Opuntia stenopetala* DBG 1985 (DES), *Opuntia strigil* Majure 5577 (DES), *Opuntia taponia* Gates s.n. (DES), *Tacinga palmadora* (Köhler et al., 2020), *Tacinga saxatilis* Majure 7084 (DES), *Airampoa corrugata* (Majure et al. 2021a), *Airampoa erectoclada* (Köhler et al., 2020), *Airampoa microdisca* DBG (DES), *Airampoa soehrensii* DBG-Salta (DES).

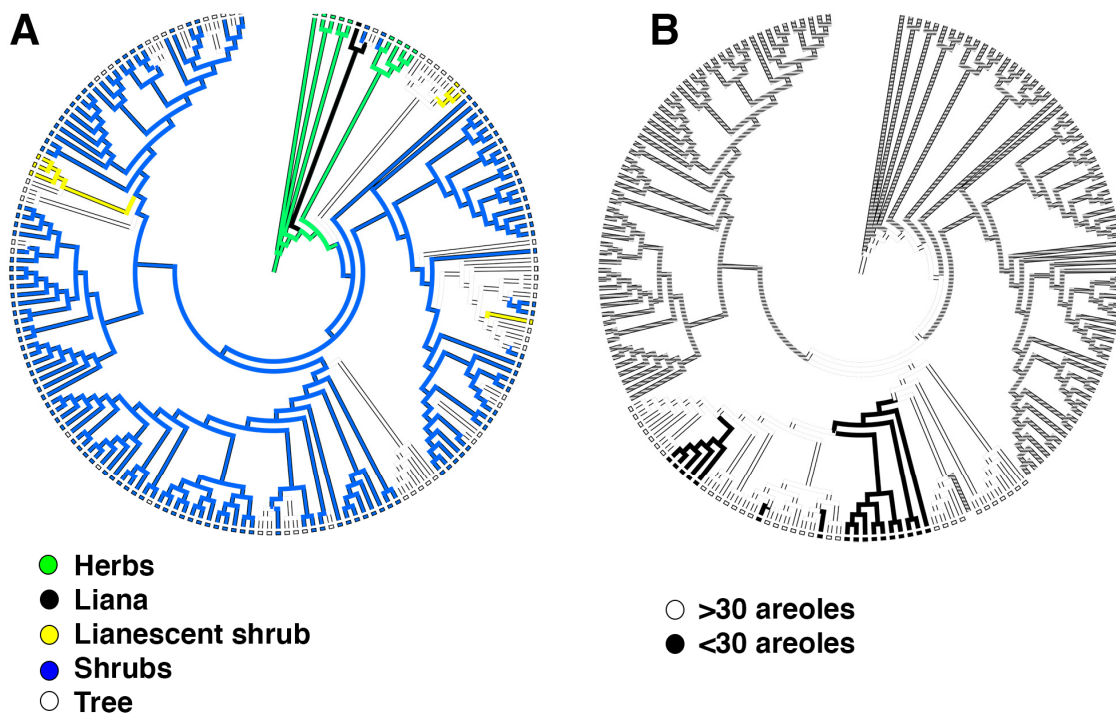
Tephrocactaeae — *Austrocylindropuntia cylindrica* (Köhler et al., 2020), *Austrocylindropuntia pachypus* DBG 1993 (DES), *Austrocylindropuntia subulata* SRR5605359, *Cumulopuntia boliviana* DBG 1993 (DES), *Cumulopuntia chichensis* DBG 1993, *Cumulopuntia leonina* HBG 18358 (HNT), *Cumuopuntia sphaerica* (Köhler et al., 2020), *Maihueniopsis arachinoides* Kattermann 1167 (DES), *Maihueniopsis atacamensis* (Köhler et al., 2020), *Maihueniopsis camachoi* DBG 1998-0050 (DES), *Maihueniopsis clavarioides* Kattermann s.n. (DES), *Maihueniopsis colorea* DBG 2014-2457 (DES), *Maihueniopsis darwinii* JB 7-09 (DES), *Maihueniopsis domeykoensis* DBG 1993 (DES), *Pterocactus gonjianii* (Köhler et al., 2020), *Pterocactus reticulatus* Kattermann 710 (DES), *Tephrocactus alexanderi* DBG 2001-0055 (DES), *Tephrocactus aoracanthus* DBG 1993-0346-0101 (DES), *Tephrocactus articulatus* (Majure et al. 2019), *Tephrocactus bonnieae* DBG 2014-2474 (DES), *Tephrocactus molinensis* DBG 2014 (DES), *Tephrocactus nigrispinus* Kattermann 1200 (DES), *Tephrocactus weberi* DBG 2012 (DES). **Cactoideae** — *Armatocereus procereus* (Majure et al. 2021b), *Arrojadoa rhodantha* (Majure et al. 2022), *Blossfeldia liliputana* (Arakaki et al., 2011), *Calymmanthium substerile* (Majure et al. 2021b), *Carnegiea gigantea* (Sanderson et al., 2016), *Cochemiea maritima* (Breslin et al. 2021), *Cochemiea poselgeri* (Breslin et al. 2021), *Cochemiea tetrancistra* (Breslin et al. 2021), *Copiapoa longistamina* Kattermann 507 (DES), *Coryocactus melanotricha* DBG 1994-0228-1001 (DES), *Coryphantha missouriensis* Majure 5595 (DES, FLAS), *Coryphantha robbinsorum* (Breslin et al. 2021), *Coryphantha sulcata* Majure 5605 (Breslin et al. 2021), *Coryphantha vivipara* (Breslin et al. 2021), *Kroenleinia grusonii* DBG (DES), *Echinocactus horizonthalonius* DBG (DES), *Echinocactus platyacanthus* DBG (DES), *Echinocereus dasyacanthus* Majure 5646 (DES), *Echinocereus reichenbachii* Majure 5679 (DES), *Eulychnia iquiquensis* Anderson 6343 (DES), *Ferocactus wislizenii* DBG (DES), *Gymnocalycium spegazzini* (Majure et al. 2022), *Harrisia divaricata* DBG 2016-0536 (DES), *Harrisia martinii* (Majure et al. 2022), *Leptocereus nudiflorus* (Majure et al. 2021b), *Leptocereus paniculatus* (Majure et al. 2021b), *Leptocereus quadricostatus* (Majure et al.

2021b), *Mammillaria heyderi* (Breslin et al. 2021), *Mammillaria prolifera* (Breslin et al. 2021), *Melocactus curvispinus* (Majure et al. 2022), *Melocactus ernestii* (Majure et al. 2022), *Melocactus lemairei* (Majure et al. 2022), *Melocactus pedernalensis* (Majure et al. 2021b), *Mila caespitosa* (Majure et al. 2022), *Parodia magnifica* (Köhler et al., 2020), *Pilosocereus polygonus* (Majure et al. 2022), *Pygmaeocereus bylesianus* (Majure et al. 2022), *Rebutia arenacea* (Majure et al. 2022), *Samaipatocereus corroanus* (Majure et al. 2022), *Sclerocactus erectocentrus* DBG 2016-0131-01 (DES), *Sclerocactus johnsonii*, *Sclerocactus papyracanthus* Majure 6730 (DES), *Selenicereus triangularis* (Majure et al. 2021b), *Stenocereus fimbriatus* (Majure et al. 2021b), *Stenocereus yunckeri* DBG 1990 (DES), *Stetsonia coryne* (Majure et al. 2022), *Weingartia kargliana* (Arakaki et al., 2011). **Pereskia & Leuenbergeria** — *Leuenbergeria bleo* SRR1698112, *Leuenbergeria portulacifolia* DBG 2016-0465-01 (DES), *Leuenbergeria quisqueyana* SRR5605380, *Pereskia aculeata* (Arakaki et al., 2011), *Pereskia horrida* SRR5605378, *Pereskia sacharosa* (Arakaki et al., 2011), *Pereskia sacharosa* DBG 2014-2153-01 (DES). **Maihuenioideae** — *Maihuenia poeppigii* (Arakaki et al., 2011).

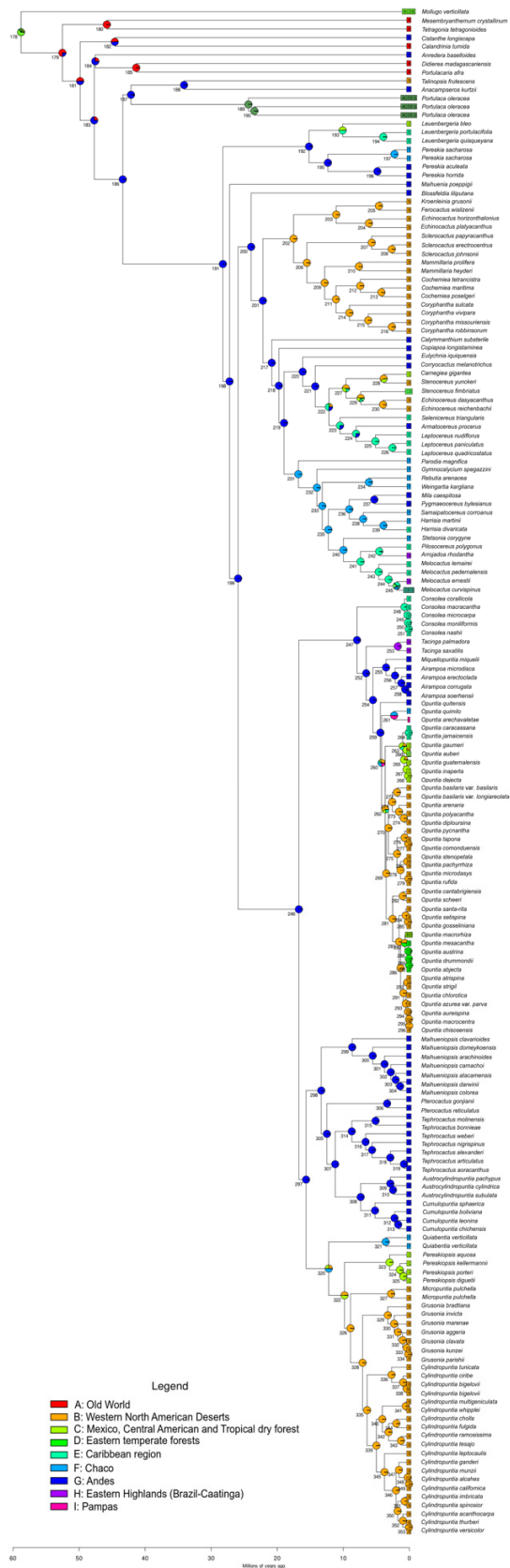
Outgroups: Aizoaceae — *Mesembryanthemum crystallinum* SRR5045118, *Tetragonia tetragonoides* SRR14907169. **Anacampserotaceae** — *Anacampseros kurtzii* (Walker et al. 2018), *Talinopsis frutescens* (Walker et al. 2018). **Basellaceae** — *Anredera baselloides* SRR5605388. **Didiereaceae** — *Didierea madagascariensis* SRR7905843, *Portulacaria afra* SRR7905870. **Molluginaceae** — *Mollugo verticillata* SRR6238187. **Montiaceae** — *Calandrinia tumida* (Moore et al. 2017), *Cistanthe longiscapa* (Moore et al. 2017). **Portulacaceae** — *Portulaca oleracea* L. Majure 6908 (DES), *Portulaca oleracea* L. NC036236, *Portulaca oleracea* L. (Arakaki et al., 2011).



Supplementary Figure S1. BEAST maximum credibility chronogram. Values above the branches represent Bayesian posterior probabilities and the blue bars, the 95% credibility interval for the clade age in millions of years.



Supplementary Figure S2. Ancestral state reconstruction of growth form across Cactaceae (A) and areole number in Opuntieae (B). A) Core Cactaceae was reconstructed as ancestrally shrubby with numerous shifts to the tree habit and several shifts to lianescent shrubs. B) Tribe Opuntieae is reconstructed as having > 30 areoles per cladode face. This is reduced to < 30 areoles per cladode face for the genus *Opuntia* then with reversals back to > 30 areoles in desert areas. One reversal back to < 30 areoles occurred in the eastern North American *Humifusa* clade.



Supplementary Figure S3. Ancestral range reconstruction based on ecoregions using the BAYAREALIKE+J model on Biogeobears and ecoregion units. The tree tips encompass the current range assigned to the taxa. Pie charts at each node are colored based on the probability of ancestral range reconstructions for each area. Colors for the habitats included match those in the map inset, except for the categories that represented a two-area range combination or more. The * symbol and grey color represent areas with <5% probability of ancestry. The x-axis represents time in millions of years ago (Mya).