Convergent evolution of the army ant syndrome and congruence in big-data phylogenetics

Supplementary figures and tables

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Supplementary Figure S27: Relative likelihoods of ranges from BioGeoBEARS under DEC+J estimated on the BEAST consensus tree. Pie charts at the nodes correspond to ancestral state estimations and pie charts on the corners correspond to ranges immediately following speciation. The region names are abbreviated as follows: Neotropical (T), Nearctic (N), Palearctic (P), Afrotropical (E), Malagasy (M), Indomalayan (O), and Australasian (A). All ages in Ma.
Supplementary Figure S28: Box plots comparison of properties of slow-evolving, compositionally homogeneous, and ”high signal” or high average bootstrap loci. A: Relative composition frequency variability (RCFV), B: Slope of regression of p-distances against distances on ML tree from a locus. Higher RCFV signifies more compositional heterogeneity and higher slope of regression signifies less potential for saturation.
Supplementary Table S1: Voucher specimens used in this study. CASENT numbers correspond to records on AntWeb.org.

| Taxon Name               | Specimen Code | Country         | Year Collected |
|--------------------------|---------------|-----------------|----------------|
| Acanthostichus AZ M277   | CASENT0324689 | United States   | 2010           |
| Acanthostichus AZ M278   | CASENT0324880 | United States   | 2009           |
| Acanthostichus BR M252   | CASENT0732106 | Brazil          | 2014           |
| Acanthostichus GF M208   | CASENT0732074 | French Guiana   | 2006           |
| Acanthostichus serratulus M166 | CASENT0732042 | Ecuador         | 2003           |
| Aenictogiton UG M189     | CASENT0317577 | Uganda          | 2012           |
| Aenictogiton ZM02 M181   | CASENT0732056 | Zambia          | 2005           |
| Aenictus bobaiensis M197  | CASENT0732068 | China           | 2014           |
| Aenictus camposi M222    | CASENT0732087 | Malaysia        | 2014           |
| Aenictus cornutus M230   | CASENT0732089 | Malaysia        | 2014           |
| Aenictus curax M245      | CASENT0732104 | Papua New Guinea| 2010           |
| Aenictus fergusoni M223  | CASENT0732088 | India           | 2001           |
| Aenictus fuchuanensis M201| CASENT0732072 | China           | 2013           |
| Aenictus gracilis M199   | CASENT0732070 | Malaysia        | 2008           |
| Aenictus hodgsoni M198   | CASENT0732069 | China           | 2012           |
| Aenictus hoeldobleri M200| CASENT0732071 | China           | 2013           |
| Aenictus laeviceps M269  | CASENT0702955 | Malaysia        | 2014           |
| Aenictus latifemoratus M266| CASENT0392370 | Malaysia        | 2014           |
| Aenictus levior M231     | CASENT0732090 | Malaysia        | 2014           |
| Aenictus rotundicollis M232| CASENT0732091 | Malaysia        | 2014           |
| Aenictus silvestrii M221 | CASENT0732086 | Malaysia        | 2014           |
| Aenictus turneri M135    | CASENT0732016 | Australia       | 2004           |
| Aenictus UG M143         | CASENT0732021 | Uganda          | 2012           |
| Aenictus yamanei M265    | CASENT0385898 | Malaysia        | 2014           |
| Aenictus ZA M228         | CASENT0764132 | South Africa    | 2011           |
| Cerapachys antennatus M263| CASENT0384548 | Malaysia        | 2014           |
| Cerapachys MY M264       | CASENT0384921 | Malaysia        | 2014           |
| Cerapachys sulcinodis M243| CASENT0732102 | China           | 2015           |
| Cerapachys TH M203       | CASENT0268115 | Thailand        | 2006           |
| Chelioniomyrmex cf andicola M174 | CASENT0732049 | Ecuador        | 2009           |
| Chelioniomyrmex cf morosus M217 | CASENT0732082 | Honduras       | 2010           |
| Chelioniomyrmex sp M146  | CASENT0732024 | Peru            | 2013           |
| Chrysapace cf crawleyi M262| CASENT0391566 | Malaysia        | 2014           |
| Chrysapace cf sauteri M261| CASENT0385026 | Malaysia        | 2014           |
| Chrysapace MG M155       | CASENT0304584 | Madagascar      | 2013           |
| Chrysapace TH M156       | CASENT0278856 | Thailand        | 2006           |
| Cylindromyrmex brasiliensis M140 | CASENT0731132 | Venezuela      | 2008           |
| Cylindromyrmex brasiliensis M72 | CASENT0731132 | Venezuela      | 2008           |
| Cylindromyrmex darlingtoni M211 | CASENT0756069 | Dominican Republic | 2015 |
| Cylindromyrmex whymperi M271 | CASENT0732116 | Costa Rica     | 2003           |
| Dorylus affinis M177     | CASENT0732052 | Kenya           | 2004           |
| Dorylus braunsi M289     | CASENT0732037 | Kenya           | 2004           |
| Dorylus cf fulvus M149   | CASENT0732026 | Uganda          | 2012           |
| Dorylus conradi M178     | CASENT0732053 | Kenya           | 2004           |
| Dorylus fimbriatus M288  | CASENT0732036 | Kenya           | 2004           |
| Dorylus fulvus M179      | CASENT0732054 | Kenya           | 2008           |
| Dorylus kohli M180       | CASENT0732055 | Kenya           | 2007           |
| Dorylus laevigatus M157  | CASENT0202245 | Malaysia        | 2010           |
| Dorylus mayri M291       | CASENT0732123 | Nigeria         | 2005           |
| Dorylus molestus M290    | CASENT0732122 | Uganda          | 2012           |
| Dorylus orientalis M244  | CASENT0732103 | China           | 2015           |
### Supplementary Table S1: Continued. Voucher specimens used in this study. CASENT numbers correspond to records on AntWeb.org.

| Taxon Name               | Specimen Code | Country        | Year Collected |
|--------------------------|---------------|----------------|----------------|
| Dorylus rubellus M287    | CASENT0732035 | Nigeria        | 2005           |
| Dorylus spininodis M292  | CASENT0732124 | Uganda         | 2012           |
| Dorylus UG M153          | CASENT0732030 | Uganda         | 2012           |
| Eburopone CM02 D0788     | CASENT0178891 | Cameroon       | 2000           |
| Eburopone MG M130        | CASENT0732012 | Madagascar     | 2013           |
| Eburopone MG M195        | CASENT0732066 | Madagascar     | 2013           |
| Eburopone MG M213        | CASENT0732077 | Madagascar     | 2013           |
| Eburopone MG M214        | CASENT0732078 | Madagascar     | 2013           |
| Eburopone UG M259        | CASENT0352799 | Uganda         | 2012           |
| Eciton burchellii M273   | CASENT0732118 | United States  | 2007           |
| Eciton hamatum M293      | CASENT0732125 | Mexico         | 2014           |
| Eciton lucanooides M239  | CASENT0732098 | Panama         | 2015           |
| Eciton mexicanum M238    | CASENT0732097 | Costa Rica     | 2013           |
| Eciton quadrigrilume M254| CASENT0732108 | Brazil         | 2011           |
| Eciton rapax M145        | CASENT0732023 | Peru           | 2013           |
| Eciton vagans M184       | CASENT0732059 | Costa Rica     | 2004           |
| Eusphinctus TH M158      | CASENT0285681 | Thailand       | 2006           |
| Labidus coecus M173      | CASENT0732048 | Ecuador        | 2009           |
| Labidus praedator M152   | CASENT0732029 | Mexico         | 2014           |
| Labidus spininodis M172  | CASENT0732047 | Ecuador        | 2009           |
| Leptanilloides erinys M246| CASENT0234600 | Ecuador        | 2009           |
| Leptanilloides femorals M188| CASENT0732063 | Venezuela      | 2008           |
| Leptanilloides gracilis M187| CASENT0732062 | Mexico         | 2008           |
| Leptanilloides mckennae D0228 | CASENT0106086 | Costa Rica     | 2003           |
| Leptanilloides nubecula M167| CASENT0732043 | Ecuador        | 2004           |
| Lioponera cf suscitata M267| CASENT0386895 | Malaysia       | 2014           |
| Lioponera longitarsus M193| CASENT0732064 | Bangladesh     | 2014           |
| Lioponera marginata M249 | CASENT0219054 | Papua New Guinea| 2009           |
| Lioponera MY M268        | CASENT0389090 | Malaysia       | 2014           |
| Lioponera nr kraepelinii M131| CASENT0732013 | Madagascar     | 2013           |
| Lioponera nr mayri M215  | CASENT0732079 | Madagascar     | 2013           |
| Lioponera PG M250        | CASENT0215868 | Papua New Guinea| 2009           |
| Lioponera princeps M137  | CASENT0732018 | Australia      | 2006           |
| Lioponera ruficornis M165| CASENT0732041 | Australia      | 2005           |
| Lioponera vesupla M210   | CASENT0234847 | Uganda         | 2012           |
| Lividopone MG M132       | CASENT0732014 | Madagascar     | 2013           |
| Lividopone MG M194       | CASENT0732065 | Madagascar     | 2013           |
| Lividopone MG M216       | CASENT0732080 | Madagascar     | 2013           |
| Lividopone MG M294       | CASENT0732126 | Madagascar     | 2013           |
| Neivamyrmex adnepos M236 | CASENT0732095 | Costa Rica     | 2006           |
| Neivamyrmex alfari M240  | CASENT0732099 | Costa Rica     | 2013           |
| Neivamyrmex asper M233   | CASENT0732092 | Costa Rica     | 2014           |
| Neivamyrmex californicis M272| CASENT0732117 | United States  | 2004           |
| Neivamyrmex cf nyensis M296| CASENT0249496 | United States  | 2003           |
| Neivamyrmex compressinodis M235| CASENT0732094 | Nicaragua      | 2011           |
| Neivamyrmex distans M242 | CASENT0732101 | Costa Rica     | 1998           |
| Neivamyrmex EC M175      | CASENT0732050 | Ecuador        | 2009           |
| Neivamyrmex gibbatus M139| CASENT0732019 | Venezuela      | 2008           |
| Neivamyrmex impudens M237| CASENT0732096 | Guatemala      | 2009           |
| Neivamyrmex kiowapach M275| CASENT0732120 | United States  | 2015           |
| Neivamyrmex melanocephalus M154| CASENT0732031 | Mexico        | 2014           |
Supplementary Table S1: Continued. Voucher specimens used in this study. CASENT numbers correspond to records on AntWeb.org.

| Taxon Name                  | Specimen Code         | Country        | Year Collected |
|-----------------------------|-----------------------|----------------|----------------|
| Neivamyrmex opacithorax M276| CASENT0732121         | United States  | 2015           |
| Neivamyrmex sumichrasti M151| CASENT0732028         | Mexico         | 2014           |
| Neivamyrmex swainsonii M169 | CASENT0732045         | United States  | 2004           |
| Neivamyrmex texanus M274    | CASENT0732119         | United States  | 2015           |
| Neocerapachys BR M295       | CASENT0732127         | Brazil         | 2014           |
| Neocerapachys cf splendens M251| CASENT0732105       | Brazil         | 2013           |
| Neocerapachys neotropicus M134| CASENT0732015       | Costa Rica     | 2014           |
| Neocerapachys sp M209       | CASENT0732075         | Costa Rica     | 2004           |
| Nomamyrmex esenbecki M129   | CASENT0732011         | Mexico         | 2013           |
| Nomamyrmex hartigi M220     | CASENT0732085         | Costa Rica     | 2006           |
| Ooceraea australis M138     | CASENT0106146         | Australia      | 2006           |
| Ooceraea FJ06 M168          | CASENT0732044         | Fiji           | 2006           |
| Ooceraea fragosa D0842      | CASENT0106215         | Sri Lanka      | 2005           |
| Ooceraea MY M270            | CASENT0722573         | Malaysia       | 2014           |
| Ooceraea PG M248            | CASENT0187824         | Papua New Guinea| 2009           |
| Parasyscia dohertyi M142    | CASENT0732020         | Malaysia       | 2010           |
| Parasyscia MG M212          | CASENT0732076         | Madagascar     | 2013           |
| Parasyscia PG M204          | CASENT021652          | Papua New Guinea| 2009           |
| Parasyscia UG M218          | CASENT0732083         | Uganda         | 2012           |
| Parasyscia UG M219          | CASENT0732084         | Uganda         | 2012           |
| Parasyscia UG M281          | CASENT0352569         | Uganda         | 2012           |
| Parasyscia VN M207          | CASENT0731211         | Vietnam        | 2007           |
| Parasyscia wittmeri M282    | CASENT0263905         | Saudi Arabia   | 2011           |
| Simopone cf oculata D0792   | CASENT0139634         | Thailand       | 2006           |
| Simopone conradti M144      | CASENT0732022         | Uganda         | 2012           |
| Simopone dryas M224         | CASENT0764130         | Kenya          | 2006           |
| Simopone grandidierti M186  | CASENT0732061         | Madagascar     | 2009           |
| Simopone marleyi M171       | CASENT0249324         | South Africa   | 1986           |
| Simopone rex M133           | CASENT0731175         | Madagascar     | 2013           |
| Simopone trita M185         | CASENT0732060         | Madagascar     | 2003           |
| Sphinctomyrmex marcoyi M202 | CASENT073146          | Argentina      | 2013           |
| Sphinctomyrmex stali M253   | CASENT0732107         | Brazil         | 2013           |
| Syscia augustae M196        | CASENT0732067         | United States  | 2015           |
| Syscia GT M127              | CASENT0732010         | Guatemala      | 2009           |
| Syscia MY M147              | CASENT0732025         | Malaysia       | 2014           |
| Syscia MY M176              | CASENT0732051         | Malaysia       | 2009           |
| Syscia typhla D0841         | CASENT0106214         | Sri Lanka      | 2006           |
| Tanipone aglandula M280     | CASENT0052407         | Madagascar     | 2003           |
| Tanipone hirsuta M279       | CASENT0147732         | Madagascar     | 2008           |
| Tanipone scelesta M159      | CASENT0229662         | Madagascar     | 2010           |
| Tanipone zona M182          | CASENT0732057         | Madagascar     | 2003           |
| Vicinopone conciliatrix M128| CASENT0731168         | Uganda         | 2012           |
| Yunodorylus eguchii M247    | CASENT0731166         | Vietnam        | 2004           |
| Yunodorylus paradoxus M190  | CASENT0731165         | Malaysia       | 2006           |
| Yunodorylus TH M160         | CASENT0139796         | Thailand       | 2006           |
| Yunodorylus TH M191         | CASENT0134717         | Thailand       | 2006           |
| Zasphinctus imbecilis M170  | CASENT0732046         | Australia      | 2005           |
| Zasphinctus MZ M229         | MCZENT00512765        | Mozambique     | 2012           |
| Zasphinctus PG M285         | CASENT0732033         | Papua New Guinea| 2000           |
| Zasphinctus KE M227         | CASENT0764121         | Kenya          | 2012           |
| Zasphinctus TH M192         | CASENT0131746         | Thailand       | 2006           |
| Zasphinctus trux M136       | CASENT0732017         | Australia      | 2006           |
### Supplementary Table S2: Statistics of data matrices used in this study.

| Alignment Name         | Number of Taxa | Alignment Length | Percent Missing | Proportion of Parsimony Informative Sites | AT Content |
|------------------------|----------------|------------------|-----------------|------------------------------------------|------------|
| Combined Data          | 164            | 892,761          | 15.476          | 0.478                                    | 0.530      |
| "High-Signal" Loci     | 164            | 177,947          | 17.534          | 0.565                                    | 0.578      |
| Slow-Evolving Loci     | 164            | 178,662          | 10.245          | 0.348                                    | 0.486      |
| Homogeneous Loci       | 164            | 97,849           | 10.177          | 0.369                                    | 0.488      |
| No *Aenictus*          | 146            | 892,761          | 15.006          | 0.469                                    | 0.528      |
| BEAST Matrix           | 155            | 44,079           | 16.489          | 0.466                                    | 0.531      |
| Amino Acids            | 164            | 89,483           | 16.104          | 0.138                                    | -          |
Supplementary Table S3: Calibration scheme used for penalized likelihood analyses in chronos. MRCA column refers to the most recent common ancestor of two tip names in the maximum likelihood tree obtained from slow-evolving loci matrix.

| Clade                          | MRCA                              | Minimum Age (Ma) | Maximum Age (Ma) | Notes                                                                                                                                 |
|-------------------------------|-----------------------------------|------------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Root                          | Harpeg-nathos_salaria_genome, Acanthos-tichus_serratulus_M166 | 94               | 135              | This calibration assumes that poneroids and formicoids shared the last common ancestor at least as early as Burmomyrma, a 94.3-99.7 Ma fossil from Burmese Amber. This taxon was has originally assigned to Anueretinae (Dhussky, 1996) but recently its placement has been questioned (LaPolla et al., 2013). Here I take a conservative view that it is at least a representative of stem formicoids. Maximum age is based on the upper bound of 95% confidence interval for this node in the time-calibrated phylogeny of the Formicidae by Moreau and Bell (2013). |
| crown Formicinae plus Myrmicinae | Camponotus_floridanus_genome, Atta_cephalotes_genome | 89.3             | 120              | Kryomyrma rufi (Grimaldi and Agosti, 2000) is a 89.3-94.3 Ma old fossil from New Jersey Amber that shows a clearly preserved acidopore, a unique formicine feature. Kryomyrma is universally treated as a stem Formicinae. Although the upper 95% confidence interval for this node was only 95 Ma in Moreau and Bell (2013), the maximum age assumed here is more conservatively placed at 120 Ma to accommodate the fact that Ward et al. (2015) inferred ages of one of the constituent clades, the Myrmicinae, up to 110 Ma. |
| crown Myrmicinae               | Pogonomyrmex_barbatus_genome, Atta_cephalotes_genome | 33.9             | 110              | Crown Myrmicinae are here calibrated with the Baltic amber Myrmica (Radchenko et al., 2007) from the Priabonian age of Eocene (33.9-37.2 Ma). Although Pogonomyrmex was a lineage branching after Myrmica in the phylogeny by Ward et al. (2015), the latest UCE-based results (Branstetter et al. (2016), M.G. Branstetter pers. comm.) suggest that Pogonomyrmex and Myrmica form a clade within the Myrmicinae. The maximum age is based on the upper bound of 95% confidence interval in time-calibrated phylogeny of (Ward et al., 2015). |
| Cerapachys, Chrysapace, and Yunodorylus | Chrysapace_TH_M156, Yunodorylus_TH_M191 | 33.9             | 85               | A recently discovered Baltic Amber fossil recognizable as Chrysapace (author’s personal observation) is used to calibrate the node of Cerapachys, Yunodorylus, and Chrysapace. Although the maximum likelihood tree places Cerapachys as sister to Chrysapace, this relationship has low support, so a conservative approach calibrates the next node down. Maximum age corresponds to the upper bound of 95% confidence interval in the time-calibrated tree of Brady et al. (2014). |
| crown Cylindromyrmex          | Cylindromyrmex_meinerti_D778, Cylindromyrmex_darlingtoni_M211 | 13.7             | 43               | Cylindromyrmex inopinitus from Dominican Amber is considered a sister species of extant C. longiceps (De Andrade, 2001) and thus used here to calibrate crown Cylindromyrmex. Maximum age is the upper bound of 95% confidence interval for Cylindromyrmex age in Brady et al. (2014). |
| crown New World army ants     | Eciton_hamatum_M293, Neivamyrmex_californicus_M272 | 16               | 46               | Neivamyrmex ectopus (Wilson, 1985) is a Dominican Amber species that is somewhat difficult to place in the extant Neivamyrmex diversity. A potentially older fossil of Neivamyrmex comes from Mexican Amber, 16-23 Ma (Coty et al., 2014). The ancestor of New World army ants is here dated with a minimum age of 16 Ma. Maximum age is based on upper bound of 95% confidence interval age for this clade in (Brady et al., 2014). |
Supplementary Table S4: Calibration scheme used for fossilized birth-death process analyses in BEAST. Total group refers to fossil that could be placed in either stem or crown group.

| Species                  | Group Calibrated         | Sampling Time (Ma) | Deposit Age (Ma) | Notes                                                                 |
|--------------------------|--------------------------|--------------------|------------------|----------------------------------------------------------------------|
| Chrysapace sp.           | total Chrysapace         | 36.6               | 33.9-37.2        | See notes in Supplementary Table S3.                                   |
| Neivamyrmex electopus    | total Neivamyrmex        | 19.2               | 13.7-20.4        | See notes in Supplementary Table S3.                                   |
| Cylindromyrmex antillanus| total Cylindromyrmex     | 19.5               | 13.7-20.4        | This species was described together with C. electrinus by De Andrade (1998a). Both are used to calibrate total group Cylindromyrmex. This fossil was described by De Andrade (1998b) as similar to A. skwarrae, A. quirozi and A. arizonensis. Although it is possible that one of the male Acanthostichus specimens sequenced here from Arizona corresponds to A. arizonensis, this fossil is used here to calibrate the total group Acanthostichus. |
| Acanthostichus hispapiolicus | total Acanthostichus | 14.5               | 13.7-20.4        | See C. antillanus notes above.                                       |
| Cylindromyrmex electinus | total Cylindromyrmex     | 18.1               | 13.7-20.4        | See C. antillanus notes above.                                       |
| Cylindromyrmex inopinatus| Cylindromyrmex excl. C. meinerti | 14.2 | 13.7-20.4        | See notes in Supplementary Table S3.                                   |
| Neivamyrmex sp.          | total Neivamyrmex        | 19.3               | 16-23            | Coty et al. (2014) reported a Neivamyrmex species from Chiapas Amber. |
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