**Supplementary Materials**

Here we describe the protocol for constructing the informal composite phylogeny of non-teleostean Actinopterygii. The tree was mainly constructed using large, “backbone” phylogenies (Hurley *et al.* 2007; Sallan 2012; Benton 2015).

A fundamental dichotomy exists for the classification of Devonian and Carboniferous actinopterygians: either they are in the crown of Actinopterygii or lie outside crown Actinopterygii (Sallan 2014). However, Sallan (2014) concluded that the finding of Devonian and Carboniferous taxa falling outside Actinopteri (Mickle *et al.* 2009) was an artefact of coding only for characters liable to homoplasy. Therefore, our tree was primarily based upon Hurley et al. (2007) for the major relationships; in this tree many of the Devonian-Carboniferous clades are unresolved, so these taxa, and Devonian-Carboniferous taxa from other studies (Cloutier and Arratia 2004; Friedman and Blom 2006; Long *et al.* 2008; Mickle *et al.* 2009; Sallan and Friedman 2012; Xu *et al.* 2014*b*) were retained as an unresolved clade. To further resolve this polytomy, most taxa were organised as in Sallan & Friedman (2012). As the consensus is that Polypteriformes and Acipenseriformes diverge before the Devonian taxon *Mimipiscis* (Hurley *et al.* 2007; Sallan 2014), the phylogeny shows these clades, and the taxa that diverge prior to *Mimipiscis*,in a polytomy between *Cheirolepis* and *Mimipiscis* (Sallan and Friedman 2012).

We present a clade-by-clade description of how the subsections of the tree were composed:

*Polypteriformes*. Extant species were based upon Near et al. (2014). Due to the large uncertainty in placing Cretaceous taxa phylogenetically, these were left as a polytomy outside the clade containing *Polypterus* and *Erpetoichthys* (Daget *et al.* 2001; Near *et al.* 2014); *Bawtrius* was also included in this polytomy (Grandstaff *et al.* 2012).

*Chondrostei*. The backbone of the phylogeny was based primarily upon Grande & Bemis (1996), and Hilton & Forey (2009). Saurichthyidae and Birgeridae were added as basal total-group Chondrostei (Xu *et al.* 2014*b*). The saurichthyid phylogeny was based upon Maxwell et al. (2013), and *Haywardia* added as sister-group to *Bobastrania*, according to Romano et al. (2012). Extant taxa were primarily based upon Krieger et al. (2008). Preference was giving to the molecular topology of Krieger et al. (2008) for the extant species, and fossil taxa were mainly ordered as in Grande & Bemis (1996). *Neochallaia tellecheai* was added from Lopez-Arbarello et al. (2010) as a basal acipenseriform.

*‘Palaeonisciformes’*. The phylogeny of these taxa was taken mainly from a published source (Romano *et al.* 2014) and they were placed in the polytomy for ‘Palaeoniscidae’ unless a different family was indicated; if a family was indicated, the taxa were placed in a polytomy within that family. *Leighiscus hillsi* is placed in Redfieldiformes according to Pledge & Blauch (2013).

*Stem Neopterygii*. Stem Neopterygii were added as in Hurley et al. (2007), in addition to Hurley et al. (2007), Choo (2011), and Benton *et al.* (2013). *Guaymayenia paramillensis* was added from Lopez-Arbarello et al. (2010). Thoracopteridae were based upon Xu et al. (2015). Peltopleuriformes were added from Lombardo (1999) and perleidids from Mutter & Herzog (2004). Additional taxa were added from Lopez-Arbarello & Zavattieri (2008). Taxa considered *incertae* *sedis* were not included from Mutter & Herzog (2004) as they are too phylogenetically uncertain, and in some cases represent *nomina* *dubia* (López-Arbarello *et al.* 2010). The position of Amblypteridae is contentious. Even though considered a *nomen dubium, Amblypterus lujanensis* was placed in Perleidiformes (López-Arbarello *et al.* 2010), so the genus was placed here with additional species from Romano et al. (2014). *Crenilepis* was added according to Zuoyo et al. (2008). Major relationships of the Neopterygi were based upon Hurley et al. (2007). Basal Neopterygii were also added from Xu, Gao & Finarelli (2014). Amiidae were also based upon Grande & Bemis (1998).

*Semionotiformes*. For the Semionotiformes, the phylogeny of Cavin (2010) was used, and taxa were also incorporated from Bermudez-Rochas and Poyato-Ariza (2014). The tribe Vidalamiini conforms to Brito et al. (2008). *Placidichthys* was added according to Brito and Alvarado-Ortega (2008). Ionoscopiformes were also added from Xu et al. (2014b).

*Ginglymodi*. Ginglymodi were primarily based upon Bermuda-Rochas and Poyato-Ariza (2014), Deesri et al. (2014), Lopez-Arbarello (2012), Gibson (2013), Murray & Wilson (2009), and Benton et al. (2013). Although the monophyly of the genera *Semionotus* and *Lepidotes* is contested (Lopez-Arbarello 2008; Lopez-Arbarello and Alvarado-Ortega 2011) both were kept as clades, albeit with a number of polytomies to reflect the underlying uncertainty.

*Halecomorphi.* The Halecomorphi were based upon Lopez-Arbarello et al. (2014). Additional halecomorphs were added from Tan & Jin (2013). *Cipactichthys* was added according to Brito & Alvarado-Ortega (2013). *Lophionotus* taxa were added according to Gibson (2013). Additional taxa were added from Lambers (1994). *Ctenognathichthys bellottii* and *Allolepidotus bellottii* were added as a polytomy with Halecomorphi (López-Arbarello *et al.* 2014). Additional Lepisosteiformes were added from Kemmerer et al. (2006). Stem Lepisosteidae were ordered according to Cavin et al. (2013), and extant and fossil Lepisosteidae were put in the topology of Grande (2010) and Wright et al. (2012). *Eoeugnathus megalepis* was added according to Herzog (2003). Amiiformes were added from Cavin & Giner (2012).

*Pycnodonitformes*. Pycnodontiformes were added according to Poyato-Ariza & Wenz (2002) and Martin-Abad & Poyato-Ariza (2013). The overall clade of Pycnodontiformes was included as a polytomy with Lepisosteidae and Amiidae (Benton 2015). Gladiopycnodontidae was added according to Taverne & Capasso (2013, 2014).

*Basal teleosts*. Basal teleosts were added from Arratia (2013). Pachycormids were added from Friedman et al. (2010; 2012). The cut-off point was chosen so as not to include Teleostei but to include Pholidophoridae (node D in Arratia 2013).

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