

## Others

The other groups are difficult to determine and characterise. Many are generally included among the protists—a loose assemblage of primarily single-celled, both autotrophic and heterotrophic, eukaryotic organisms of which the colourless forms were previously called protozoa (Brusca and Brusca 2003, Hallegraeff pers. comm.<sup>143</sup>). It is often difficult to know what constitutes a species in many groups, and to determine in what Kingdom the various phyla should be placed or whether (as in the case of Chromista etc) they form a Kingdom of their own. Molecular phylogenetic and cladistic studies have resulted in major reorganisations of eukaryotic groups of organisms (see Meeûs and Renaud 2002). Many species previously included with algae or fungi have now been split from those groups and are included in this report under the Chromista, Cyanophyta or Protoctista. The green algae, red algae and glaucophytes, etc treated under the ‘Others’ section in the previous report, have been included under plant algae in this report. The fungi that were treated under the ‘Others’ section in the previous report, have been placed in a separate section of their own, excluding the chromistan and protoctistan fungi which are treated separately.

## Prokaryota (Bacteria [Monera] of previous report<sup>144</sup>)

The estimates of numbers of Prokaryota in the world (and in Australia) are complicated by many factors. It is generally believed that many species cannot be cultivated or identified, using existing techniques. The Cyanophyta (Cyanobacteria) have been treated separately.

The estimated number of described bacteria species in the world varies from 3,000–4,000 (Hawksworth and Colwell 1992) through 4,000 (Hawksworth and Kalin-Arroyo 1995), 4,760 (McNeely *et al.* 1990), 5,432 (Euzéby 2004), 7,643 (Euzéby 2009) to 10,000 (Groombridge and Jenkins 2002). I have accepted the figures of Euzéby (2009). Shimura (2004) provided a figure of 8,500 species, but from Euzéby (2004) it is obvious that these are names, and as stated by Euzéby (2009) of the 9,435 currently validly published species names, these apply to just 7,643 currently accepted species names.

Estimates of the total number of species (described and undescribed) vary from 50,000 to 3 million (Hawksworth and Kalin-Arroyo 1995) with generally accepted figures varying from 400,000 (Groombridge and Jenkins 2002) to 1 million (Hawksworth and Kalin-Arroyo 1995).

Figures for Australia are virtually non-existent other than an estimate of 40,000 for the total number of species in Australia by Saunders *et al.* (1996). These authors also gave a figure of 0.1% described which would indicate a figure of about 40 species. This appears to be a gross under-estimate for the number of described species. No further information has become available since the previous report (Chapman 2006).

World Descr./ Accepted min.	World Descr./ Accepted max.	World Descr./ Accepted	World Estimate	Australia Descr./ Accepted	Australia Percent.	Australia Estimate	Australia Endemic	World Threatened <sup>145</sup>	Australia Threatened	Australian Threatened as percentage of World Threatened
3,000	10,000	7,643	400,000–1,000,000	~40	0.5%	40,000	unknown	0	0	–

143 pers. comm. Gustaaf Hallegraeff, School of Plant Science, University of Tasmania, July 2009.

144 Change recommended by J.P.Euzéby, Société de Bactériologie Systématique et Vétérinaire (SBSV), France (pers. comm.).

145 The IUCN Red List of Threatened Species (2009b).



## Cyanophyta (Cyanobacteria)

The Cyanophyta are an important group in Australia, although comparatively little is known of them.

Watanabe *et al.* (2004) gave the number of described species in the world at about 3,234. Groombridge and Jenkins (2002) reported that there are about 1,000 genera. Hoek *et al.* (1995) gave 150 genera and about 2,000 species for the Class Cyanophyceae, whereas *AlgaeBase* (Guiry and

Guiry 2009) lists 2,664 species in the Class. I have accepted the figure from *AlgaeBase* which is lower than the figure I cited in the previous report (Chapman 2006).

Actual diversity is very difficult to determine, but the total number of species of cyanobacteria in Australia is unlikely to exceed 500 (McCarthy pers. comm.).

Entwisle and Huisman (1998) provided an estimate for the blue-green algae (Cyanobacteria) in Australia of 270 made up of 10 Chamaesiphonales; 60 Chroococcales and 200 Nostocales/Oscillatoriales.

Order	World ( <i>AlgaeBase</i> ) Descr./Accepted	Metting (1996) Estimate	Australia (Entwisle & Huisman 1998)
Chroococcales	711		60
Nostocales	686	1000	200
Oscillatoriales	584	1000	
Pseudanabaenales	325		–
Stigonemetales	3		–
Synechococcales/Chamaesiphonales	355		10
TOTAL	2,664	unknown	270

World Descr./ Accepted min.	World Descr./ Accepted max.	World Descr./ Accepted	World Estimate	Australia Descr./ Accepted	Australia Percent.	Australia Estimate	Australia Endemic	World Threatened <sup>146</sup>	Australia Threatened	Australia Threatened as percentage of World Threatened
3,234	3,234	2,664	unknown	270	10%	~500	unknown	0	0	–

146 The IUCN Red List of Threatened Species (2009b).

## Chromista (including some species previously included under either algae or fungi)

Again, it is difficult to estimate the number of species of chromistans, partly due to varying circumscriptions of the group. Summaries for the various classes and phyla, where available, are given in the accompanying table.

Estimates for the number of described species of chromistan 'algae' (i.e. chromistan species previously regarded as algae) are difficult to determine due to the circumscriptions of different authors, and the separation into Plantae and Chromista by some but not others. The biggest deficiency is in the Bacillariophyta (diatoms) where *AlgaeBase* (Guiry and Guiry 2009) records just 5,530 species 'but no clarity on what is what' (Guiry pers. comm.<sup>147</sup>). Guiry (pers. comm.) goes on to estimate that there are about 20,000 published species of diatoms. Hallegraeff (pers. comm.<sup>148</sup>) states that diatoms exhibit prominent morphological diversity of characters but molecular sequencing is now indicating that they have been overclassified. I have used the figure of 23,605 for the world for the chromistan 'algae' based on the numbers in *AlgaeBase*—see table below. Chromista species previously regarded as fungi (chromistan 'fungi') are also not well known. Kirk *et al.* (2008) report 1,039 species for the world. Recently, Class Opalineae has been moved into the Chromista (Nishi

*et al.* 2005) but with little certainty of where it is placed within the group. Some authors (e.g. GBIF 2009b) still retain it in the Protoctista under the Phylum Sarcomastigophora. Both Corliss (2000) and Adl *et al.* (2007) reported figures of 400 published species of Opalineae, while Patterson (pers. comm.<sup>149</sup>) suggests that there are about 300 species worldwide.

Few estimates of the total number of chromistan 'algae' have been found, however Hawksworth and Kalin-Arroyo (1995) gave a figure of 400,000 (for all algae) with cited estimates ranging from 150,000 to 1 million, while *Biodiversity: the UK Action Plan* (Anon. 1994) suggested that there could be up to 10 million species of diatoms. Michael Guiry (pers. comm.<sup>147</sup>), the manager of *AlgaeBase* (<http://www.algaebase.org>), reports that there are about 20,000 described species of diatoms with about another 80,000 undescribed species. The data from *AlgaeBase* indicate that a figure of 400,000 is too high, and I have settled on a figure of about 200,000 (assuming 100,000 species of diatom) which is at the lower end of the range reported by Hawksworth and Kalin-Arroyo (1995). For Opalineae, Adl *et al.* (2007) provided an estimate of about 500 species. I have no estimates for the total number of world Chromista species previously regarded as fungi.

I have found no comprehensive list of Australian species of Chromista. For the species previously regarded as algae I have relied largely on *AlgaeBase* (Guiry and Guiry 2009), but not all species there have distribution records, so where other data are available, I have cited those in preference. Scott and Marchant (2005) list 187 species of diatoms in the Class Bacillariophyceae for the Australian Antarctic Territory.

Estimates for the total number of species of chromistan 'algae' in Australia have been taken largely from Entwisle and Huisman (1998). Patterson (pers. comm.<sup>149</sup>) states that there are about 20 species of Opalineae in Australia. It would appear that most of the Australian species occur as parasites of the intestines of frogs. May (pers. comm.<sup>150</sup>) provided the figures for chromistan species previously regarded as fungi.

DEH (2001) and ABRS (2004) reported that there are 10,000–12,000 species known for Australia, but ABRS (2004) suggested that 'this is certainly an underestimate'. I have followed the figures of Entwisle and Huisman (1998), but using the higher of their estimates in most cases.

	World Descr./ Accepted min.	World Descr./ Accepted max.	World Descr./ Accepted	World Estimate	Australia Descr./ Accepted	Australia Percent.	Australia Estimate	Australia Endemic	World Threatened <sup>151</sup>	Australia Threatened	Australian Threatened as percentage of World Threatened
Chromistan 'algae'	23,605	44,000	~23,605	200,000	2,044	8.7%	<14,000	unknown	6 (0.03%)	0	0%
Opalineae	300	400	400	500	~12	3.0%	~20	unknown	–	0	–
Chromistan 'fungi'	1,039	1,039	1,039	unknown	74	7.0%	unknown	unknown	–	0	–
TOTAL	24,944	45,439	~25,044	~200,500	~2,130	8.5%	>15,000	unknown	6 (0.02%)	0	0%

147 pers. comm. Michael Guiry, *AlgaeBase*, June 2005.

148 pers. comm. Gustaaf Hallegraeff, School of Plant Science, University of Tasmania, July 2009.

149 pers. comm. David Patterson, *Encyclopedia of Life*, July 2009.

150 pers. comm. Tom May, National Herbarium of Victoria, July 2009.

151 The IUCN Red List of Threatened Species (2009b).

152 Scott and Marchant (2005).

153 Cowan (2006).

154 Data for Diatoms in *AlgaeBase* are not complete—pers. comm. Michael Guiry (*AlgaeBase*) who provided the figures of about 20,000 with about a further 80,000 undescribed.



Chromistan 'algae' (species previously included in the algae)

Phylum	Class	World Descr./Accepted			World Estimate	Australia Descr./Accepted	Australia Estimate
		<i>AlgaeBase</i> (Guiry & Guiry 2009)	Corliss (2000)	Adl <i>et al.</i> (2007)	Adl <i>et al.</i> (2007)	<i>AlgaeBase</i> (Guiry and Guiry 2009) unless otherwise noted	Entwisle & Huisman (1998)
Bacillariophyta (diatoms)	Bacillariophyceae	4,256				187 <sup>152</sup>	
	Coscinodiscophyceae	933				57 <sup>153</sup>	
	Fragilariophyceae	339					
	ENTIRE GROUP	~20,000 <sup>154</sup>	10,000–20,000	10,000–20,000	200,000	1,300 <sup>155</sup>	13,000
Cryptophyta (cryptomonads)	Cryptophyceae	127				14	50
	ENTIRE GROUP	127	~200	70	200	14	50
Haptophyta (yellow brown algae)	Haptophyta (incertae sedis)	123				10	–
	Pavlovophyceae	15				1	4
	Prymnesiophyceae	273				42	155
	ENTIRE GROUP	411	500	350	<400	53	159
Heterokontophyta (golden and brown algae)	Aurearenophyceae	1	–	–	–	0	–
	Bicosoecophyceae	21	~40	72	100	3 <sup>156</sup>	16 <sup>162</sup>
	Bodonophyceae	28	–	–	–	1 <sup>156</sup>	–
	Bolidophyceae	2	–	–	–	0	–
	Chrysophyceae	374	~1,250	1,000	2,000	80 <sup>157</sup>	300
	Dictyochophyceae	44	~200	15	30	4	20
	Eustigmatophyceae	35	–	15	30	4	–
	Pelagophyceae	10	–	12	20	0	–
	Phaeophyceae (Fucophyceae)	1,778	<1,600	1,500–2,000	2,000	451 <sup>158</sup>	308–318
	Phaeothamniophyceae	26	–	25	40	1	–
	Pinguiphyceae	6	–	5	20	1 <sup>159</sup>	10
	Raphidophyceae	23	<36	20	40	2	–
	Schizocladophyceae	4	–	–	–	0	–
	Synchromophyceae	1	–	–	–	0	–
	Synurophyceae	284	–	200	350	60 <sup>160</sup>	40
Tribophyceae/Xanthophyceae	430	–	600	800	70 <sup>161</sup>	25	
ENTIRE GROUP	3,067	3,126	3,464–3,964	5,430	677	790–800	
TOTAL		~23,605	~13,826–23,826	~13,884–24,384	~206,030	2,044	~13,999–14,009

155 Data for diatoms in Australia is very sketchy. In the absence of other information, I have used the lower of the figures cited by Entwisle and Huisman (1998), (1,300) but actual number of published species of diatoms in Australia is likely to be much lower.

156 GBIF (2009b).

157 McCarthy and Orchard (2007) give a figure of 80 published species of which two are endemic.

158 AMANI (Cowan 2006).

159 *AlgaeBase* (Guiry and Guiry 2009) list only one species from Australia.

160 Many of the Australian non-marine distribution records in *AlgaeBase* (Guiry and Guiry 2009) are based on Day *et al.* (1995).

161 Entwisle and Huisman (1998) do not include this Class, however McCarthy & Orchard (2007) list 70 species for Australia.

162 pers. comm. David Patterson, *Encyclopedia of Life*, February 2009.

## Chromista (including some species previously included under either algae or fungi) *continued*

### Opalineae

Phylum	Class	World Descr./Accepted		World Estimate	Australia Estimate
		Corliss (2000)	Adl <i>et al.</i> (2007)	Adl <i>et al.</i> (2007)	Patterson (pers. comm. <sup>162</sup> )
Incertae sedis	Opalineae	400	400	500	~20
	TOTAL	400	400	500	~20

### Chromistan 'fungi' (species previously included in the fungi)

Phylum	World Kirk <i>et al.</i> (2008)	Australia (May pers. comm. <sup>163</sup> )
Hyphochytriomycota	24	1
Labyrinthista	56 <sup>164</sup>	0
Oomycota (water moulds and downy mildews)	956	73
Incertae Sedis	3	0
TOTAL	1,039	74

163 pers. comm. Tom May, National Herbarium of Victoria, July 2009.

164 Adl *et al.* (2007) give a figure of 40 and an estimate of <100 for the Labyrinthulomycetes.



## Viruses

The main problem in estimating the number of species of viruses is knowing just what constitutes a species in the group. In general, virus species are taken as being a collection of isolates with similar characteristics (ICTV 2002). There are many more virus names than there are 'species'. There are about 2,000–2,500 species currently recognised by the ICTV, but there are more than 40,000 to 50,000 recorded virus names. Most publications do not differentiate between virus species and virus names (Büchen-Osmond pers. comm.<sup>165</sup>). A full list of virus species can be found at <http://www.ictvonline.org/virusTaxonomy.asp?version=2008>. Many viruses occur in the marine areas of the world, but very few of these are as yet specified (Büchen-Osmond pers. comm.<sup>165</sup>).

Estimates for the number of described species of viruses range from about 2,000 (Mayo *et al.* 2005) through 2,085 (ICTV 2008), 4,000 (Hawksworth and Kalin-Arroyo 1995)

to 5,000 (Anon. 1994), with estimates of the total number at about 400,000 (varying from 50,000 to 1 million) (Hawksworth and Kalin-Arroyo 1995). I have accepted the official numbers from the *International Committee on the Taxonomy of Viruses* (ICTV 2008).

The only figure I have been able to find for Australia is a list of 178 plant viruses (Büchen-Osmond 1988). I have not come across a similar list for animal viruses so, extrapolating, one obtains a figure of about 400 species in total. Büchen-Osmond (pers. comm.<sup>165</sup>) suggests that 10–20% of the total would occur in Australia at one time or another, with less than 5% Australia/Australasia specific. Those figures suggest about 200–400 Australian species with somewhat less than 50% of those endemic. These figures are very inaccurate and should not be relied upon.

There are no species of virus listed as threatened.

World Descr./ Accepted min.	World Descr./ Accepted max.	World Descr./ Accepted	World Estimate	Australia Descr./ Accepted	Australia Percent.	Australia Estimate	Australia Endemic	World Threatened <sup>166</sup>
2,000	5,000	2,085	400,000	200–400	9.6–19.2%	unknown	40–50%	–

<sup>165</sup> pers. comm. Cornelia Büchen-Osmond, ICTVdB Management (retired), Columbia University, April 2009.

<sup>166</sup> The IUCN Red List of Threatened Species (2009b).

## Protoctista (mainly Protozoa—others included under fungi, algae, Chromista, etc)

The main problem in estimating numbers of Protoctista is in identifying the inter-relationship between different treatments—see following table. There is considerable overlap between what some authors include under Protoctista and what others include as algae, fungi or Chromista. Trying to sort out relationships between the treatments of different authors has not been easy, but the following table is used to enable comparisons with the previous report. For the summary, I have used the data from this table along with data from a number of other sources.

The order of arrangement in the summary table below is to allow for comparisons only and is not meant to imply a taxonomic classification. A lot more work needs to be done to determine accurate numbers for the Protoctista, and the numbers given here are very rough and not to be relied upon. Estimates for the number of Protoctista range from >20,000 (Anon. 1994) through 30,800 (Tangley 1997) to 34,000 (Adl *et al.* 2007), but these often depend on what groups are included or excluded.

Since the previous report a paper has been published that gives some detailed figures for the protists (Adl *et al.* 2007), and I have relied heavily (but not exclusively) on the figures given therein for this report. The *Dictionary of the Fungi* (10<sup>th</sup> edition) (Kirk *et al.* 2008) includes 1,165 Protoctista that were previously included as fungi.

The following table has been created from information in Corliss (2000), Groombridge and Jenkins (2002), Brusca and Brusca (2003), and Adl *et al.* (2007). Groombridge and Jenkins (2002) estimated that there are 80,000 described Protoctista with an estimated total of 600,000 species, however these figures include non-protocistan taxa such as the diatoms, Chlorophyta, and some fungal groups.

Figures for the number of Australian species have been hard to find, however there are estimates for the total number of species in Australia of 65,000 (Saunders *et al.* 1996) and 80,000 (ACIL Consulting 2002). See Scott and Marchant (2005) for information on Antarctic marine protists. Patterson (pers. comm.<sup>167</sup>) prepared a list of known species

and collections for Australia prior to 2005. I have used that unpublished list to determine some of the numbers in the table below, but again, I have found difficulties in fitting the numbers from various sources into the different classifications. It is also obvious that the list contains a number of nomenclatural synonyms and orthographic variants that have not been combined. With the Patterson list there are many undescribed species, and it is clear that the list is far from complete for some groups. It is, however, a good starting point. May (pers. comm.<sup>168</sup>) reports that there are 192 Australian species of fungoid protoctista (predominantly Mycetozoa, and a few Plasmodiophorales).

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167 pers. comm. David Patterson, *Encyclopedia of Life*, February 2009.

168 pers. comm. Tom May, National Herbarium of Victoria, July 2009.

169 The arrangement does not follow the classification used in Adl *et al.* (2007) which is a more modern classification than the others, but has been modified to allow comparisons with the earlier publications. I apologise to the authors for the liberties I have taken and mistakes made in doing this.

170 Included as Choanomonada and Mesomycetozoa in the Amoebozoa.

171 Rhizaria (excl. Foraminifera)—includes Cercozoa: <500 ( $n \times 10^3$ ); Haplosporidia: 31 ( $n \times 10^2$ ); Acantharia: 160 (<200); Polycistinea 700–1000 (1,500); Nucleochelea 160–180 (200); Actinophryidae 5 (<10).

172 Excavata (includes Fornicata) 146 (<200); Preaxostyla 96 (<120); Jakobida 10 (200); Heterobosea 80 (200); Euglenozoa 1,520 (2,000).



Names as used by			Numbers			
Groombridge and Jenkins (2002)	Corliss (2000) (except for species included under Fungi, Algae or Chromista)	Brusca and Brusca (2003)	Groombridge and Jenkins (2002)	Corliss (2000)	Brusca and Brusca (2003)	Adl <i>et al.</i> (2007) (estimates in brackets) See other species under Algae <sup>169</sup>
Archaeoprotista (Amitochondriates)	Archamoebae (Karyoblastea)	Diplomonadida	accepted?	10	~100	–
Discomitochondria (flagellates, zoomastigates)	Neomonada	(under Diplomonadida)	accepted?	30	–	120 (300) <sup>170</sup>
Rhizopoda (amastigote amoebae and cellular slime moulds)	Rhizopoda (Amaeoboza)	Rhizopoda (amoebas)	~200	5,000	~200	>3,006 (~13–23,000)
Myxomycota (Plasmodial slime moulds)	Mycetozoa	Excluded (fungi?)	~500	900	–	Peronosporomycetes 676 (10 <sup>3</sup> –10 <sup>4</sup> ), Mesomycetozoa 47 (thousands)
Granuloreticulosa (Foraminifera and reticulomyxids)	Foraminifera (Granuloreticulosa)	Granuloreticulosa	~4,000	~5,000	~40,000 (incl. many fossils)	>10,000 (15,000)
Xenophyophora (Xenophyophores)	(under Foraminifera)	(under Granuloreticulosa)	42	–	–	–
(under Actinopoda)	Heliozoa	(under Actinopoda)	–	~4,000	–	–
Actinopoda (Radiolarians)	Radiozoa (Radiolaria)	Actinopoda (incl. Polycistina = Radiolaria, Phaeodaria, Heliozoa, Acantharia)	~4,000	1,700–4,000	~4,240	Rhizaria <sup>171</sup> (excl. Foraminifera) 1556–1876 (thousands)
	Percolozoa	Excluded (fungi?)	–	100	–	–
	Euglenozoa	Euglenida	–	1,600	1,600	–
	(under Euglenozoa)	Kinetoplastida (trypanosomes)	–	–	600	–
			–	–	–	Excavata (except Parabasala) <sup>172</sup> 1,852 (2,720)
Dinomastigota (Dinoflagellates)	Dinozoa	Dinoflagellata	~4,000	~2,000	4,000	2,000 (<3,000)
	Metamonada	(under Dinoflagellata)		300	–	
	Parabasala	Parabasilida (Trihomonads and Hypermastigotes)		400	~300	466 (500)
Apicomplexa (Sporozoa)	Apicomplexa	Apicomplexa	~5,000	~5,000	~5,000	6,000 (1.2–10 million)
Haplospora	(under Apicomplexa)		33			
Plasmodiophora	(under Apicomplexa)		29			
Paramyxa	(under Apicomplexa)		6			
Ciliophora (Ciliates)	Ciliophora	Ciliophora	~10,000	7,800	12,000	3,500 (30,000)



## Protoctista (mainly Protozoa—others included under fungi, algae, Chromista, etc) *continued*

Summary Table<sup>173</sup>

	Other names and inclusions	World Descr./ Accepted	World Estimate	Australia Descr./ Accepted	Australia Percent.	Australia Estimate	Australia Endemic
Amoebozoa (incl. cellular slime moulds, excl. fungoid protists)		~3,006	13,000–23,000	~305	10.1%	–	–
Apicomplexa	(parasitic protists)	~5,000	>1,000,000	unknown	unknown	–	–
Ciliata	(protists with cilia)	~4,000	~30,000	151 <sup>174</sup>	3.8%	–	–
Flagellata	(protists with flagella)	~2,200	~3,300	675	25.9%	–	–
Foraminifera	(foraminiferans incl. Radiolaria)	>13,500	>18,000	>23	0.2%	–	–
Fungoid protists	Mycetozoa, Myxomycota, Plasmodiophoromycota	1,165	thousands	192	16.5%	–	–
TOTAL		~28,871	>1,000,000	>1,346	4.7%	~65,000	unknown

173 Numbers are approximate only, and have often been hard to place into a category.

174 Scott and Marchant (2005) list 151 species for the Australian Antarctic Territory. I have no figures for the rest of Australia.

