throughout the entire cortical mass, physiological and anatomical differences among cortical areas have been documented (*19, 20*). Here I have identified a molecularly distinct class of neuron with a restricted distribution in the cerebellar cortex. The areas that contain the Rat-302 cell, the flocculus, paraflocculus, and vermis, have been considered identical to the rest of the cerebellum in cytoarchitecture but distinct from other areas in connectivity. In most areas of the cerebellum, Purkinje cells project to neurons in the deep cerebellar nuclei, which, in turn, project out of the cerebellum. In the flocculus and vermis, Purkinje cells project directly out of the cerebellum (without a relay in the deep cerebellar nuclei) to the vestibular nuclei (*21, 22*). By cytoarchitectonic criteria the neuron in the granule cell layer identified by Rat-302 represents a novel cell class in the cerebellar cortex. As Rat-302 also recognizes Purkinje cells, it is possible that the Purkinje cell and the Rat-302 cell are functionally related. In other parts of the cerebellar cortex the Purkinje cell projects to the deep cerebellar nuclei, and is interposed between cortical processing and cerebellar efferent projections. In the flocculus and vermis, the Purkinje cell projects directly out of the cerebellum. The Rat-302 cell in these areas might function like the Purkinje cell, as a cell interposed between cortical processing and the cerebellar efferent projections of the floccular and vermal Purkinje cells. Indeed, some Rat-302 cell axons appear to be locally confined.

Here I have generated monoclonal antibodies to cerebellar neurons using an effective, general method to target the immune response toward antigens of interest. Neonatal tolerization reduces the immune response to the tolerizing antigens later in life. In contrast to other suppression strategies with immunosuppressive drugs in adult animals (*23*), the suppression reported here is achieved without inducing a general immunocompromised state. When combined with footpad immunization, this method provides a strategy to rapidly generate high-affinity monoclonal antibodies of desired specificity, which will permit the identification of a previously unrecognized class of cerebellar neuron.

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Early Archean (3.3-Billion to 3.5-Billion-Year-Old) Microfossils from Warrawoona Group, Australia

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Cellularly preserved filamentous and colonial fossil microorganisms have been discovered in bedded carbonaceous cherts from the Early Archean Apex Basalt and Towers Formation of northwestern Western Australia. The cell types detected suggest that cyanobacteria, and therefore oxygen-producing photosynthesis, may have been extant as early as 3.3 billion to 3.5 billion years ago. These fossils are among the oldest now known from the geologic record; their discovery substantiates previous reports of Early Archean microfossils in Warrawoona Group strata.

PUTATIVE CELLULARLY PRESERVED microfossils have been reported from at least 28 Archean (>2.5-billion-year-old) geologic units (*1–4*). However, virtually all have recently been reinterpreted (*1*) as dubiofossils or as nonfossils: pseudofossils, artifacts, or contaminants. Thus, in contrast with the relatively well-known microbial (*5, 6*) and stromatolitic (*7*) fossil records of the younger (Proterozoic) Precambrian, the Archean record remains poorly documented. The composition of the Archean biosphere and time of origin of such evolutionary innovations as oxygen-producing photosynthesis have yet to be determined.

The oldest apparently authentic (*1*) cellularly preserved microbiota known is that reported (*1, 2*) from cherts of the 3.3-billion to 3.5-billion-year-old Towers Formation of the Warrawoona Group of Western Australia. However, the precise collecting site of these microfossiliferous cherts is unknown (*1*, p. 234; *2*). For this and related reasons, the significance of this microbiota has been open to question (*8*). We now describe additional fossils recently discovered (*4*) in two formations of the Warrawoona Group. This discovery confirms the occurrence of microfossils in this sequence; the cell types detected suggest that oxygen-producing photoautotrophic cyanobacteria may have been extant as early as 3.3-billion to 3.5-billion years ago.

The Warrawoona Group, stratigraphically the lowest group of the Pilbara Supergroup, is a 14-km-thick sequence of volcanics containing extensive cherty sedimentary units less than 50 m thick (*9*). The stratigraphy (*9*) and geochronology (*10*) of the sequence are summarized in Table 1.

The microfossils here reported occur in petrographic thin sections of carbonaceous cherts from the Towers Formation and the Apex Basalt (Table 1). The former is a stratigraphic marker unit, generally about 0.5 km thick (*9*), in part deposited in a shallow subaqueous to intermittently subaerial environment (*11*). The directly overlying Apex Basalt is composed of minor chert units interbedded with pillow lavas (*9*). In metamorphic grade, the Warrawoona Group ranges from prehnite-pumpellyite to green schist facies (*12*).

The age of the microfossiliferous forma-

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tions is well constrained. Three techniques (U-Pb, Sm-Nd, and model Pb) indicate an age of 3.4 billion to 3.5 billion years for the Duffer Formation (*10*), immediately underlying the Towers Formation. Model Pb ages from veins transecting the Towers Formation similarly are about 3.4 billion years (*10*). Age constraints on the Apex Basalt are provided by model Pb dates (3.34 billion years, 3.33 billion ± 0.01 billion years, and 3.19 billion ± 0.01 billion years) from veins stratigraphically above the Towers Formation and below the Wyman Formation (*10*). Thus, the age of both microfossiliferous Warrawoona units is evidently between 3.3 billion and 3.5 billion years.

Thin sections of black and cross-bedded black-and-white chert from the "middle chert horizon" of the Towers Formation near Strelley Pool [Fig. 1, locality 1 (*13*)] contain carbonaceous or iron-stained, three dimensionally preserved colonies of a few to many sheath-enclosed spheroidal cells (Fig. 2, H to L). Two types occur: relatively small-celled, spheroidal (Fig. 2, H and I) or globular (Fig. 2J) colonies containing cells about 8 μm in diameter (average, 8.3 ± 0.5 μm; range, 5.5 to 10.2 μm; $n = 28$); and a large-celled, spheroidal colony (Fig. 2, K and L) encompassed by a multilamellated sheath and composed of cells about 21 μm in diameter (average, 21.3 ± 0.5 μm; range, 16.8 to 24.2 μm; $n = 4$). The colonies are permineralized in fine-grained (5 μm to about 15 μm in diameter) anhedral quartz; they occur in organic-rich zones that in the black-and-white chert are finely laminated.

The microfossiliferous cherts of the Apex Basalt occur along Chinaman Creek near Marble Bar [Fig. 1, locality 2 (*14*)]. The cherts occur as a 10-m-thick bed, concordant and interfingering with associated volcanics, which merges laterally into a continuous 20- to 30-m thick bedded, brecciated, gray chert unit. The unit contains subangular to rounded, light-brown, sedimentary lithic clasts one to a few millimeters in diameter. Within some clasts occur dark-brown, carbonaceous, filamentous microfossils (Fig. 2, A to G), permineralized in fine-grained quartz. These sinuous unbranched filaments are about 3 μm in diameter (average, 3.4 ± 0.5 μm; range, 1.8 to 6.0 μm; $n = 9$) and 30 μm to more than 40 μm in length (Fig. 2, A, B, and F); relatively well-preserved specimens (Fig. 2, A, and D to F) are composed of uniseriate, more or less equant cells. Microfossils have not been detected in the matrix encompassing these clasts.

Table 1. Stratigraphy (*9*) and geochronology (*10*) of the Archean Pilbara Supergroup, Western Australia.

Geologic unit	Approximate age ($\times 10^9$ years)
Pilbara Supergroup	
Whim Creek Group	3.0
Gorge Creek Group	
Warrawoona Group	
Wyman Formation	
Euro Basalt	
Panorama Formation	3.3
Apex Basalt	
Towers Formation	≥3.4
Duffer Formation	3.4–3.5
Mount Ada Basalt	
McPhee Formation	3.7
North Star Basalt	

To be considered authentic (*1*), the microfossils must be indigenous to and syngenetic with deposition of the cherts in which they occur. All fossils occur in thin sections (Fig. 2, A to L), thoroughly encased within the chert matrix. Thus, they are demonstrably indigenous, rather than being contaminants or artifacts. The fossils also are syngenetic: (i) all fossils occur within bedded sediments, permineralized in fine-grained chert; (ii) fossils have not been detected in secondary or later state chert (which at both localities occurs as cross-cutting veins); (iii) microfossils of the Towers Formation occur within sedimentary organic-rich zones including those with cross-laminations; (iv) microfossils of the Apex Basalt occur within clasts that were deposited in this unit prior to its lithification; and (v) the carbonaceous fossils are similar in color and texture to particulate kerogen occurring in the same rocks.

In salient morphology, filaments of the Apex Basalt (Fig. 2, A to G) resemble trichomes of extant (*15*) and fossil (*1, 5, 16*) prokaryotes. Morphological analogs are abundant among cyanobacteria (Oscillatoriaceae) but occur also among modern non-oxygen-producing prokaryotes (for example, beggiatoaceans and chloroflexaceans). Thus, even if it is assumed that these fossils are not representatives of extinct lineages that differed in physiology from modern morphological counterparts, morphology is of limited aid in inferring their affinities and physiology.

In contrast, the relatively large cell-size and lamellated sheaths of colonial microfossils from the Towers Formation (Fig. 2, H to L) seem suggestive of cyanobacterial (chroococcalean) affinity. Among comparable extant taxa, cells of the size occurring in these colonies (8 μm to more than 20 μm) are decidedly more typical of cyanobacteria than other prokaryotes (*15*): About 70% of extant spheroidal cyanobacteria (80 of 114 species) are 4 μm or more in diameter whereas virtually all free-living coccoid bacteria (56 of 57 taxa) are 4 μm or less in diameter (the exception is *Thiovulum majus*, 5 to 25 μm in diameter); like the fossils, numerous extant chroococcalean (for example, *Chroococcus* spp.) are in the 8 to 20 μm range, two to five times as large as 98% of living coccoid bacteria (*5*, p. 355). In addition, multilamellated sheaths like those of the large-celled colony (Fig. 2, K and L) are common in the Chroococcales but rare among noncyanobacterial colonial prokaryotes (*5, 15*). Chroococcaleans are well known from the Proterozoic (*5, 16*). Thus, the chroococcalean-like Warrawoona colonies appear reasonably interpreted as early members of a lineage that became well established during the Precambrian. Like all cyanobacteria, chroococcaleans are capable of oxygenic photosynthesis; although some extant cyanobacteria exhibit facultative anoxygenic photosynthesis [for example, *Oscillatoria limnetica* (*17*)], oxygen-producing photoautotrophy is a characteristic of the group. It therefore seems reasonable to infer that these fossil colonies may have been both photoautotrophic and oxygen-producing.

Other lines of evidence are consistent with this inference. For example, $\delta^{13}C$ values of Warrawoona kerogen (*18*) seem indicative of the existence of autotrophs, although not necessarily oxygen-producing autotrophs (*1, 2, 6*). Similarly, the occurrence of stromatolites in the Warrawoona Group (*11*) [and in other Early Archean units (*7*)], the occurrence of cyanobacterium-like fossils in other Archean deposits (*1–3*), and the presence of banded iron-formations and other oxidized sediments in numerous Archean terranes (*19, 20*) are all consistent with the existence of oxygen-producing microbial photoautotrophs. Thus, although the evidence cannot be considered "compelling" (*6, 21*), available data are consistent with, and seem supportive of, the Early Archean presence of oxygenic photosynthesis.

The fossil microorganisms here described are significant for a variety of reasons: (i) Their discovery substantiates previous (*1, 2*) but disputed (*8*) claims of Early Archean

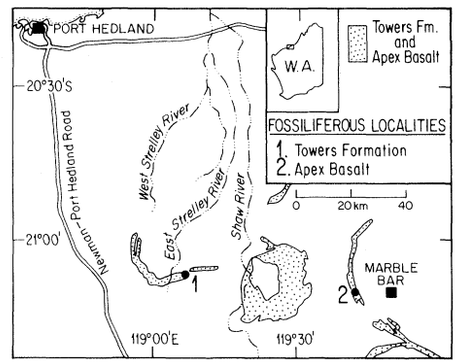

Fig. 1. Location in Western Australia of described fossiliferous localities.

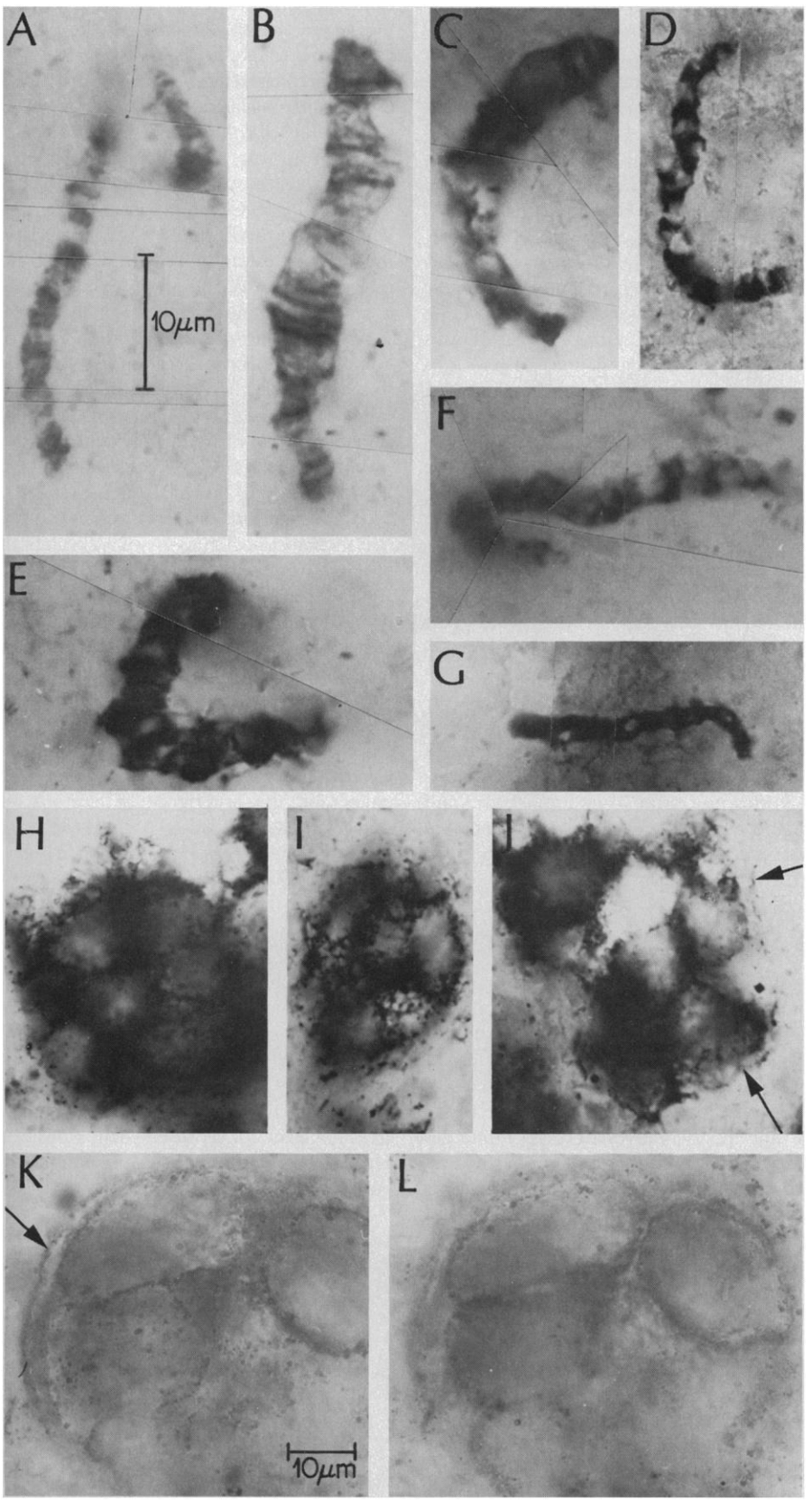

Fig. 2. Optical photomicrographs showing microfossils in thin sections of carbonaceous chert from the (**A to G**) Apex Basalt and (**H to L**) Towers Formation (*22*). (A) to (G) show photomontages; arrows in (J) and (K) point to remnants of encompassing sheaths. Scale in (A) is for (A) to (J); scale in (K) is for (K) and (L), which show the same colony at two different focal depths.

microfossils in Warrawoona Group strata. (ii) They are among the oldest fossils yet described and include the earliest examples known to us of sheath-enclosed colonial unicells. (iii) If they were, in fact, oxygen-producing, the gradual buildup prior to the mid-Proterozoic of a photosynthetically produced oxygenic environment must have occurred over a substantially longer segment of the Precambrian than has been suggested (*6, 19*). (iv) Together with other relevant data, they establish that microbial communities were extant, morphologically varied, and possibly physiologically advanced as early as 3.3 billion to 3.5 billion years ago.

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21. Among uncertainties, inferences based on cell size assume that the relation between morphology and physiology exhibited by living microbes has not varied significantly during evolution.
22. Thin section (T.S.) number and stage coordinates (Leitz Orthoplan microscope with T.S. number to right) for specimens in Fig. 2: (A) T.S.4-6/15/82-1d, 29.2 by 110.9; (B) T.S.4-6/15/82-1d, 29.1 by 110.8; (C) T.S.4-6/15/82-1b, 25.6 by 112.1; (D) T.S.4-6/15/82-1e, 42.9 by 122.1; (E) T.S.4-6/15/82-1b, 25.7 by 112.9; (F) T.S.4-6/15/82-1d, 30.1 by 111.4; (G) T.S.4-6/15/82-1e, 43.7 by 120.8; (H) T.S.4-6/13/82-1b, 51.5 by 111.8; (I) T.S.4-6/13/82-1a, 54.8 by 115.8; (J) T.S.4-6/13/82-1b, 48.5 by 109.2; (K and L) T.S.4-6/13/82-2a, 59.7 by 121.1.
23. We thank participants in the Precambrian Paleobiology Research Group (PPRG) fieldwork of June 1982: K. J. Armstrong, D. Blight, D. J. Chapman, J. M. Hayes, A. H. Hickman, C. Klein, D. D. Radke, J. C. G. Walker, and M. R. Walter. For review of this manuscript, we thank S. M. Awramik, J. Lake, T. Moore, J. Shen-Miller, G. Vidal, and M. R. Walter. The 1982 fieldwork was supported by NASA grant NGW-825 to the PPRG. The 1986 fieldwork was supported by NASA grant NGR-05-007-407 to J.W.S. and by both the Western Australia Geological Survey, Perth, and the Bureau of Mineral Resources, Canberra, to which organizations we are grateful. Laboratory studies supported by NSF grant BMR 79-21777 to J.W.S.

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Local Retinal Regions Control Local Eye Growth and Myopia

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In chicks, visual deprivation leads to myopia and enlargement of the vitreous chamber of the eye. When chicks were raised with white translucent occluders over their eyes so that either the nasal half, the temporal half, or all of the retina was visually deprived, the resulting myopia (median = −15 diopters) was limited to the deprived part of the retina, regardless of which half of the retina was visually deprived; the nondeprived part remained nearly emmetropic. Correspondingly, the vitreous chamber was elongated only in the region of the visual deprivation, resulting in eyes with different asymmetric shapes depending on which retinal region was deprived. These results argue for a local regulation of ocular growth that is dependent on vision and suggest a hypothesis to explain the epidemiological association of myopia in humans with large amounts of reading. Because most nonfoveal retinal neurons have large receptive fields, they cannot resolve the individual letters on the printed page; this may lead to their activity being less during reading than during most other forms of visual stimulation. Thus, the impoverished stimulus situation of reading may lead to myopia, as do other types of visual form deprivation.

IN MOST ANIMALS THE OPTICAL POWER of the eyes is well matched to their length so that images of distant objects are in focus on the retina (emmetropia). In humans, however, this matching of optical power and eye size is frequently lacking. This results in significant degrees of myopia (nearsightedness) if the eye is too long compared with its optical power, or hyperopia (farsightedness) if the eye is too short. At birth, eyes of several species are hyperopic and very variable in refractive status but quickly grow toward emmetropia (*1*). This raises the possibility that myopia and hyperopia may reflect disorders of the emmetropization process. Various hypotheses, some rather curious, involving dietary, hormonal, occupational, and psychological causes of myopia have enjoyed periods of popularity, as have a variety of mechanisms of myopia involving, for example, eyestrain, accommodation, convergence, inflammation, traction on the optic nerve, and pressure on the veins leaving the eye (*2*).

Within the past decade, it has become clear that alterations in visual experience can provoke myopia: monkeys, tree shrews, and probably cats become myopic when deprived of form vision early in life (*3–6*). In these cases, as in typical human myopia (*7, 8*), the myopia involves an increase in the length of the eye. Children also have been found to become myopic when deprived of form vision because of a variety of disorders that have in common an obstruction of vision, such as ptosis, hemangiomas, or congenital cataracts (*9, 10*).

These demonstrations that an aspect of vision could influence myopia have been seen as consistent with the view that typical human myopia is due to an excess of ocular accommodation (the focusing of the eye for near distances) caused by long periods of near viewing, as in reading. The principal support for this hypothesis has come historically from observations that professions requiring much reading or other close work tend to be occupied by myopes, and that there is a consistent correlation between educational level and degree of myopia (*11*). In addition, one study in an Inuit community suggested that the advent of compulsory schooling, along with other accoutrements of Western civilization, was associated with an increased incidence of myopia (*12*). A long history of observations such as these has entrenched the idea that near work is a primary factor in the etiology of myopia.

Some animal research also supports an association of increased accommodation and myopia. Young reported that a small amount of myopia was produced by restricting the vision of monkeys to white drapes 18 inches away (*13*). Evidence of an effect of near vision was also suggested, but not proven, by studies showing that cage-reared cats and monkeys (*14*) are myopic compared with wild conspecifics. Of course, many differences other than the amount of near vision distinguish wild from captive animals. Chimpanzees raised in cages show a progression toward greater myopia as they get older, presumably as a result of captivity (*15*).

The results of experimental tests of the accommodation hypothesis are equivocal. There are some positive results showing reduced progression of myopia when children or animals are given daily doses of atropine, a drug that paralyzes the muscles of accommodation (*16, 17*). On the other hand, an equally careful study, in which the need for accommodation was reduced by having children wear bifocals, produced no change in myopic progression (*18*). Denervation of the ciliary muscles in chicks reduced, but did not eliminate, myopia caused by visual deprivation (*19*). Recently, Raviola and Wiesel have mentioned in a review

Table 1. Median refractive error of three locations of visually deprived eyes.

Deprived area	*n*	Median refractive error (diopters)		
		Nasal retina	Optic axis	Temporal retina
Nasal retina				
2 weeks	30	−13.6	−7.7	+0.8
6 weeks	21	−9.1	−5.5	+0.8
Temporal retina				
2 weeks	26	−2.6	−15.0	−17.7
6 weeks	20	+1.7	−1.7	−10.2
Total retina				
2 weeks	19	−20.2	−28.4	−28.1
6 weeks	18	−18.6	−22.7	−17.6

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