Cell, Volume 147

Supplemental Information

The Microbial Opsin Family of Optogenetic Tools

Feng Zhang, Johannes Vierock, Ofer Yizhar, Lief Fenno, Satoshi Tsunoda, Arash Kianianmomeni, Matthias Prigge, Andre Berndt, John Cushman, Jürgen Polle, Jon Magnuson, Peter Hegemann, and Karl Deisseroth

Supplemental Sequences

> *Dunaliella salina* Channelrhodopsin-1 (DChR1)

```
ATGAGGCGACGCGAAAGCCAGCTTGCGTACCTGTGTCTGTTTGTGCTCATTGCGGGCTGGGCACCTCGACTGACGGA
ATCGGCTCCAGACTTGGCTGAGAGGCGCCCACCCTCGGAGCGCAACACACCCTACGCCAACATCAAAAAGGTTCCGA
ACATCACTGAGCCAAATGCAAACGTGCAGCTGGATGGGTGGGCTCTGTACCAGGACTTTTATTACCTCGCGGGCAGT
GACAAGGAGTGGGTCGTGGGCCCTTCAGACCAATGCTACTGCAGGGCCTGGTCTAAGAGTCATGGCACTGACAGAGA
GGGAGAAGCTGCTGTGGTCTGGGCGTACATTGTGTTCGCCATCTGCATTGTGCAGCTGGTATATTTCATGTTTGCAG
CATGGAAGGCCACAGTCGGCTGGGAGGAGGTCTACGTTAACATTATTGAGTTGGTGCACATTGCCCTGGTCATTTGG
GTCGAGTTCGACAAGCCGGCCATGCTGTACTTGAATGATGGACAGATGGTGCCTTGGCTGCGCTACTCTGCCTGGCT
TCTCTCATGCCCAGTCATCCTGATCCACTTGTCCAACTTGACAGGGTTGAAGGGCGATTACAGCAAGCGCACAATGG
GCCTCCTGGTTTCTGATATCGGAACCATTGTGTTTGGAACATCGGCAGCGCTGGCGCCACCCAACCATGTTAAGGTT
ATTTTGTTCATCATCGGTCTTCTGTACGGCCTGTTCACTTTCTTCACAGCTGCAAAGGTGTACATTGAGGCATACCA
CACAGTGCCCAAGGGGCAATGCCGGAACCTTGTGCGTGCCATGGCATGGACCTACTTTGTGAGCTGGGCCATGTTCC
CCATTCTTTTCATCCTGGGCCGCGAAGGGTTTGGCCACATCACATATTTTGGATCCAGCATTGGCCACTTCATCCTT
GAAATCTTCTCCAAGAACTTGTGGTCACTGCTGGGTCACGGTCTCCGTTACAGGATCCGCCAGCACATCATCATCCA
TGGCAACCTGACCAAGAAGAACAAGATCAACATTGCGGGTGACAATGTGGAGGTGGAGGAGTACGTGGATTCCAACG
ACAAGGACTCCGATGTCATTAACAACGGCACCAAGGAGTTTTCCAACAGGCACTCCTTCATGGTCATGAAAGATCGT
ATGCAAAAGAACGGCACTCAAACACGCGCGTCCCTCGAGGGCGAGGCCCCTCCTGATGAAGAAATGCCCAGCGGCAA
GAAGGGCAAGCTGGACACGTTGGAGGAGGGCAGCGACAGCTTGGAGGACGATGTGCCCAGTTCAAAGGGAGGACTGA
GTGGCATGGGCATGGACGGCATGCCCACGCTGCAGCCTGGGCGTGTGGTGCTTGTGGTGCCAGACATGGAGCTGGTG
GAGTTCTTCAGGCAGCAGTTCTCCTTCCTACCCGTGCCCTTTGAGGTGTATCCCGCCATTGGCGCCGACCAGGGTGT
GCAGCTGGCGCAGCAGGGCCTGCAGCTGGGAGGCACCCCCTACTTGGACTTTGTGCTGGTGGCCCCTGACTTCCTGC
ACAACCGCAGCCCCTCTGGCCTGGTAGCCCGCCTGAAGATGATGGGCATGCGCGTGTGCGCATTTGGCTGGCAGCCC
CAGGGTCCCCAGCGGGAACTCATCGAGTCTTCTGGTGTCGACGGCTTCCTCATGGGCCCCATCCACCCACAGGGCAT
CCACCGCGGGCAGTTTGTGCAGCTCATCGCGCGCATGCAGGCCCTCAAGCGCATGCCCACCACACAGAACATGGGCG
GCATGAACATGGGCATGGGCAGCATGGCAGGCATGGGCATGGGCATGGGCATGGGAAGCTTGGGGGGCATGCCTCCT
GTGGCCCCCATGGGCTCCATGGGTGGCAGCCCCGGCATGTACGGCTCCACCATGCCCCGTGGTGCAGCCCCAGCCCC
TAATCCCCTGTTCAATGCTCCTCCCTCTCCCATGGGTAGCCAGCCCGGCATGATGATGGGCGGTGCTGCGGGCATGC
AGCCGCAAGGCAGCATGCAGGGTGGCGCTGCGTCCCCGCATGGAACTGCCAGCCCTGCGCCCCCTGCCCCCGCCCCG
GGAGGTGCTGATGGGGAGGCGCAGATGATGCAGCAGCTGATGGCTGAGATCAACCAGCTGCGTGCAGAGCTCAACCA
GAACTAA
```

>*Dunaliella salina* Channelrhodopsin-1 (DChR1), codon-optimized for mammalian expression used in Figure 4

```
ATGCGTAGAAGGGAGTCTCAGCTCGCATACCTTTGCCTGTTCGTTTTGATCGCTGGCTGGGCCCCACGTCTGACTGA
AAGCGCCCCTGATCTAGCCGAGCGGCGGCCTCCCTCCGAGCGAAACACCCCTTACGCCAATATTAAAAAGGTGCCCA
ATATAACTGAACCCAACGCCAATGTGCAACTTGATGGGTGGGCTCTGTACCAGGATTTTTACTACCTGGCTGGTTCA
GATAAGGAATGGGTCGTTGGCCCTAGCGACCAGTGTTACTGCCGAGCATGGTCTAAATCACACGGCACCGACAGAGA
GGGCGAGGCGGCTGTGGTGTGGGCGTACATCGTATTCGCCATTTGTATCGTACAACTGGTTTATTTCATGTTTGCCG
CTTGGAAGGCAACGGTCGGATGGGAGGAAGTCTACGTGAACATCATTGAGCTGGTGCACATTGCCCTGGTGATTTGG
GTCGAGTTCGATAAACCCGCCATGCTCTACCTTAACGACGGTCAGATGGTTCCATGGTTGCGCTATAGTGCATGGCT
```

CCTTTCCTGCCCAGTCATCCTAATTCACCTGAGCAACTTAACAGGGCTAAAGGGGGACTATAGTAAGAGAACCATGG
GGCTTTTGGTCTCTGACATCGGAACCATAGTGTTTGGTACAAGCGCCGCACTCGCTCCGCCAAACCATGTCAAAGTC
ATCTTATTTACAATTGGGTTGCTGTATGGACTCTTCACTTTTTTCACGGCAGCGAAGGTATATATTGAGGCCTACCA
CACCGTTCCAAAAGGCCAATGTAGAAACCTCGTGAGGGCTATGGCCTGGACTTATTTCGTAAGTTGGGCGATGTTCC
CCATCCTGTTTATCCTGGGAAGAGAGGGTTTTGGCCATATTACATATTTTGGCTCATCCATCGGACACTTCATACTG
GAGATATTTTCAAAAAATCTGTGGAGTCTACTGGGCCACGGATTACGGTATCGCATAAGGCAGCATATCATCATTCA
TGGCAATTTGACAAAGAAGAATAAGATTAATATCGCAGGGGACAACGTCGAAGTGGAAGAGTACGTGGATTCTAACG
ACAAGGACAGCGACGTT

>*Pyramimonas gelidicola* Channelrhodopsin-1 (PgChR1)
ATGGTTGGCCTTAAGCCTGAAGAAACGGACGAATGGATCGCGTACTCCGCTATGTGGGCTGCACTGGTGTTTTCCCT
CCTCTCCGGAGTCTTCTACGCGAGGGAGTATCACATGAAGAGGTGCGGCTGGGAGGTGATGTACGTCGCTACCCTGG
AGACCCTCAACTACGTCTTCCTCATCGGCTGGGGCGATCTCGCCCCGTTTCACTGGAAGCTTGACACCACGTGCCAT
GGCGAAGACGACCACTCGGGCTGCTGGGATGACCCTCTTCGAGACCGAAAAATCAACGAAGTGCCGGTGGCGCGCTA
CATGGAGTGGCTGATCACGTGTCCGGTACTCCTCATCGCGTTATCTAACTTGACGGGCCTGAAAGACGACTACAATT
GGCGGACCATGAAGCTGATCACCGCCGACCAGGGCACGATTCTGTTCGGAGCCACGGGCGCTTTGGCCACCGGCACC
GTCAAGCCCGTCTTCTTCTGCGTGGGATTAATGTACGGCGGCGTCACGTACTTCACTGCCTTGGAGGTGTACGTGGA
GTCTTACGCGAACGTGCCGCCCAATGCCAAGAAGACCGTGAGCATCATGGCCTACATGTTCTTTCTCTCTTGGATGT
GTTTCCCTCTCTTCTGGCTTCTTGGTCAAGAGGGTTTCGGCCACGTCAACCAGCACGTGTCGACCACCTTGCACGCG
ATTGCCGACTTGTTTTCCAAGAACTTGTGGGGACTCTACTCGTGGTATCTTCGCCTCCAGGTGCGCGAGTACCACCG
CAAGAAGTGGCACGAGGAGCAGGAGCGCTTAAACCAGGGCGAGAAGGAGTTTGAAATTCCCAAGGAGCG

>*Pleodorina starrii* Channelrhodopsin-1 (PsChR1)
GGAACAAATGCGGAGAAGTTGGCTGCCAACATTCTGCAGTGGGGTGCGTTAGCGCTCTGCGTGATGTTCTCCGGCTA
CCAGACCTGGAAGTCTACTTGCGGGTGGGAGGAGATTTACGTGGCCAAGATCGAGATGATCAAGTTCATCATCGAGT
ATTTCCATGAGTTTGACGAACCTGCGGTGATTTATTCATTCAACGGCAACAAGACCGTGTGGCTTCGTTACGCGGAG
TGGCTGCTGACCTGCGTCATTCTTATCCATCTGAGCAACCTTACGGGTCTGGCGAACGACTATAACAACCGTACCAT
GGGTCTGCTGGTGTCAGATGTCGGCACGAGCGTGTGGGGCACCACGGCCGCGCTGTCCAAGGGATACAGTCCGTGTC
ATTTTCTTCCTGATTTGGCCTACGGCATCTACACATTCTTCAACGCAGCCAAGGTCTACATTGAGGCGTACCACACC
GTGCCCAAGGGCATTTGCCGCGACCTGGTCCGCTACCTTGCCTGGCTCTACTTCTGTTCATGGGCTAGTTTCCCGGT
GCTGTTCCTGCTGGGCCCCGAGGGCTTTGGCCACATCAACCAATTCAACTCTGCCATCGCCCACGCCATCCTGGACC
TTGCCTCCAAGAACGCTTGGAGTGTGATTGGTCAC

>*Pleodorina starrii* Channelrhodopsin-2 (PsChR2)
GGCACAAACGGTGCCCAAACGGCGTCGAACGTGCTGCAATGGCAACTTGCTGCTGGCTTCTCCATCCTACTGCTTAT
GTTTTACGCCTACCAAACATGGAAGTCAACCTGCGGCTGGGAGGAGATCTATGTGTGCGCTATCGAGATGGTCAAGG
TGATTCTCGAGTTCTTCTTCGAGTTTAAGAACCCGTCCATGCTGTATCTAGCCACAGGCCACCGCGTCCAGTGGTTG
CGTTACGCCGAGTGGCTTCTCACCTGCCCGGTCATTCTCATCCACCTGTCAAACCTGACGGGCTTGTCCAACGACGA
CAGCAGTCGCACCATGGGTTTGCTGGCTTGCAGTATTGGCACAATTGTGTGGGGCGCCACTTCCGCCATGGCCTCCG
GATACGTCAAGGTCATCTTCTTCTGCCTGGGTGTTTATTGTGCGAACACGTTCTACCGCGCACAGGCCTACATCAAG
GGTTACCACACCGTGCCGAAGGGCCGGTGTCGCCAGGTGGTGACTGGCATGGCTTGGCTCTTCTTCGTATCATGGGG
TATGTTCCCCATCCTGTTCATCCTCGGCCCCGAGGGCTTCGGCGTCCTGAGCGTGTACGGCTCCACCGTCGGCCACA
CCATCATTGACCCGATGTCGAAGAACCGCTGCGGGCTGCCCGGCCACTACCCGCGCGTGCTGGTG

>*Coccomyxa vulgaris* C-169 (formerly *Chlorella vulgaris)* (CvRh)
ATGGCTGTGCACCAGATTGGAGAAGGCGGACTGGTTATGTACTGGGTTACATTTGGCCTGATGGCTTTTAGCGCTCT
GGCTTTTGCCGTGATGACATTCACAAGGCCCCTGAACAAAAGAAGCCACGGATATATCACCCTGGCCATTGTGACAA
TCGCTGCTATTGCTTACTACGCTATGGCTGCTTCTGGCGGAAAAGCTCTGGTGTCTAATCCAGATGGAAACCTGAGG
GACATCTACTACGCCAGATATATCGACTGGTTCTTCACAACACCCCTGCTGCTGCTGGATATTATTCTGCTGACCGG
AATCCCAATCGGAGTGACACTGTGGATTGTGCTGGCTGATGTGGCTATGATTATGCTGGGACTGTTTGGAGCCCTGA
GCACAAATTCTTACAGATGGGGCTACTACGGCGTGTCCTGCGCTTTTTTCTTTGTGGTGCTGTGGGGACTGTTTTTC
CCAGGCGCTAAAGGCGCTAGAGCTAGAGGCGGACAGGTGCCAGGACTGTACTTTGGACTGGCTGGATACCTGGCTCT
GCTTTGGTTCGGATACCCAATTGTGTGGGGCCTGGCTGAAGGATCTGATTACATTTCTGTGACAGCTGAGGCTGCTT
CTTACGCTGGACTGGATATTGCTGCTAAGGTGGTGTTTGGATGGGCTGTGATGCTGTCTCACCCACTGATTGCTAGG
AACCAGACAGATGGAAGCCTGCTGATCAACAGCACCAACGATCCATTTGTGGCCAGCACAACACACATTCCAGAAAG
ACAGGGCGGAATCTTTGGAGGACTGATGGGAAAAAAGAGGGGAGCTGGAACACCACTGGCTACAAATGAAGGCGTGC
CAAGAAAAGCTGCTCCAACAGCTGCTACAACAACAGCTGGAAATCCAGCTACAGCTGCTGAAGTGCGTACGAGCAAA

AGCTGA

Note that PgChR1, PsChR1 and PsChR2 sequences are taken from genome project of *Pyramimonas gelidicola* and *Pleodorina starrii* and may be inaccurate in some nucleotides; *C. vulgaris* sequence identified by Suneel Kateriya.