**Neuron, Volume *99***

## Supplemental Information

# How Diverse Retinal Functions Arise from Feedback at the First Visual Synapse

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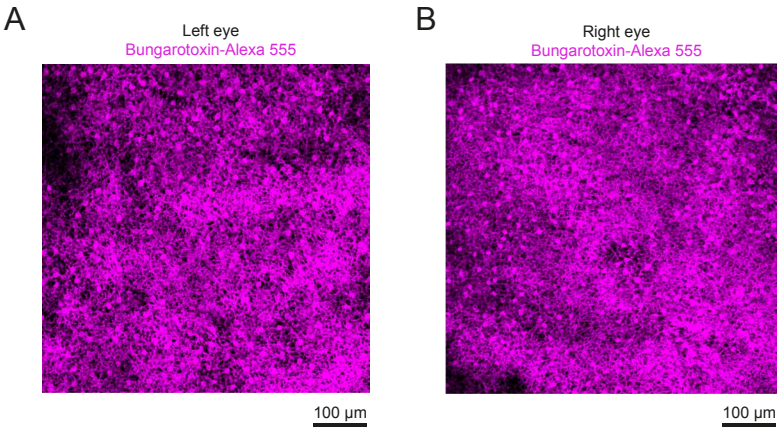
Figure S1


A
Left eye
Bungarotoxin-Alexa 555
100 µm
B
Right eye
Bungarotoxin-Alexa 555
100 µm

# Figure S2

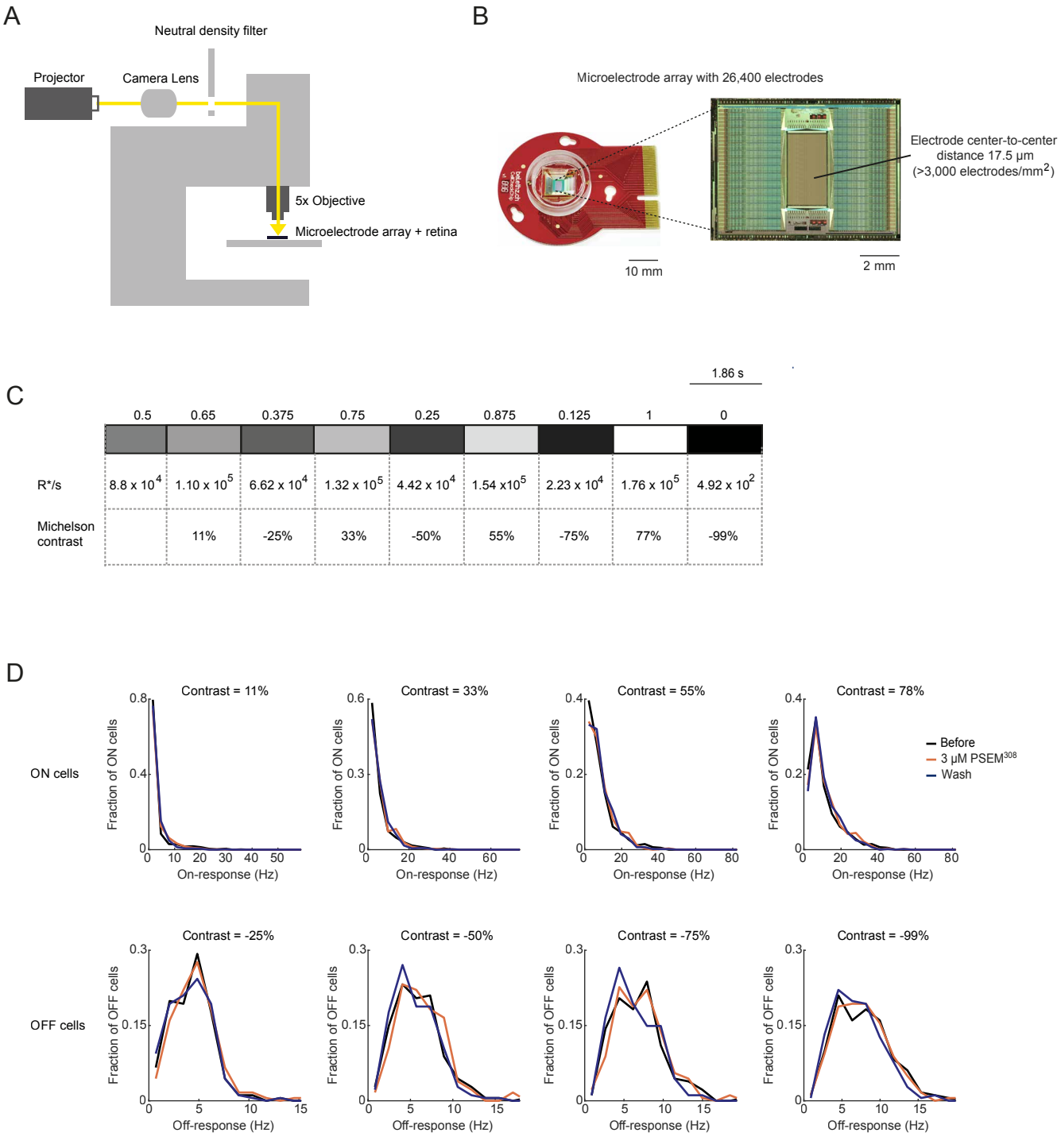
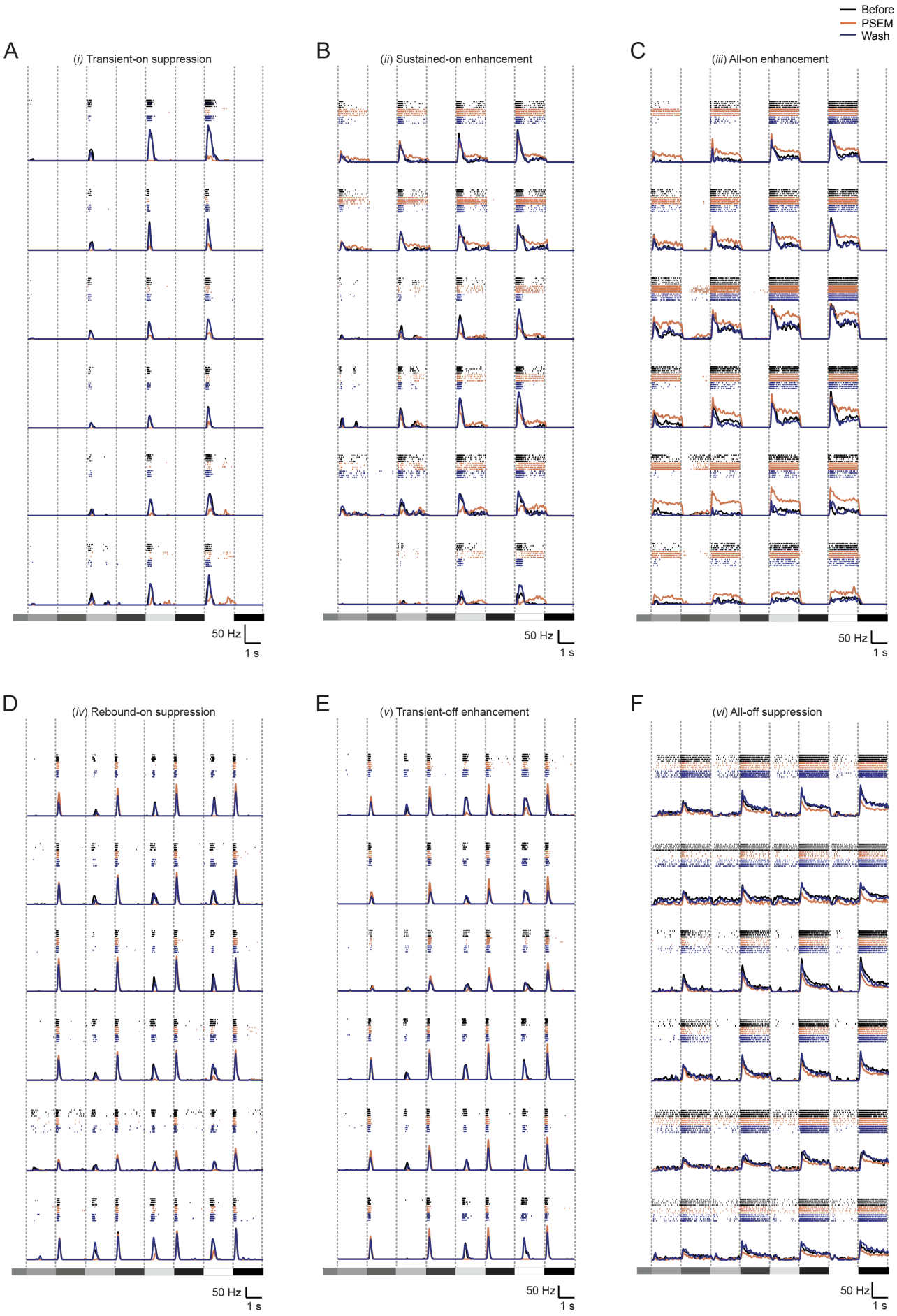
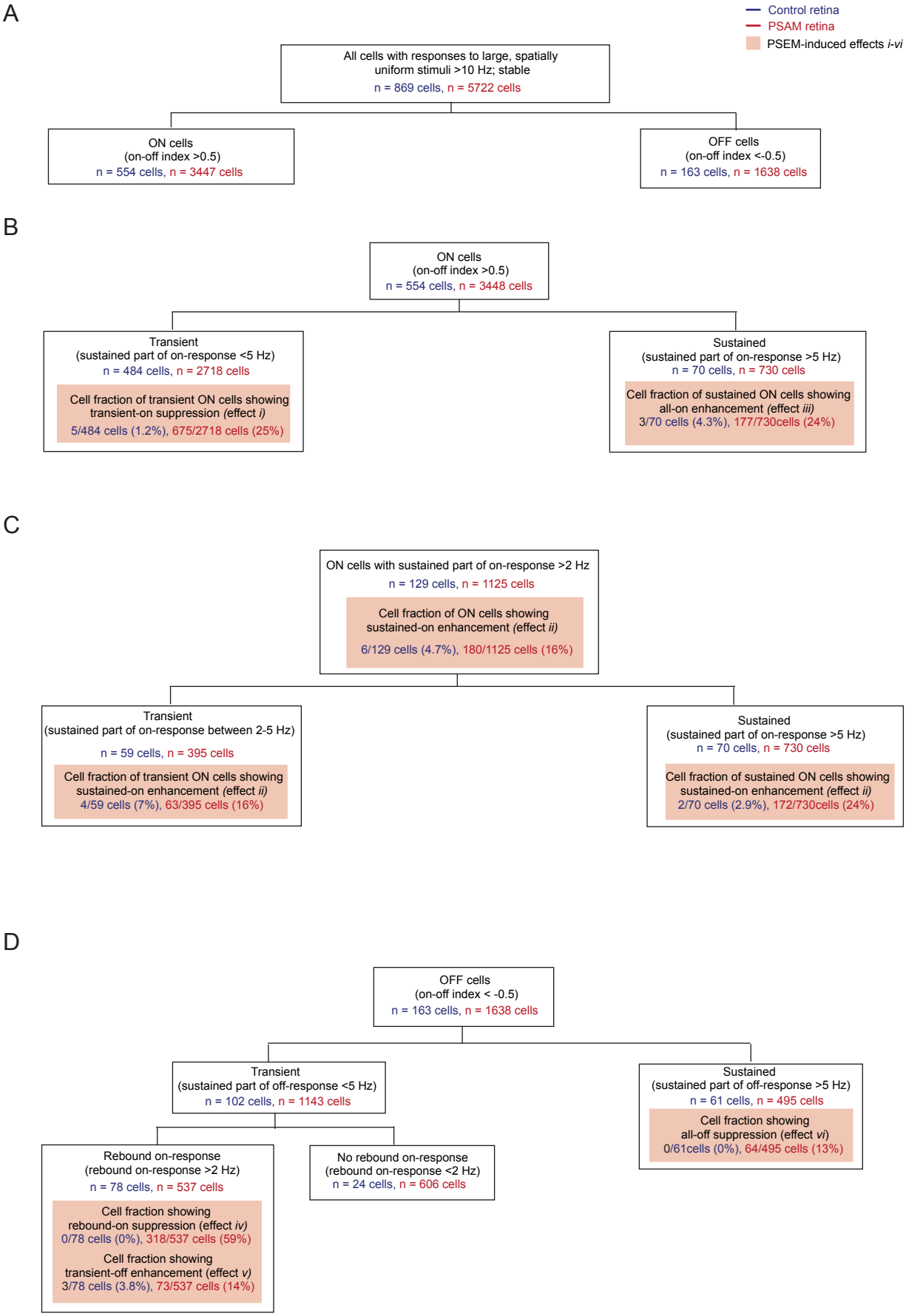

A
Neutral density filter
Projector
Camera Lens
5x Objective
Microelectrode array + retina
B
Microelectrode array with 26,400 electrodes
Electrode center-to-center distance 17.5 µm (>3,000 electrodes/mm2)
10 mm
2 mm
C
1.86 s
0.5 0.65 0.375 0.75 0.25 0.875 0.125 1 0
R*/s
8.8 x 10^4 1.10 x 10^5 6.62 x 10^4 1.32 x 10^5 4.42 x 10^4 1.54 x10^5 2.23 x 10^4 1.76 x 10^5 4.92 x 10^2
Michelson contrast
11% -25% 33% -50% 55% -75% 77% -99%
D
ON cells
OFF cells
Contrast = 11%
Contrast = 33%
Contrast = 55%
Contrast = 78%
Contrast = -25%
Contrast = -50%
Contrast = -75%
Contrast = -99%
Fraction of ON cells
Fraction of OFF cells
On-response (Hz)
Off-response (Hz)
Before
3 µM PSEM308
Wash

Figure S3

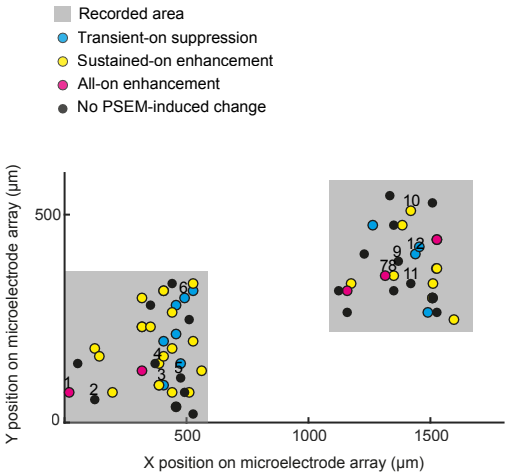

Before
PSEM
Wash
A
(i) Transient-on suppression
B
(ii) Sustained-on enhancement
C
(iii) All-on enhancement
D
(iv) Rebound-on suppression
E
(v) Transient-off enhancement
F
(vi) All-off suppression
50 Hz
1 s

# Figure S4

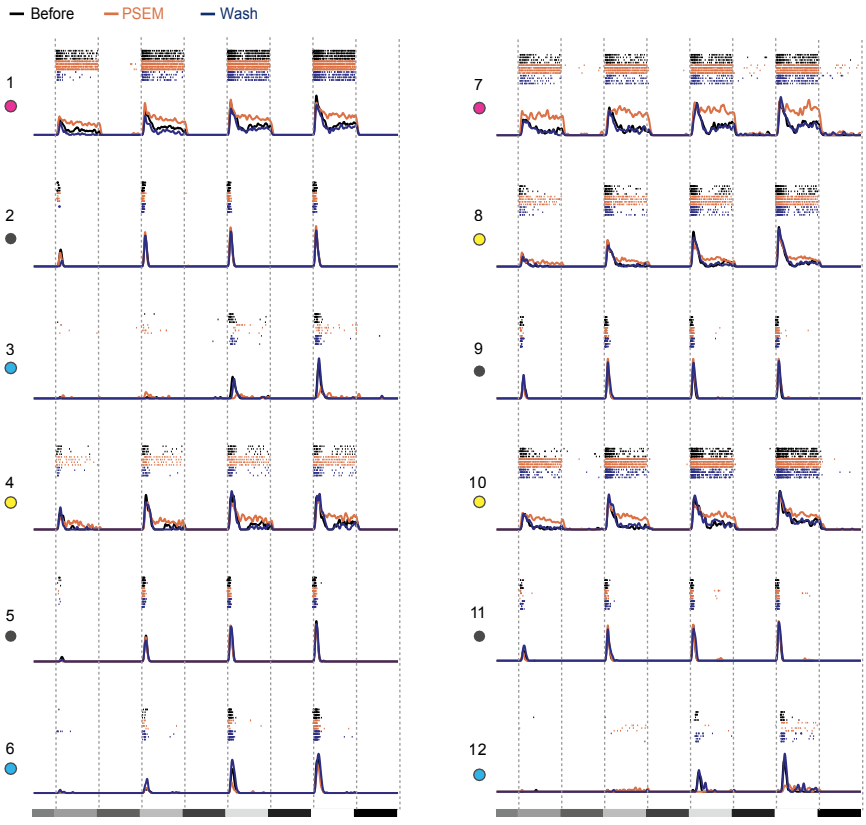

A
Control retina
PSAM retina
PSEM-induced effects i-vi
All cells with responses to large, spatially uniform stimuli >10 Hz; stable
n = 869 cells, n = 5722 cells
ON cells (on-off index >0.5)
n = 554 cells, n = 3447 cells
OFF cells (on-off index <-0.5)
n = 163 cells, n = 1638 cells
B
ON cells (on-off index >0.5)
n = 554 cells, n = 3448 cells
Transient (sustained part of on-response <5 Hz)
n = 484 cells, n = 2718 cells
Cell fraction of transient ON cells showing transient-on suppression (effect i)
5/484 cells (1.2%), 675/2718 cells (25%)
Sustained (sustained part of on-response >5 Hz)
n = 70 cells, n = 730 cells
Cell fraction of sustained ON cells showing all-on enhancement (effect iii)
3/70 cells (4.3%), 177/730cells (24%)
C
ON cells with sustained part of on-response >2 Hz
n = 129 cells, n = 1125 cells
Cell fraction of ON cells showing sustained-on enhancement (effect ii)
6/129 cells (4.7%), 180/1125 cells (16%)
Transient (sustained part of on-response between 2-5 Hz)
n = 59 cells, n = 395 cells
Cell fraction of transient ON cells showing sustained-on enhancement (effect ii)
4/59 cells (7%), 63/395 cells (16%)
Sustained (sustained part of on-response >5 Hz)
n = 70 cells, n = 730 cells
Cell fraction of sustained ON cells showing sustained-on enhancement (effect ii)
2/70 cells (2.9%), 172/730cells (24%)
D
OFF cells (on-off index < -0.5)
n = 163 cells, n = 1638 cells
Transient (sustained part of off-response <5 Hz)
n = 102 cells, n = 1143 cells
Sustained (sustained part of off-response >5 Hz)
n = 61 cells, n = 495 cells
Cell fraction showing all-off suppression (effect vi)
0/61cells (0%), 64/495 cells (13%)
Rebound on-response (rebound on-response >2 Hz)
n = 78 cells, n = 537 cells
Cell fraction showing rebound-on suppression (effect iv)
0/78 cells (0%), 318/537 cells (59%)
Cell fraction showing transient-off enhancement (effect v)
3/78 cells (3.8%), 73/537 cells (14%)
No rebound on-response (rebound on-response <2 Hz)
n = 24 cells, n = 606 cells

# Figure S5

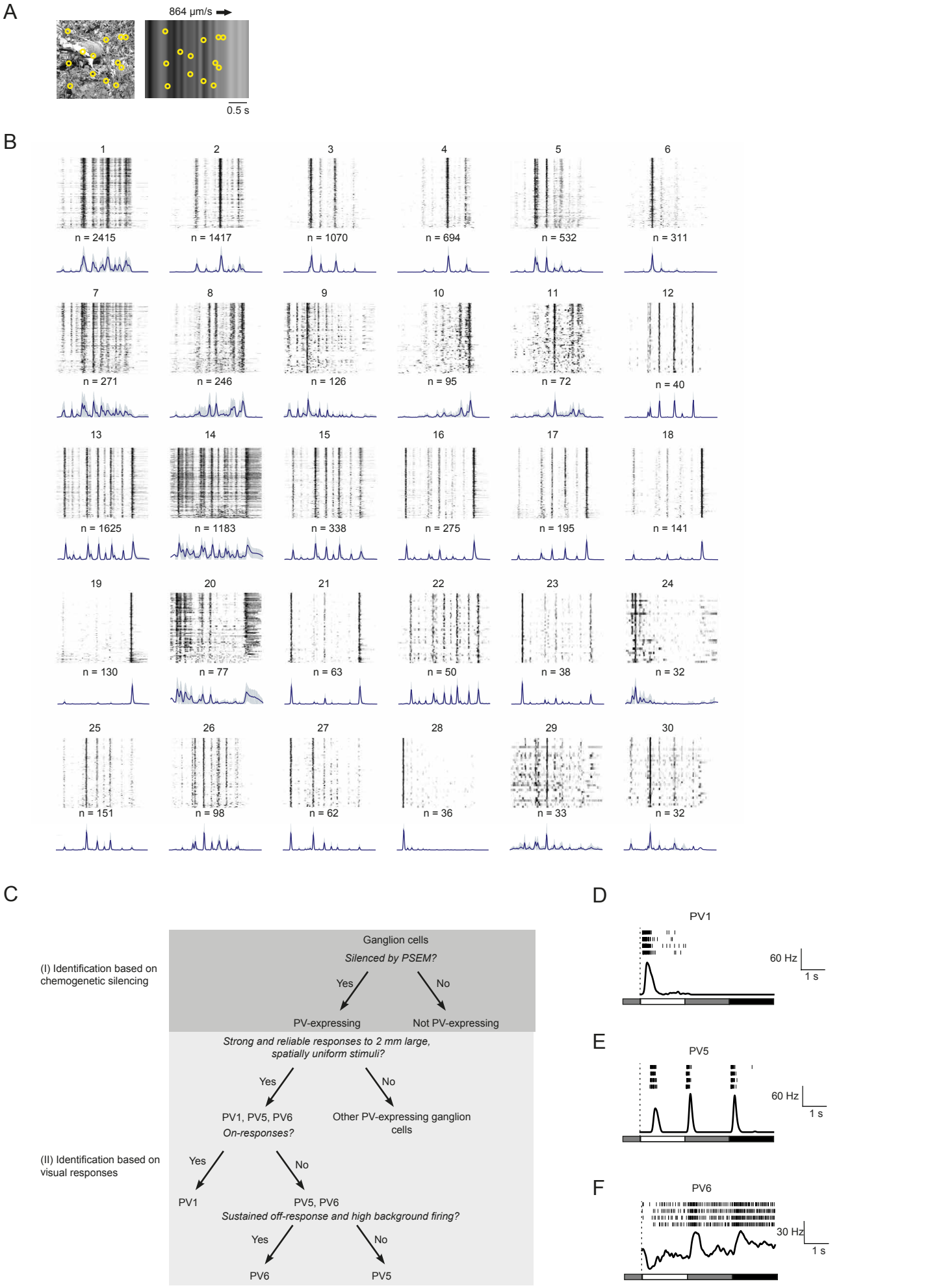
A


Recorded area
Transient-on suppression
Sustained-on enhancement
All-on enhancement
No PSEM-induced change
Y position on microelectrode array (µm)
X position on microelectrode array (µm)
0
500
500
1000
1500
1
2
3
4
5
6
7
8
9
10
11
12

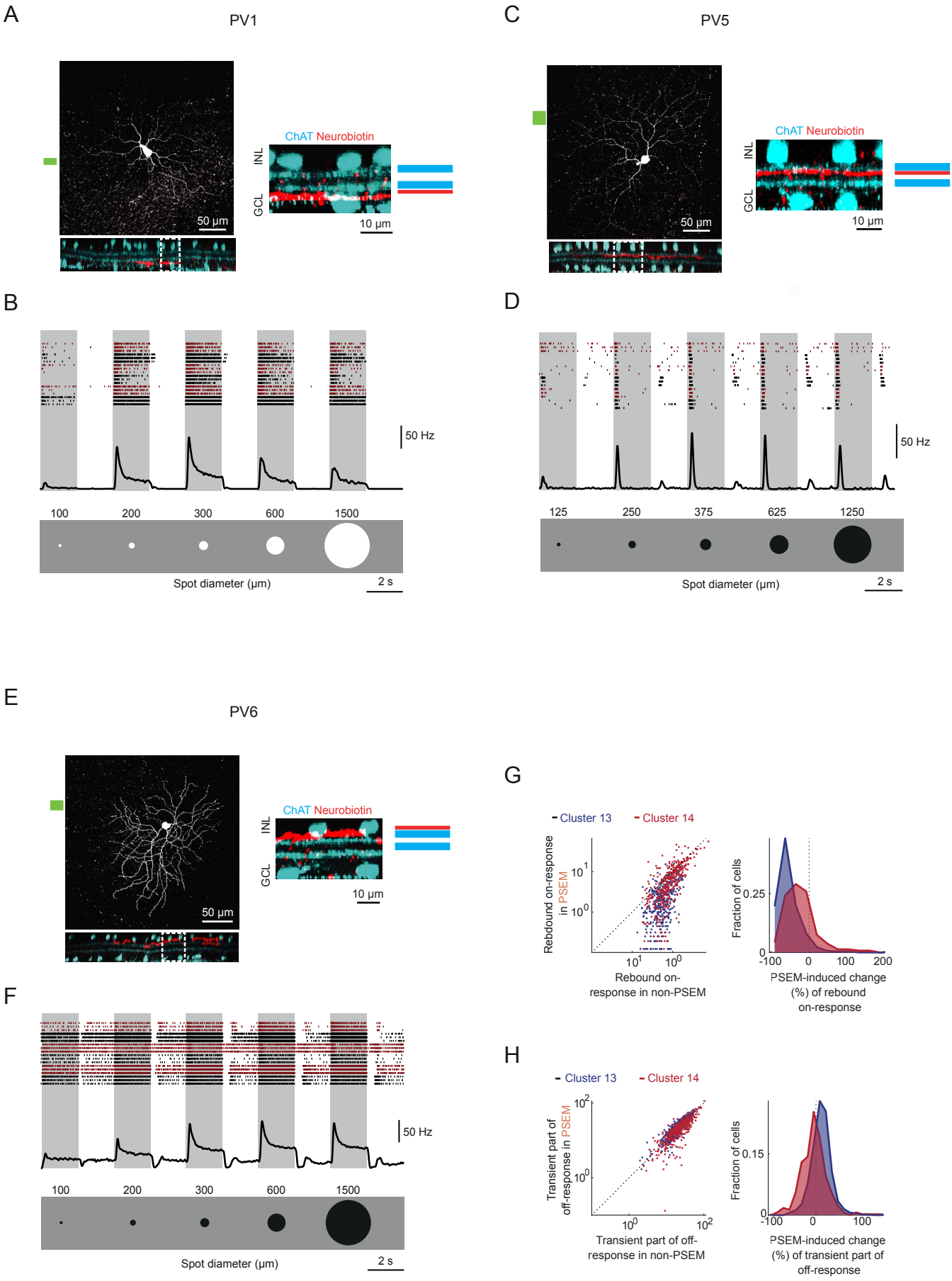
B


Before
PSEM
Wash
1
2
3
4
5
6
7
8
9
10
11
12

# Figure S6


A
864 µm/s
0.5 s
B
1
n = 2415
2
n = 1417
3
n = 1070
4
n = 694
5
n = 532
6
n = 311
7
n = 271
8
n = 246
9
n = 126
10
n = 95
11
n = 72
12
n = 40
13
n = 1625
14
n = 1183
15
n = 338
16
n = 275
17
n = 195
18
n = 141
19
n = 130
20
n = 77
21
n = 63
22
n = 50
23
n = 38
24
n = 32
25
n = 151
26
n = 98
27
n = 62
28
n = 36
29
n = 33
30
n = 32
C
(I) Identification based on chemogenetic silencing
Ganglion cells
Silenced by PSEM?
Yes
No
PV-expressing
Not PV-expressing
Strong and reliable responses to 2 mm large, spatially uniform stimuli?
Yes
No
PV1, PV5, PV6
On-responses?
Other PV-expressing ganglion cells
(II) Identification based on visual responses
Yes
No
PV1
PV5, PV6
Sustained off-response and high background firing?
Yes
No
PV6
PV5
D
PV1
60 Hz
1 s
E
PV5
60 Hz
1 s
F
PV6
30 Hz
1 s

# Figure S7


A
PV1
50 µm
ChAT Neurobiotin
INL
GCL
10 µm
C
PV5
50 µm
ChAT Neurobiotin
INL
GCL
10 µm
B
50 Hz
100
200
300
600
1500
Spot diameter (µm)
2 s
D
50 Hz
125
250
375
625
1250
Spot diameter (µm)
2 s
E
PV6
50 µm
ChAT Neurobiotin
INL
GCL
10 µm
F
50 Hz
100
200
300
600
1500
Spot diameter (µm)
2 s
G
Cluster 13
Cluster 14
Rebdound on-response in PSEM
Rebound on-response in non-PSEM
Fraction of cells
PSEM-induced change (%) of rebound on-response
H
Cluster 13
Cluster 14
Transient part of off-response in PSEM
Transient part of off-response in non-PSEM
Fraction of cells
PSEM-induced change (%) of transient part of off-response

# Figure S8

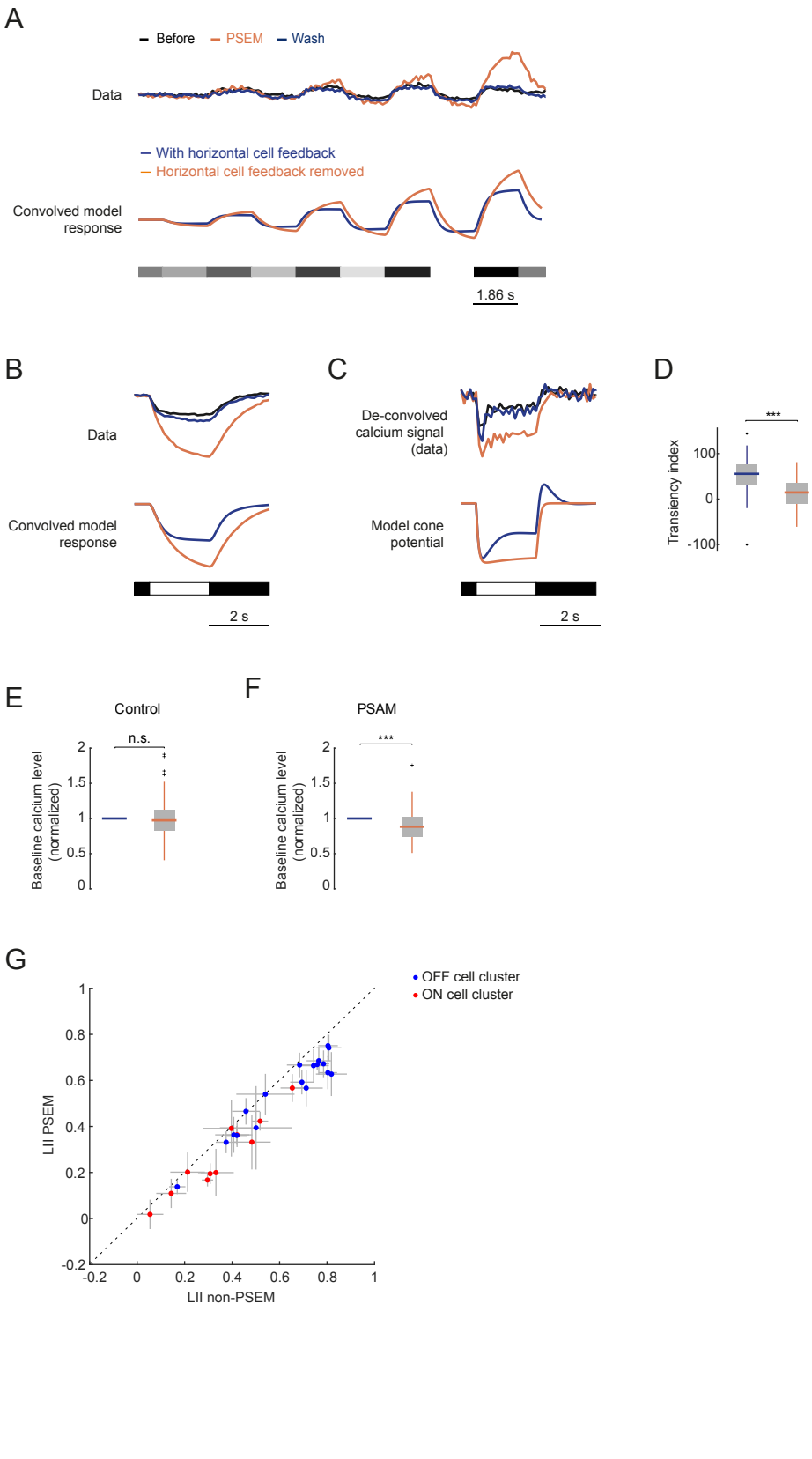

A
Before
PSEM
Wash
Data
With horizontal cell feedback
Horizontal cell feedback removed
Convolved model response
1.86 s
B
Data
Convolved model response
2 s
C
De-convolved calcium signal (data)
Model cone potential
2 s
D
***
Transiency index
100
0
-100
E
Control
n.s.
Baseline calcium level (normalized)
F
PSAM
***
Baseline calcium level (normalized)
G
OFF cell cluster
ON cell cluster
LII PSEM
LII non-PSEM

**Figure S1.** Related to **Figure 1.** (**A-B**) Confocal images of inner nuclear layer and outer plexiform layer (top view) of left (A) and right (B) retinas of *Gja10-Cre* mouse that was injected intravenously with PHP.B AAV Ef1a-DIO-PSAM. PSAM was labeled with bungarotoxin-Alexa 555 (magenta).

**Figure S2.** Related to **Figure 3.** (**A**) Schematic of experimental setup used for microelectrode array recordings. The light path for retinal stimulation is shown in yellow. The light was generated by a custom-built projector with two LEDs (395 and 505 nm) and focused on the microelectrode array by a camera lens and a 5× objective lens, after passing a neutral density filter (ND20). (**B**) Photos of packaged CMOS-based high-density microelectrode array. Left, overview of packaged chip. Right, zoom-in to electrode area. (**C**) Sequence of spatially uniform light steps of increasing and decreasing contrasts used for retinal stimulation. The sequence starts with grey background light and consists of eight light steps. Top, grey values ranging from 0 (black) to 1 (white). Center, light intensity given in photoisomerizations per rod per second (R*/s, measured and computed as described previously, Farrow et al., 2013). Bottom, Michelson contrast values. (**D**) Spiking activity of ganglion cells recorded with microelectrode arrays from retinas of non-injected *Gja10-Cre* mice ('control retinas', $n = 5$ mice) in response to spatially uniform light steps of different contrasts before, during and after application of 3 μM PSEM. Responses were quantified as the mean spike rate during the entire duration (1.86 s) of the light step. Top row: the distributions of on-responses in ON cells were not statistically different between PSEM and non-PSEM conditions, for all four contrast steps tested (KS test, *P*-values at each contrast: 0.40, 0.57, 0.44, 0.44). Bottom row: the distributions of off-responses in OFF cells were not statistically different between PSEM and non-PSEM conditions, for all four contrast steps tested (KS test, *P*-values at each contrast: 0.21, 0.32, 0.32, 0.72).

**Figure S3.** Related to **Figure 3.** (**A-F**) Spiking activity (top, raster plot, four repetitions per condition; bottom, spike rate, mean values of four repetitions) of ganglion cells recorded with microelectrode arrays in retinas of *Gja10-Cre* mice that were injected systemically with AAV Ef1a-DIO-PSAM. Six example cells are shown for each PSEM-induced effect (**Figure 3,** effects *i-vi*). The grey shaded rectangles below the response trace indicate the stimulus contrast.

**Figure S4.** Related to **Figure 3.** (**A**) The tree diagram shows the classification into 'ON cells' and 'OFF cells', based on the on-off index (STAR methods) in retinas of non-injected *Gja10-Cre* mice ('control retinas', blue) and in retinas of *Gja10-Cre* mice, which were injected systemically with AAV Ef1a-DIO-PSAM ('PSAM retinas', red). (**B-D**) The tree diagrams show the PSEM-induced effects in control retinas (blue) and PSAM retinas (red) for ON cells (B, C) and OFF cells (D). Cells were excluded from analysis if their mean spike rate during the respective time window before PSEM application was <2 Hz. ON and OFF cells were classified as transient or sustained based on their responses during the last 0.5 seconds of the light step: cells with <5 Hz activity were classified as 'transient', while cells with >5 Hz activity were classified as 'sustained'. Transient OFF cells were further categorized into cells with rebound on-response (rebound on-response >2 Hz) or without rebound on-response (rebound on-response <2 Hz). For each of the six PSEM-induced effects (*i-vi*, **Figure 3**), the fraction of

PSEM-affected cells (red areas) was computed based on the distribution of PSEM-induced change of response values in control retinas (STAR methods).

**Figure S5.** Related to **Figure 3.** (**A**) The plot shows the spatial locations of ganglion cells exhibiting different PSEM-induced effects (blue, yellow, magenta), or no PSEM-induced response change (black), on a microelectrode array in an example PSAM retina. The cells were recorded simultaneously. The grey rectangles indicate areas with active electrodes. (**B**) Spiking activity (top, raster plot, four repetitions per condition; bottom, spike rate, mean values of four repetitions) of the twelve example cells whose locations are shown in (A). The grey shaded rectangles below the response traces indicate the stimulus contrast. The numbering and color-code of the spots below the numbers correspond to the numbering and color-code of (A).

**Figure S6.** Related to **Figure 5.** (**A**) Left, schematic of a population of ganglion cells (yellow circles) exposed to a frame of natural movie (background image). Stimulation with natural movies poses the challenge that each cell of the population samples from a different movie patch, depending on its retinal location. Right, scheme of the same cell population exposed to a frame of the barcode stimulus (background image). Cells distributed vertically along the bars are exposed to the same stimulus. Since the stimulus is drifting across the retina at a constant speed (indicated by black arrow), horizontally distributed cells are also exposed to the same stimulus, just shifted in time. (**B**) Spiking responses of ganglion cells recorded with microelectrode arrays in response to the barcode stimulus. The figure shows raster plots (top) for all cells within each of the 30 clusters. For each cluster, responses were aligned with respect to cross-correlation with a randomly chosen cell of the cluster, and sorted by correlation with the cluster average in descending order. The spike rates of each cluster are shown below the raster plots. Curves show mean values, shaded areas represent ± s.d., 'n' denotes the number of ganglion cells per cluster. (**C**) Schematic of the decision tree to identify PV1, PV5, and PV6 cells on microelectrode arrays in retinas of *PV-Cre* mice injected with AAV ProA5-DIO-PSAM. Identification was performed in two steps: In a first step, PV ganglion cells were identified by determining those cells whose spiking activity was reversibly reduced by PSEM application. In a second step, PV1, PV5 and PV6 cells were selected by choosing cells with strong and reliable responses to large stimuli and the cells were further categorized into PV1, PV5, and PV6 cells based on their responses to light steps of different contrasts. (**D-F**) Spiking activity of three examples of chemogenetically labeled cells in response to spatially uniform light steps of different contrasts (grey shaded areas below response traces). Based on the previously characterized responses of PV ganglion cells (Farrow et al., 2013; Viney, 2010), these chemogenetically labeled cells were identified as PV1 (D), PV5 (E) and PV6 (F) cells.

**Figure S7.** Related to **Figure 6.** (**A**) Left, confocal image of a large, GFP-labeled ON cell filled with neurobiotin recorded in *PV-Flp* × *Flp-GFP*-reporter mice. Top panel shows maximum-intensity projection of filled cell (white); the green rectangle indicates the range and position of the stack shown below. Bottom panel shows side view of filled cell (red) overlaid on an antibody staining of ChAT-expressing cells (cyan). Dashed white rectangle indicates the area shown on the right. Right, zoom-in on side view. Scheme on the right indicates the two bands

in the inner plexiform layer labeled by the ChAT antibody (cyan) and the dendrite of the neurobiotin-filled ganglion cell (red). GCL: Ganglion cell layer; INL: Inner nuclear layer. (**B**) Spiking responses of large, GFP-labeled ON cells recorded in *PV-Flp* × *Flp-GFP*-reporter mice. Spike raster plots of individual cells (top, three stimulus repetitions per cell; six example cells are shown in alternating black and red colors) and spike rate averaged across cells (middle) in response to flashed spot stimuli of different sizes (spot size and contrast indicated at bottom). The cells were identified as PV1 cells based on previous literature (Farrow et al., 2013; Viney, 2010). (**C-F**) As in (A-B), but for large, GFP-labeled OFF cells. Based on previous literature (Farrow et al., 2013; Viney, 2010), the cells were identified as PV5 (C-D) and PV6 cells (E-F). (**G-H**) Left, scatter plots of ganglion cell responses in non-PSEM (x-axis) and PSEM (y-axis) conditions. Data points represent individual cells of cluster 13/15 (blue) and cluster 14 (red). Responses were quantified as in Figure 6G-H, J-K. Dashed line indicates the unity line. Right, distributions of PSEM-induced relative changes (%) of responses for the data shown in the left panel.

**Figure S8.** Related to **Figure 8.** (**A**) Top, example responses of a single cone axon terminal to a sequence of contrast steps. Curves show the mean ΔF/F values of five stimulus repetitions before, during, and after PSEM application. Middle, model cone calcium signals to the same stimulus in the presence and absence of horizontal cell feedback. Curves were obtained by convolving the model cone potential with an exponential filter reflecting the temporal characteristics of the calcium indicator. For both data and model traces, the baseline level at the beginning of the response was subtracted. Bottom, the grey shaded rectangles indicate the stimulus contrast. (**B**) Top, average responses of cone axon terminals to a contrast step before, during, and after PSEM application. Curves show ΔF/F values, average over three stimulus repetitions and 58 cone terminals from Figure 2 that showed a PSEM-induced response increase of at least 0.3 ΔF/F. Middle, model cone calcium signals to the same stimulus in the presence and absence of horizontal cell feedback. Curves were obtained by convolving the model cone potential with the same filter as in (A). For both data and model traces, the baseline level at the beginning of the response was subtracted. Bottom, the grey shaded rectangles indicate the stimulus contrast. (**C**) Top, average cone responses from (B) deconvolved with the same filter used to convolve the model responses in (A, B). Middle, model cone potential in response to the same stimulus as in (B). (**D**) Box-plot representation of the distribution of the transiency index (%-change of cone response amplitude 200-500 ms and 500-800 ms after contrast step) in non-PSEM (blue) and PSEM (orange) conditions for the same cone terminals for which the average responses were shown in (B, C). (**E-F**) Box-plot representation of the distributions of the baseline calcium level in non-PSEM (blue) and PSEM (orange) conditions measured by performing calcium imaging of cone axon terminals in whole-mount retinas of control (E, *Gja10-Cre* mice injected with AAV ProA1-GCaMP6s) and PSAM (F, *Gja10-Cre* mice injected with AAV ProA1-GCaMP6s and AAV Ef1a-DIO-PSAM) mice. The value of each cone was normalized to the non-PSEM condition. In box-plot representations of panels (D-E), bottom and top whiskers indicate minima and maxima of data points not considered as outliers; bottom and top of boxes indicate first and third quartiles; central line indicates the median; black crosses indicate outliers (more than 1.5 times the

interquartile range away from the top or bottom of the box). ***: $P < 0.001$, n.s.: $P >= 0.05$. (**G**) Scatter plot of LII values measured in ganglion cells ($n = 1341$ cells) in non-PSEM (x-axis) and PSEM (y-axis) conditions. Data points represent individual functional clusters obtained using the barcode stimulus. Clusters in which cells responded stronger to light increments (ON cell cluster) are shown in red; clusters in which cells responded stronger to light decrements (OFF cell cluster) are shown in blue. Only clusters with at least 8 cells ($n = 27$ clusters) are shown. Grey lines indicate the s.e.m. Dashed line indicates the unity line.

**Table S1.** Related to **Figure 2, 3, 4, 6, 8.** Quantification and statistical analysis.

| | Figure | Quantity | Test | P-value | Condition 1 | Value 1 | Number of cells | Condition 2 | Value 2 | Number of cells |
|---|---|---|---|---|---|---|---|---|---|---|
| a | 2F | LII (mean ± s.e.m) | sign test | 0.21 | non-PSEM | 0.28 ± 0.02 | 228 | PSEM | 0.30 ± 0.03 | same cells |
| b | 2F | LII (mean ± s.e.m) | sign test | $9.0\times10^{-43}$ | before NBQX | 0.28 ± 0.03 | 228 | NBQX | −0.020 ± 0.003 | same cells |
| c | 2L | LII (mean ± s.e.m) | sign test | $9.2\times10^{-54}$ | non-PSEM | 0.25 ± 0.01 | 256 | PSEM | −0.00090 ± 0.003 | same cells |
| d | 2L | LII (mean ± s.e.m) | sign test | 0.29 | before PSEM | 0.24 ± 0.01 | 256 | after washout of PSEM | 0.26 ± 0.01 | same cells |
| e | 2L | LII (mean ± s.e.m) | sign test | $5.3\times10^{-11}$ | PSEM | −0.00090 ± 0.003 | 256 | NBQX | −0.032 ± 0.008 | same cells |
| f | 3G | PSEM-induced change (%) (median ± s.e.m) | MWU | $1.9\times10^{-30}$ | control retina | 0.75 ± 0.9% | 484 | PSAM retina | −14 ± 0.7% | 2,718 |
| g | 3H | PSEM-induced change (%) (median ± s.e.m) | MWU | $1.9\times10^{-7}$ | control retina | 7.2 ± 5% | 129 | PSAM retina | 37 ± 3% | 1,125 |
| h | 3I | PSEM-induced change (%) (median ± s.e.m) | MWU | $9.7\times10^{-4}$ | control retina | 1.9 ± 2% | 70 | PSAM retina | 19 ± 2% | 729 |
| i | 3J | PSEM-induced change (%) (median ± s.e.m) | MWU | $8.1\times10^{-37}$ | control retina | −3.0 ± 3% | 78 | PSAM retina | −63 ± 1% | 537 |
| j | 3K | PSEM-induced change (%) (median ± s.e.m) | MWU | $5.3\times10^{-4}$ | control retina | 5.9 ± 2% | 78 | PSAM retina | 14 ± 1% | 537 |
| k | 3L | PSEM-induced change (%) (median ± s.e.m) | MWU | $8.3\times10^{-4}$ | control retina | 5.1 ± 2% | 61 | PSAM retina | −1.0 ± 1% | 495 |
| l | 4D, effect i | response range (median ± s.e.m) | sign test | $6.5\times10^{-118}$ | non-PSEM | 0.92 ± 0.007 | 675 | PSEM | 0.45 ± 0.009 | same cells |
| m | 4D, effect ii | response range (median ± s.e.m) | sign test | $4.7\times10^{-19}$ | non-PSEM | 1.2 ± 0.02 | 180 | PSEM | 1.8 ± 0.1 | same cells |
| n | 4D, effect iii | response range (median ± s.e.m) | sign test | 0.13 | non-PSEM | 0.79 ± 0.02 | 177 | PSEM | 0.78 ± 0.03 | same cells |
| o | 4D, effect iv | response range (median ± s.e.m) | sign test | $4.1\times10^{-68}$ | non-PSEM | 0.96 ± 0.02 | 318 | PSEM | 0.10 ± 0.008 | same cells |
| p | 4D, effect v | response range (median ± s.e.m) | sign test | $1.4\times10^{-4}$ | non-PSEM | 0.57 ± 0.02 | 73 | PSEM | 0.69 ± 0.04 | same cells |
| q | 4D, effect vi | response range (median ± s.e.m) | sign test | $2.0\times10^{-8}$ | non-PSEM | 0.46 ± 0.02 | 64 | PSEM | 0.30 ± 0.02 | same cells |
| r | 6E | PSEM-induced change (%) (median) | MWU | $5.7\times10^{-4}$ | control retina | 1% | 28 | PSAM retina | 41% | 638 |
| s | 6G | PSEM-induced change (%) (median) | MWU | $3.2\times10^{-22}$ | control retina | 3% | 42 | PSAM retina | −62% | 444 |
| t | 6H | PSEM-induced change (%) (median) | MWU | 0.0033 | control retina | 3% | 55 | PSAM retina | 12% | 675 |
| u | 6J | PSEM-induced change (%) (median) | MWU | $4.3\times10^{-10}$ | control retina | 8% | 33 | PSAM retina | -29% | 375 |
| v | S7A | PSEM-induced change (%) (median) | MWU | $4.3\times10^{-10}$ | cluster 13/15 | −62% | 422 | cluster 14 | -29% | 375 |
| w | 6K | PSEM-induced change (%) (median) | MWU | $3.1\times10^{-4}$ | control retina | 5% | 35 | PSAM retina | -4% | 454 |
| x | S7B | PSEM-induced change (%) (median) | MWU | $3.1\times10^{-4}$ | cluster 13/15 | 12% | 675 | cluster 14 | -4% | 454 |
| y | 8D | normalized inhibition (mean ± s.e.m) | paired *t*-test | 0.012 | non-PSEM | 0.99 ± 0.001 | 3 | PSEM | 1.1 ± 0.01 | same cells |
| z | 8E | PSEM-induced change (%) (mean ± s.e.m) | MWU | $9.7\times10^{-54}$ | fast-responding | −0.2 ± 1% | 830 | slow-responding | −21 ± 0.8% | 1,888 |
| aa | 8F | PSEM-induced change (%) (mean ± s.e.m) | MWU | $3.9\times10^{-27}$ | ON cells | −21 ± 0.8% | 1,888 | OFF cells | 2.5 ± 2.2% | 333 |
| bb | 8G | baseline spike rate (Hz) (mean ± s.e.m) | sign test | $9.1\times10^{-16}$ | non-PSEM | 2.4 ± 0.5 Hz | 177 | PSEM | 7.1 ± 0.8 Hz | same cells |
| cc | 8G | baseline spike rate (Hz) (mean ± s.e.m) | sign test | $1.1\times10^{-8}$ | non-PSEM | 12 ± 1 Hz | 64 | PSEM | 6.5 ± 0.8 Hz | same cells |
| dd | S8D | transiency index (%) (mean ± s.e.m.) | paired t-test | $5.3\times10^{-7}$ | non-PSEM | 51 ± 5% | 58 | PSEM | 12 ± 4% | same cells |
| ee | S8C | normalized baseline fluorescence (median ± s.e.m) | sign test | 0.57 | non-PSEM | 1 ± 0 | 113 | PSEM | 0.97 ± 0.02 | same cells |
| ff | S8D | normalized baseline fluorescence (median ± s.e.m) | sign test | 0.57 | non-PSEM | 1 ± 0 | 111 | PSEM | 0.88 ± 0.02 | same cells |
| gg | 8F | LII (mean ± s.e.m) | sign test | $5.8\times10^{-13}$ | non-PSEM | 0.53 ± 0.02 | 447 | PSEM | 0.45 ± 0.02 | same cells |

**Table S2.** Related to **Figure 3.** Overview of the six perturbation-induced effects (*i-vi*).

| Number | Name | Cell category | Polarity of response | Part of response | Direction of effect | Effect on response range |
|---|---|---|---|---|---|---|
| *(i)* | transient-on suppression | transient ON cells | on-response | transient part | suppressive | compressed |
| *(ii)* | sustained-on enhancement | transient and sustained ON cells | on-response | sustained part | enhancing | expanded |
| *(iii)* | all-on enhancement | sustained ON cells | on-response | entire response | enhancing | - |
| *(iv)* | rebound-on suppression | transient OFF cells with rebound response | on-response | rebound response | suppressive | compressed |
| *(v)* | transient-off enhancement | transient OFF cells with rebound response | off-response | transient part | enhancing | expanded |
| *(vi)* | all-off suppression | Sustained OFF cells | off-response | entire response | suppressive | compressed |

**Table S3.** Related to **STAR METHODS.** Sequences of cell-type specific promoters used in this study.

| | |
|---|---|
| ProA1 | AGAGGCAGGCCGAGTTTGAGGCCAGCCTGGTCTACACAGGCGTTCTAGGAGAACCTGTCTCATATGCACATGGGCCTGGGATTACACATACAACTGCA<br>ATGGCAGCACTTGGAAAGCGGAAGCAGGAGAATCGGAATTTCACACTCATCCTTCATTATAGAAGTCCAAACCTGTGCTAAGCTACTTGGACATCGCTAA<br>AAAACAGCAAAAATCTTTCTAGGAATTGCCAATGTATACACACCAAGTTGTATTTTTGTAGGGCAGACTTTTCCAACTTGCCAGATGATAATAATCATTTAT<br>ATTAGCTACATTTCAGGCTCCAGAATTAACACTGTTACTGAAATGTATAGGTTCTAAAACATACCATTTCCAAATATTTTAAAGGATTAACATTTTTGAAAAG<br>CATGTGATCTTCCAACCATATTTTAGGGAACAGACATAAGAAGTAGGCAAGTTTGGGAAGAAACAGTTCCTGAGGGCATTTCTTCCCAACCTTGAATGCC<br>CTGTGGGTTAACTGAGGTCTTGGTAAAATGTAGATTATTTACTGGACTTTTTGAACTGAGAGTGCATTTCTAACAAAACTCCAGGGTATGTGGTCCTTGCA<br>TTACATATGGGGTAGCAACATTCTAAAGCAGTGTTTTTCAACCTGTGGATCAAGACCCACAGAAGTCACATAGCAGATATCCTGCCTATTAGATATTTACA<br>TTAAGATTCAGAGCAGTAGCAGAATAGGAGTCATCCCAACCTGAGGAACTGCATCAGAGTCCCAGCATCAGGAAGGGTGAGAGCCACTGAGCTAAAGTC<br>CTCTAGGTGAGGGGGCTGCCCCGGAAAGACTCATTTAAATGAAACCACTGACACAGAGAGCTGACAGATGAGGTGGGTTCCGTGTCTGTGAGGCTCTG<br>CTGGTCGTCTCCTCACTCCCATGGAAGAACCACCGAGATGAGGGCGAGGGGCAGAGCTAACCCAGCCTCTAAGTAGGCAGAGTCTAGTGTCCAGCTGC<br>CCAAGGAAGAAGTTTGCTGTGTGAGGTGGCCCTGATGTCCGCACACACAAAATGCCAGTGAAGTCTACTTGACCAAGTGAAGCTGGTGTGGAATGGGAA<br>GAAGCACACACAGTCAGTCTCTCTGCACACACTCTGTCCTTCACTTCTTCACTTACCAGAGATTTGATGAGAACCTACTAGCAGATCAGATTTGATCCCTG<br>AGTGGAAAAAACGTACAGTGGGAGATAAAAGAGGAAAACAACGGATCTGAGTTTGAGGTTAGCCTAGTCTGAGCAAGCCGGATACACAGTAAGACCCTG<br>TCTCACATACATCCACTCGCACGCGCGCGCACACAAACACACACACACACACACACACACACACACACACACACATCGTGCTAAGGACAAGATAG<br>GCATCCTGAGAGATGAGCCAGGACAAAGAACCAGTAATAGCTCCTGGAGCAGCACATCTGTTTTGCCAGGATTATCCCTTGGATCTCTTAAAACCGAGA<br>CCTTGTAATCTGAAGACTCAACTTGGGCTGTACCCTTAACCTTCAGCTCTATGATGCAAGTGAGTCCACAGGACCGGAGGCTTTGAGATGAGCTTTTCAG<br>AAGGGAGGAGTTGGCCGCTTGCTCCCAGAGCTCCAGCACCTGCATTCTTCTGGCTATGTCAGAAGCCAGATCATTTCCCTCGTTAAAAACAAAAACAAAA<br>AAACAAACAAACAAAATGTTAGTCTTTGCCCTTTATCTGCCTGGCAAAGCTTTTAATTGGCTTGATCTGTCATTCCGCTAGACATAAAGGGGACAATCCCC<br>GGATTAGGAAGGAGCTCTCCAGCTCGGGTAAGGAGTCTCAAGGCAAGGTAGGCAAGCACCACCGGTCCGCACTCTCGCCCAGCTTTTACGGGAAGAAG<br>AGAATGTTACTCTATCCTAACATATTTTTCCTTTTCCTCTATCTCACAGATAGGAAAAATTTAAGAGCCAGAGGGAACGTCCCTTCTCAGAGGAGACAGCA<br>GAA |
| ProA5 | GGTGCCCAGGCAGTGGGAGCAGGGCTGACCAGAGTTCTGCAGAGATTGCCTGGAGGCCTTCCTGGAAGAAGAGATCCTGGCACCGCACAAAGAGAAG<br>CACAGGCTTTCCAGGGCTGAGGAGAGGGAGGTCAAGTGAGGCCCAGGTGCCCCTGCCTGAGCCTGTGTCCCCAGAAACCTCCTCTCCCTCTCATCACC<br>CCCACATCCTCCCTGCCACTCCCCGCAGCTCCCTGTGGCCAAGTGCACTGCAGCACTCGGCTCTGCTCCACAAACGGTCTGCTCCACTCCAGGAAGGC<br>CACCTCCTCCCCCCCCCCCCACCTCCGGCTGTCACCACTCACCGCTCTAGCCTCCAGGGGGTGGGGACCCCAGAGCTGGACACACCCCATCGAAGCC<br>CCACAGCTCAGCCAGCCGGACAGACTCACGGTCGGACTCAAGACCCCGGAGCCCTGAGGTGGGCAGCGCGCCAGGGTTCCTCGCAGCCTCTTCAAGG<br>TCAGTGCAAGTTGGGTGTGCAGCCCTTTGGAGCCTTTGAGGTCTGTGGGACTCAGCTCAGAACCCTCATCCCAGACCACGAGCCCCAAGGTGGGCTTC<br>ACTCCAGGTGCACCTGAGCCAAGTGCTGGGCAAAGGGCGCCCAGGTCCACAGTCAGCACAGGTCCAGGGGTCCATCAGGAGGGGCCCCAGGCTGGG<br>GGCCAACCCCTTGCTGAGGCCTCTTTGGGGACACTCCCCACCGGCCATGGGGAGCTAAAATTGGAAAGTGGCGAGTGGGAGGCAGCTGACACAGCTA<br>TTTTGTGCGCTCTTCATCCGCTCCGGTTTCACTCTCCTGCTCCACTAACCTGATCCTGTGCTTCCCTCCCCCACCCTGCCGATGAAGAGGTGTCTCAGCC<br>CTCCAGCCACAGTGCAGAGGCTGCTCAGGAGGGCCAGGCCGGGAGCGAGCAGGGCCAGCGTGGTCTGGTCTGAGCCGGGACTCACCAGGAGCACCT<br>GCCCTTCAGAGAAGCTCACTGGATGGCCTCCCGGGTCCCTGACCCTTTGTGACCCACACCTCTCTGTCAGTGTAGCAAGGAGCGGCCTCCCAGAGCCC<br>CAACTACAGGGCTGGAGGAGACAGATCTGCAACTGGGAGATCTTGGGTTGGGAGAGATGGGGTGACCCTACCCATCTCCAAAAGGGCACTGCACCGTG<br>TTCCCCTTTCCCTCGGTTCCAGGTCTGGACCTAAGCAACCACTGGAAGACTGGCGGCCAGGCTGAAGAGGGTGGGAGGGGCTTAGGTACTGGCCCAG<br>ACCCCAGGGATGGCCCAGCAGGGTAGCCAGAGGGAGTGACCAGACACATCCTGGACTTGATACCAGTCAGCACCTTGGACAGCAGCCAGCACCCTCC<br>CAGTTGCTGCCTGGCCCTGCCTGGTCCAGCTCTGGCCACTCTGGGGCCTCAAAGAGCCCAACATCCAGCCTGCAGCAAGAGCTTAGACTACACAGCAC<br>TTCAAGGGGGACAGTGGGTGAACACAGGCAGGGACCTGAGATAAAACAGACTCACGGCTTGGCGGAGGAATGGAGTCAGCAGAGCCCGGAGTTGAGC<br>GAGTCTGGGAAGTTAGTGCTAGAGGAGTTCACGGGATCTCAGGGGACCTCGTGGGCAGGGCTTTGCTGAGGTTAAGAGAGGCTCACTGTGAGACGGG<br>AGAACTGACAGAGTCTTCCACCATGGGAAAGACCCCATGGTTGGGGAAGTCTTGCAGGAACAGTTTGGTGTCCCAAACTTGTCAGCCCATCAGAGAGGT<br>ATGAAGGAGAGGAAGCTAGTCTGTGCGAAGTCTGGGCTTTGGAGAATCTTCAAAGGAAGCAAGATTGAGAGCTGCAGAGGAAAGGAAGAAGGTGTCTG<br>GGTGTGTTGGGGGGGGTAGATTTACTGACAGCATCCCCAGGGGATGGCTGAGTGGACCAGTCTCCTCAGAGGGTCCACCAGGGGAGGCGAGGCAAG<br>GCTGGGACTGGGGGTTCTCACTCATGCTTCTCCTTCAGCCCTCTCCAGGCC |