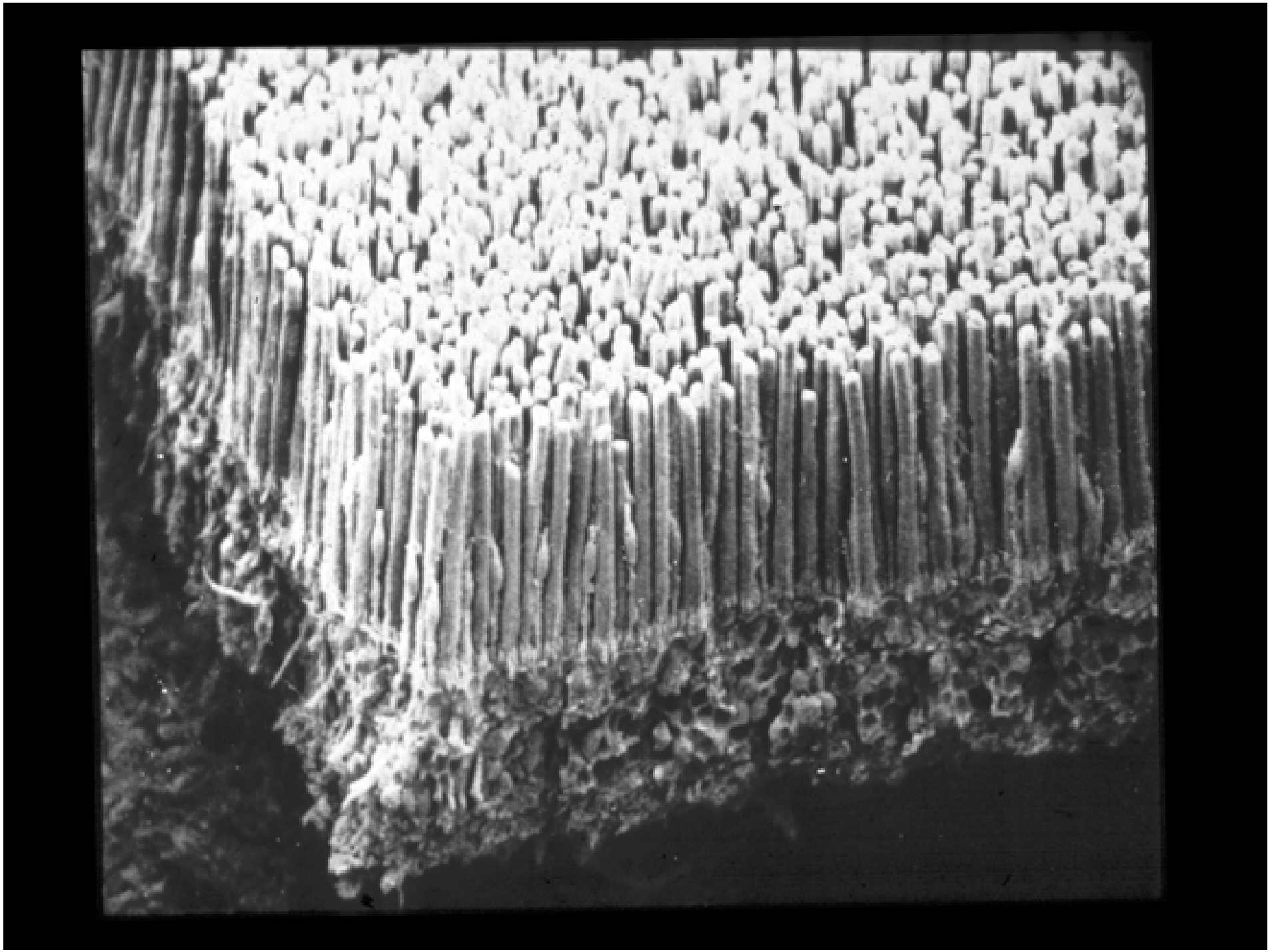
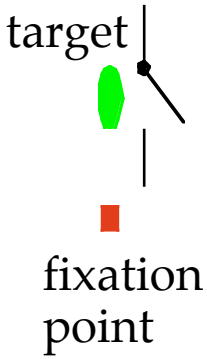
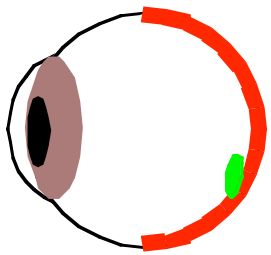
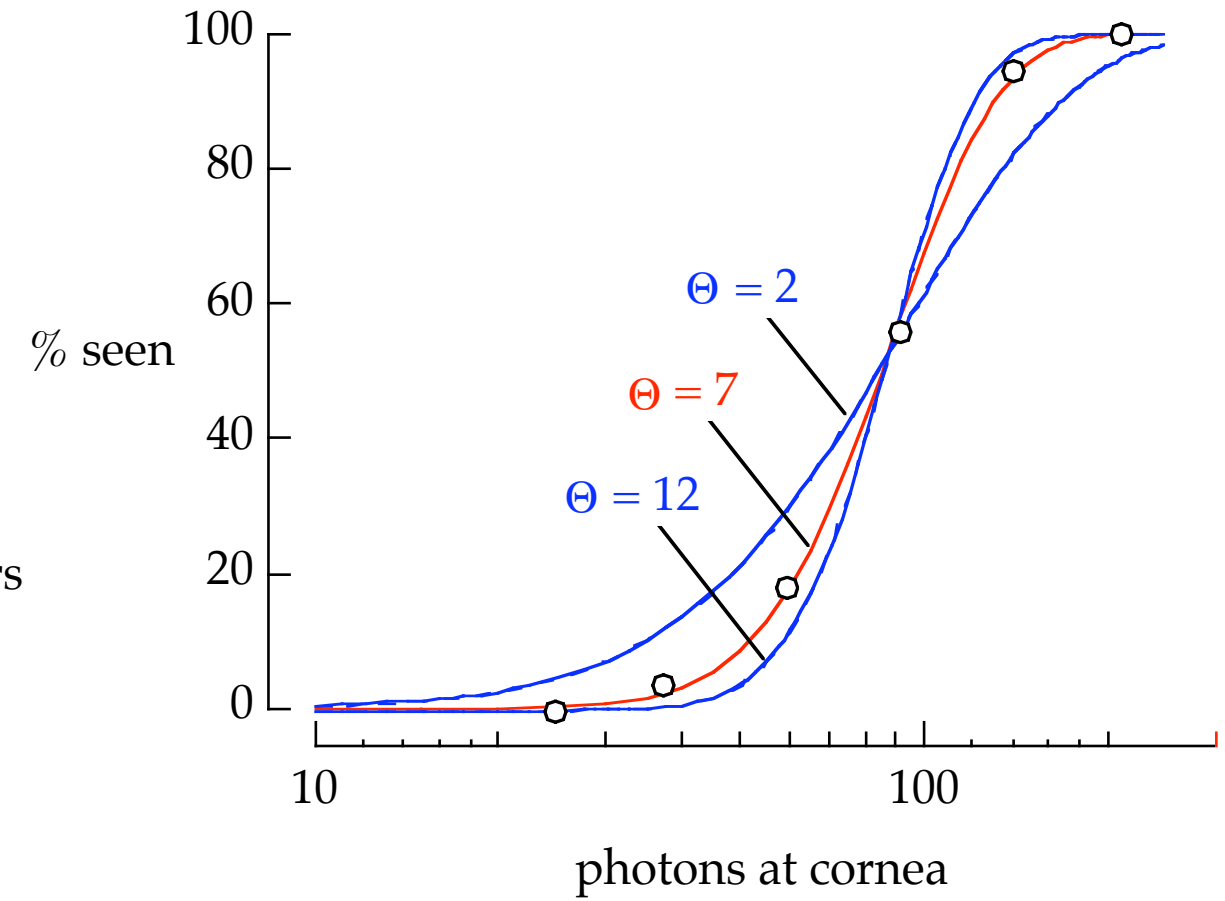


FREQUENCY OF SEEING EXPERIMENTS
(Hecht, Shlaer and Pirenne, 1942)



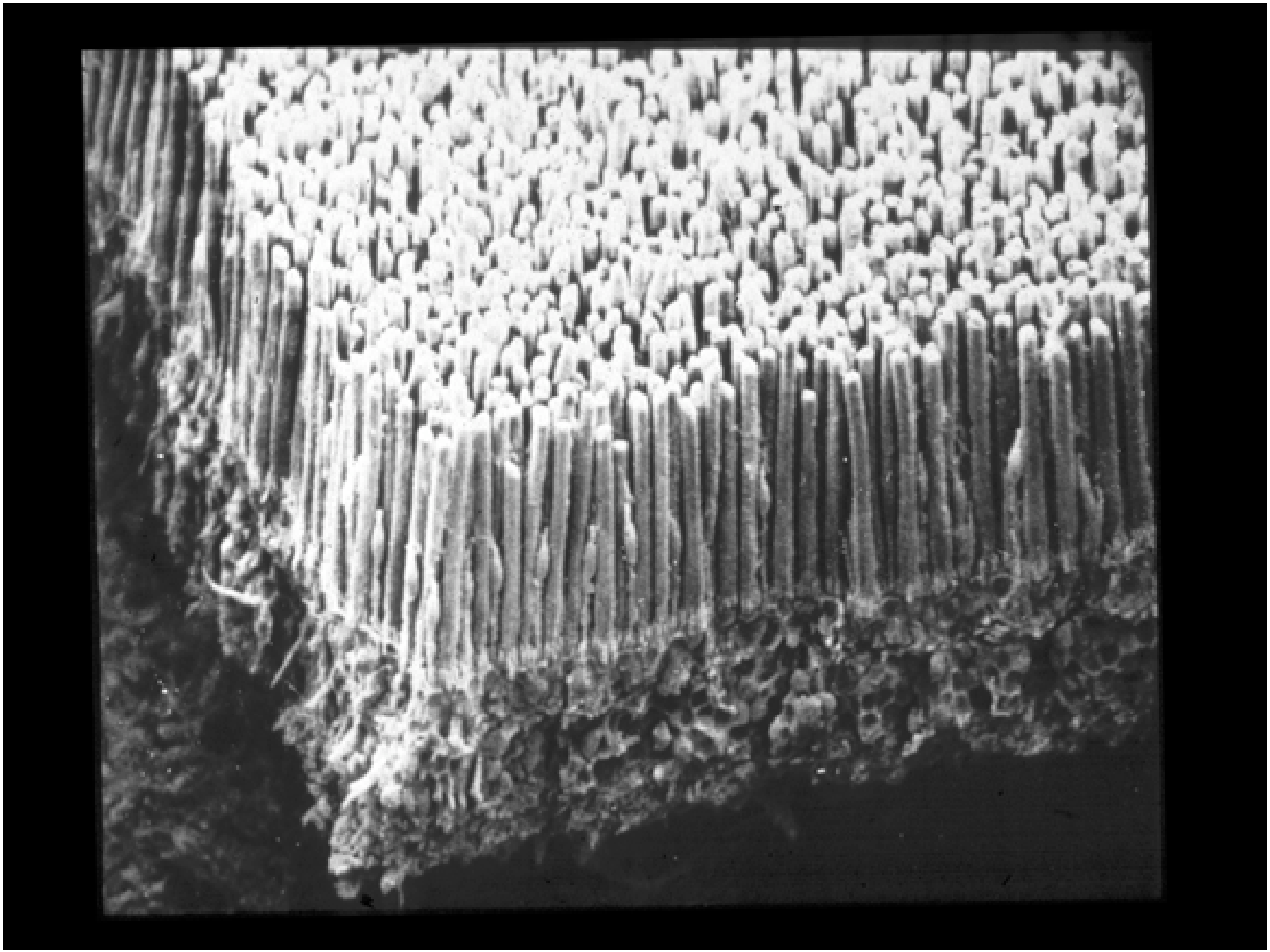


target covers
~500 rods

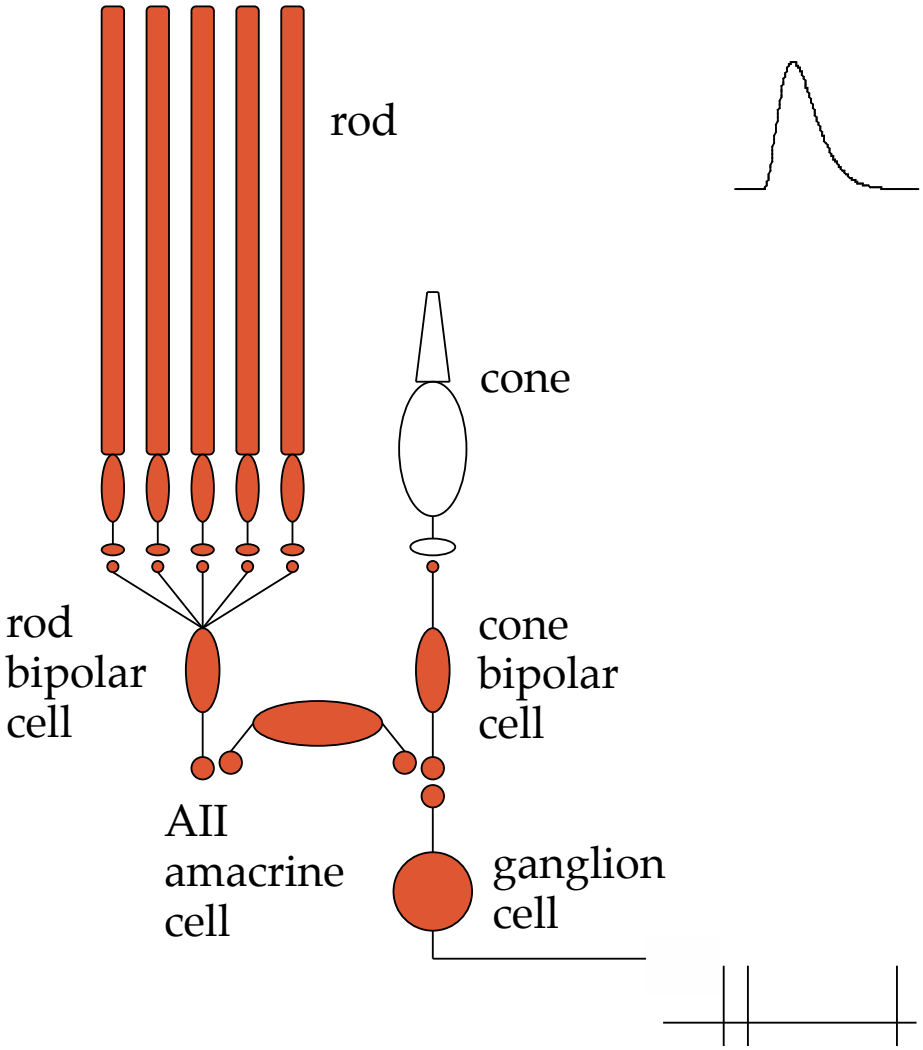


CONCLUSION: Θ = 5-7 photons absorbed spread over 500 rods

PROBLEM: No way to account for false positives (noise)



IMPLICATIONS OF BEHAVIORAL SENSITIVITY

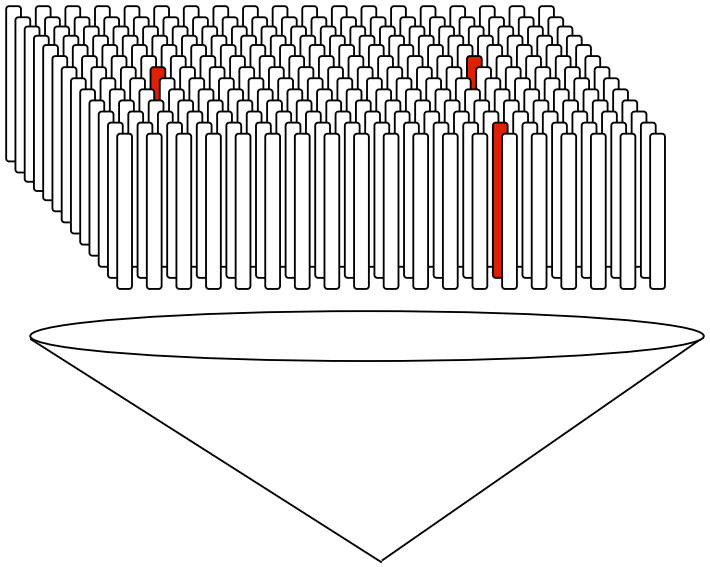


- **phototransduction**
  - single photons reliably transduced

- **synaptic transmission**
  - reliable transmission of single photon responses

- **neural coding**
  - absorption of a few photons produces change in optic nerve activity

CONVERGENCE AND SPARSE SIGNALING IN MAMMALIAN RETINA

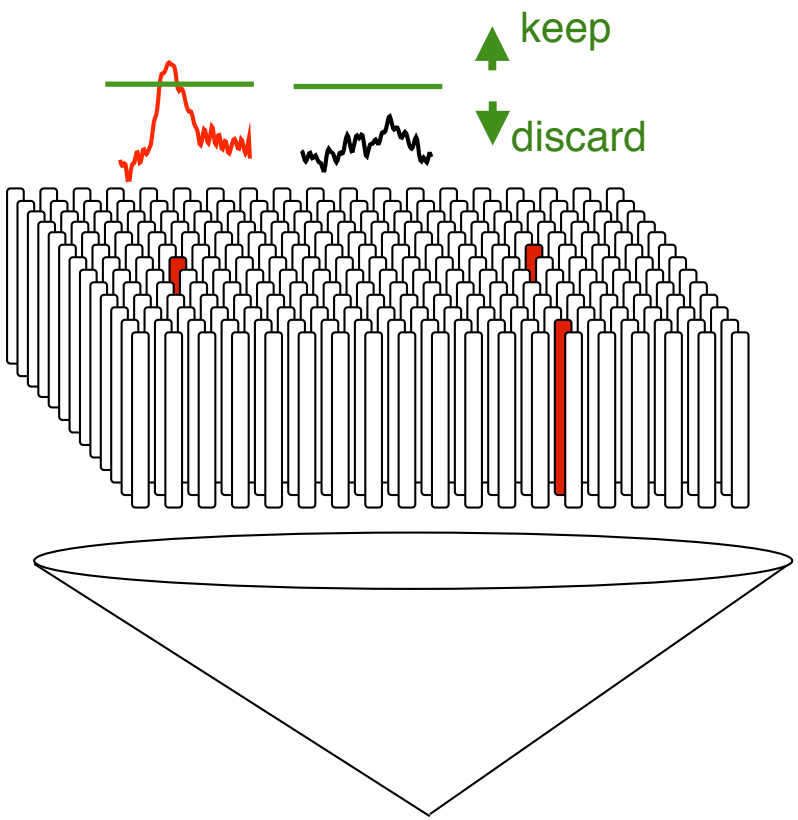


- At visual threshold photons < 0.1% of the rods contribute signals while all rods generate noise

- Under these conditions averaging is a disaster

- General problem in nervous system

ROD-ROD BIPOLAR SIGNAL TRANSFER AND ABSOLUTE VISUAL SENSITIVITY



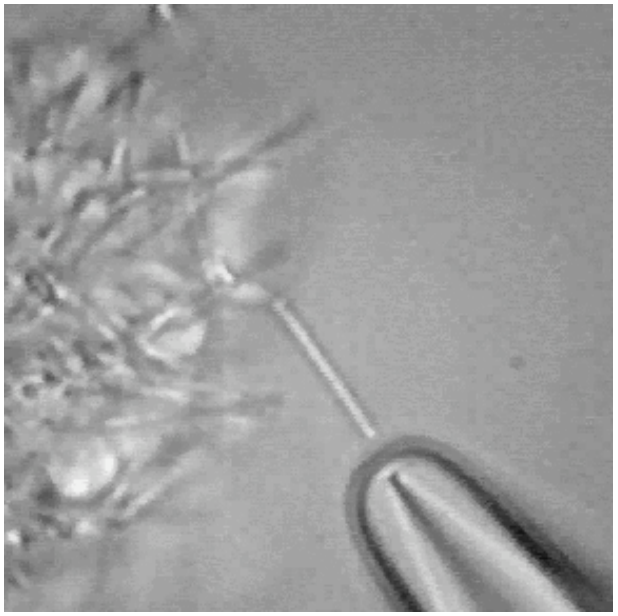
- Rod-rod bipolar signal transfer is nonlinear.

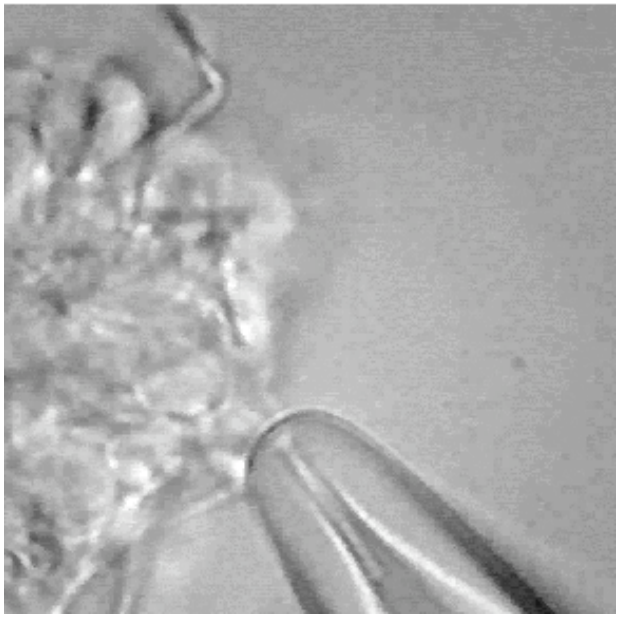
- Nonlinear signal transfer eliminates or severely attenuates majority of rod's single photon responses.

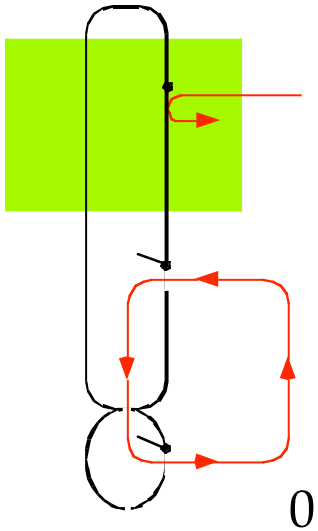
- Rejection of noise more than compensates loss of signal - thus rod bipolars provide near-optimal readout of rod signals near visual threshold.

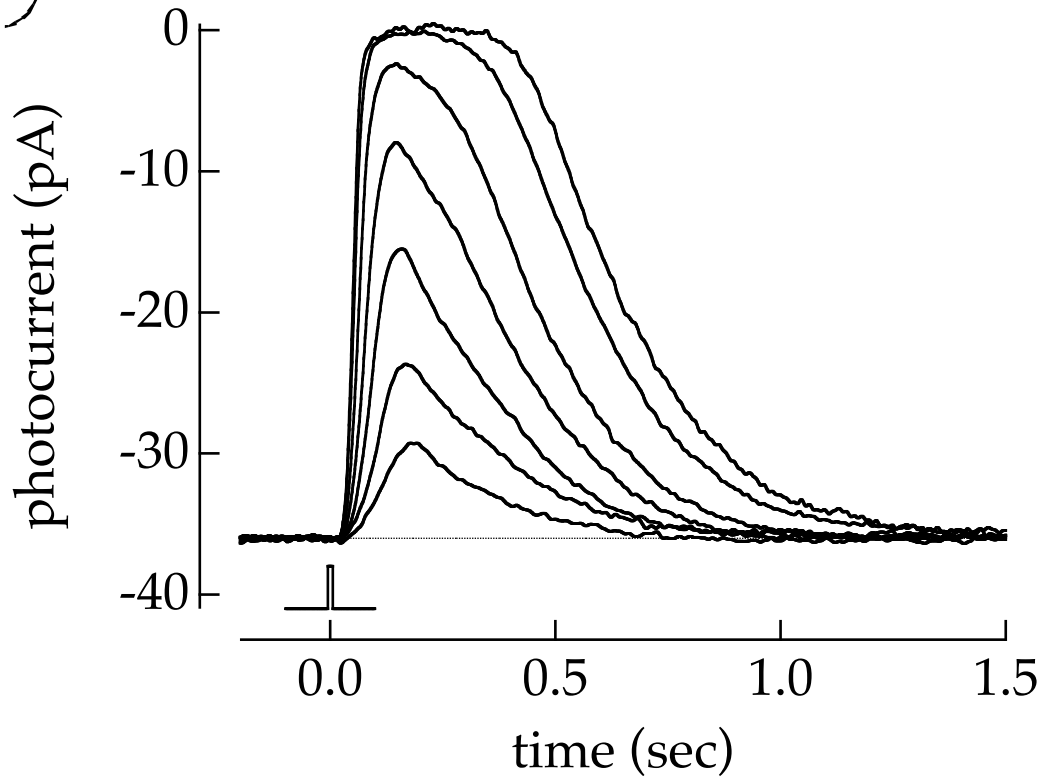
SUCTION ELECTRODE RECORDING

(Baylor et al., 1979)



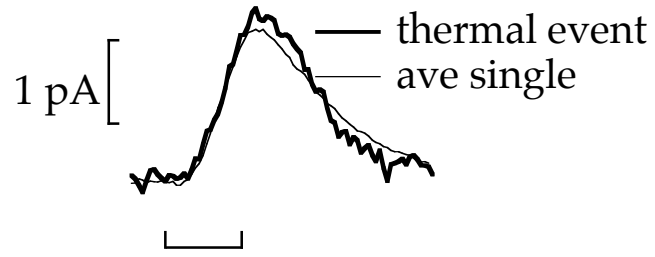




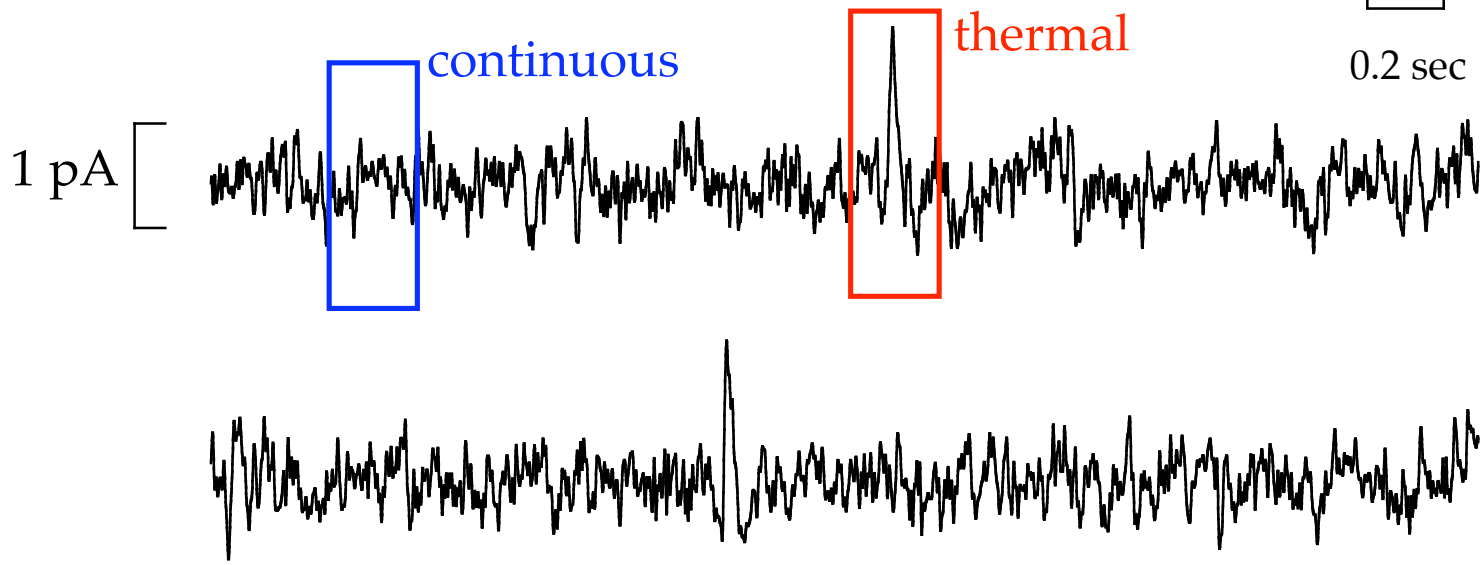


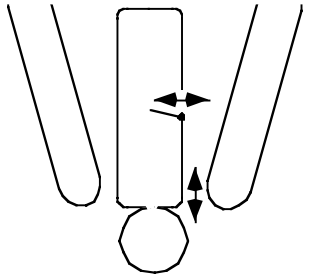
DARK NOISE IN MAMMALIAN RODS

(Baylor et al., 1984)

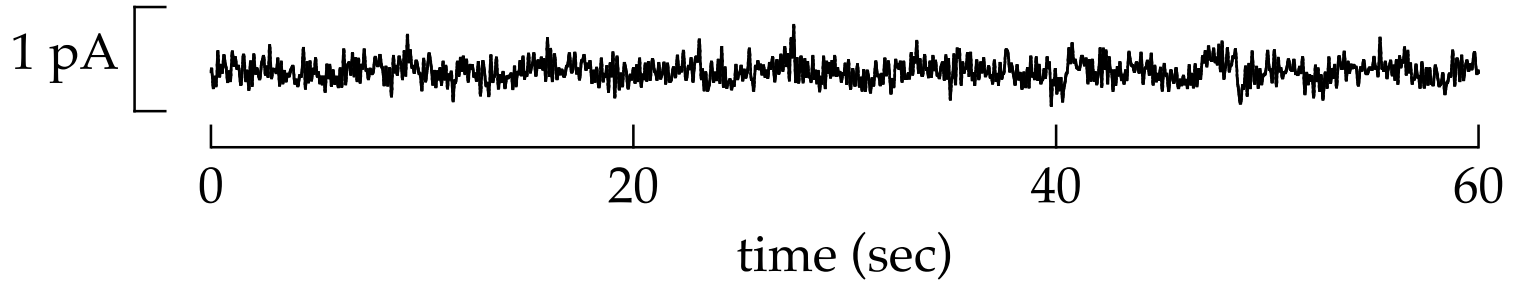


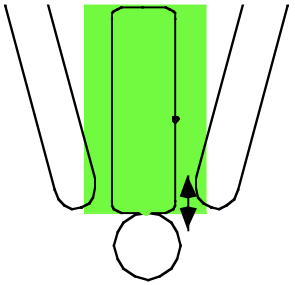
Dark + Instrumental Noise



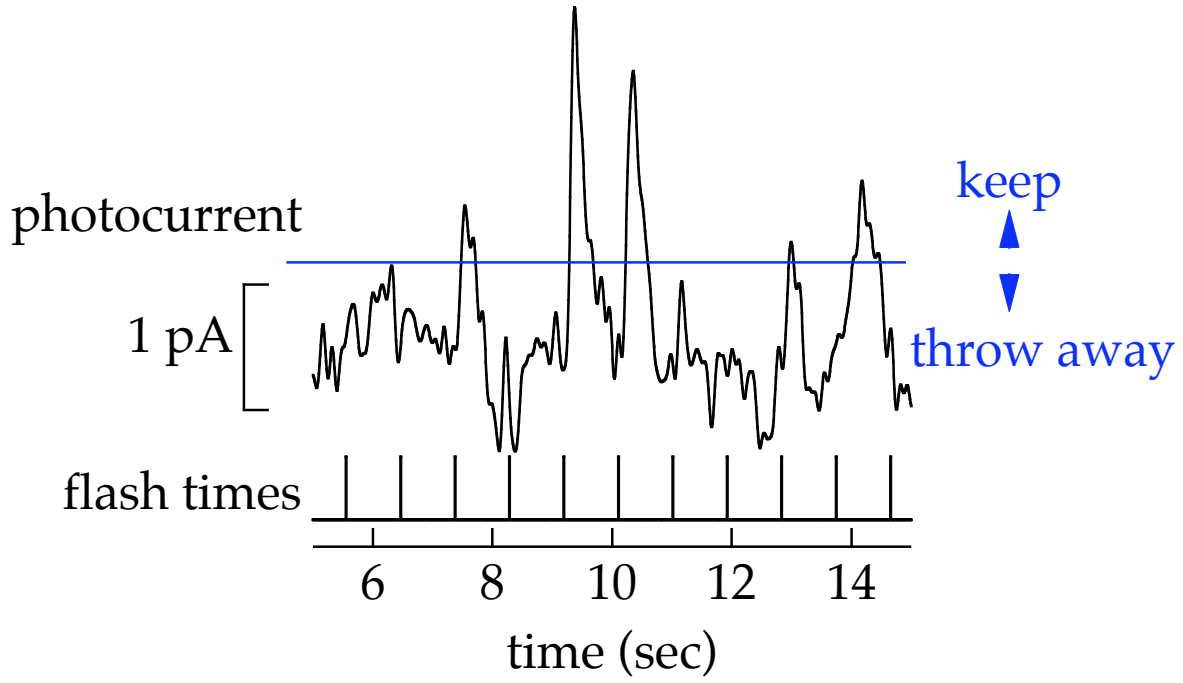


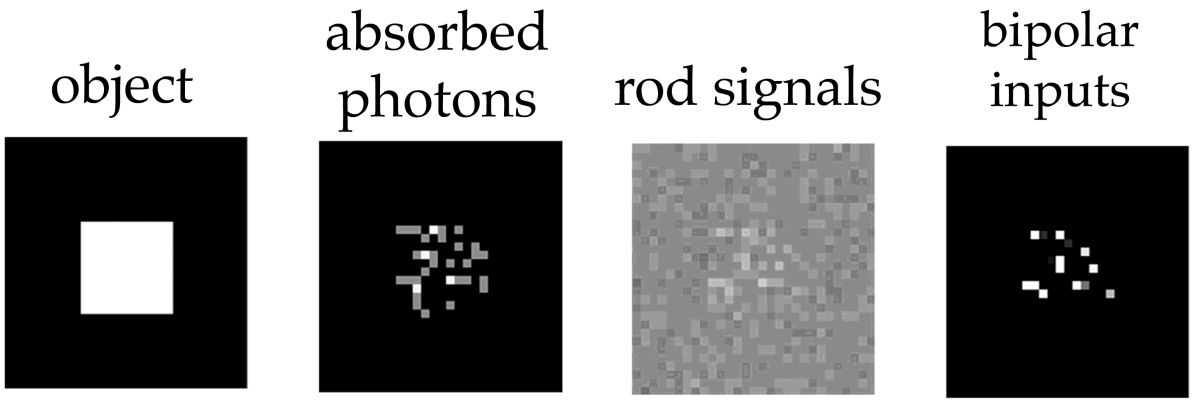
Instrumental Noise



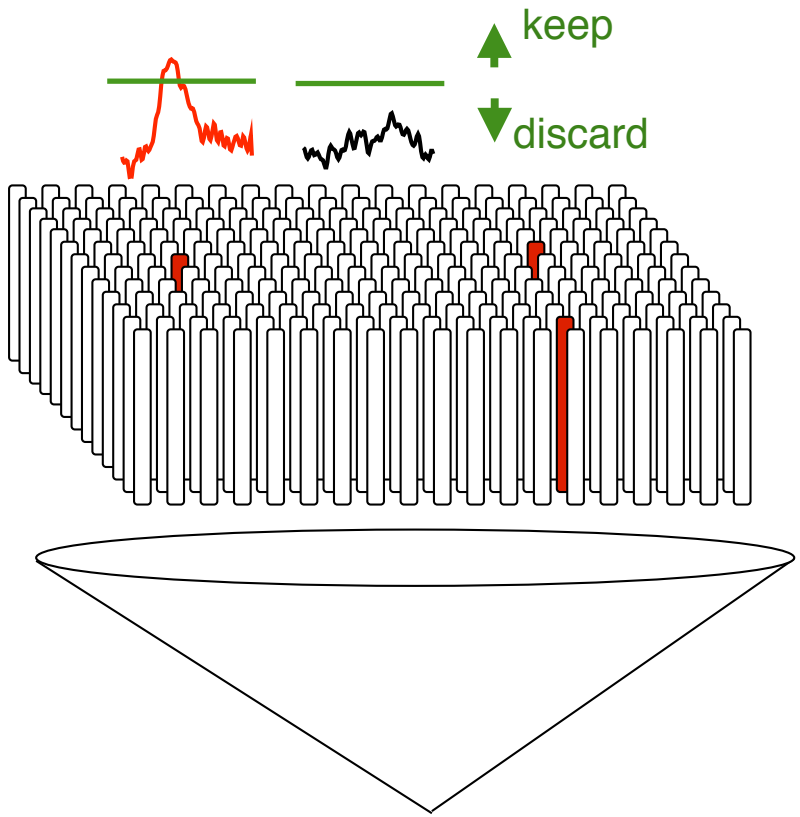


SEPARATION OF ROD SIGNAL AND NOISE BY THRESHOLDING NONLINEARITY





(modified from Wilson, 2002)

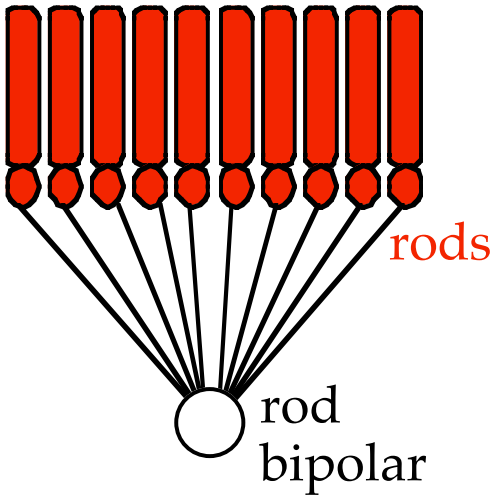


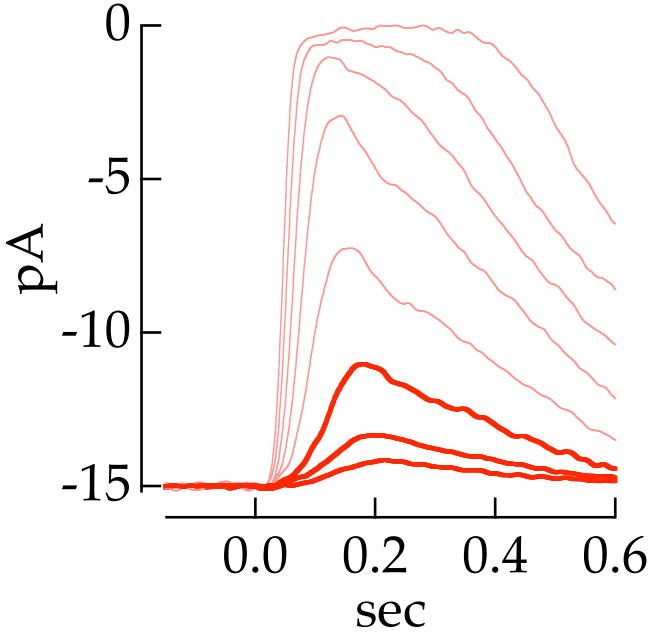
• Mouse rod-rod bipolar signal transfer is nonlinear.
  - dependence of response on flash strength
  - discreteness of dim flash response

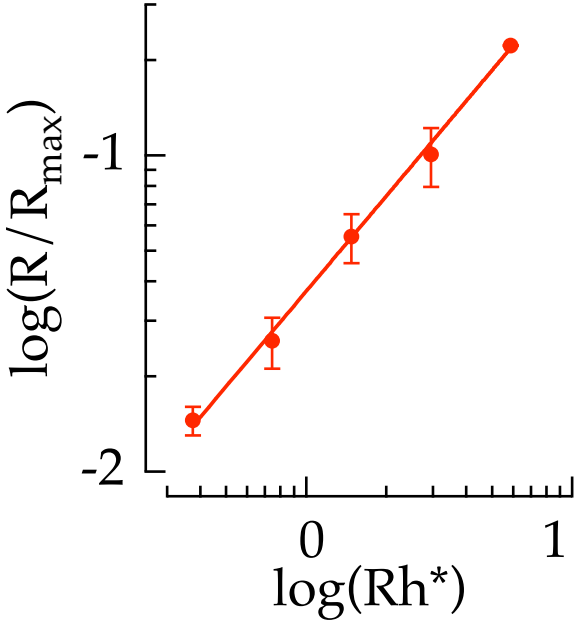
• Nonlinear signal transfer eliminates or severely attenuates majority of rod's single photon responses.

• Rejection of noise more than compensates loss of signal - thus rod bipolars provide near-optimal readout of rod signals near visual threshold.

DIM FLASH RESPONSES OF RODS GROW LINEARLY WITH FLASH STRENGTH

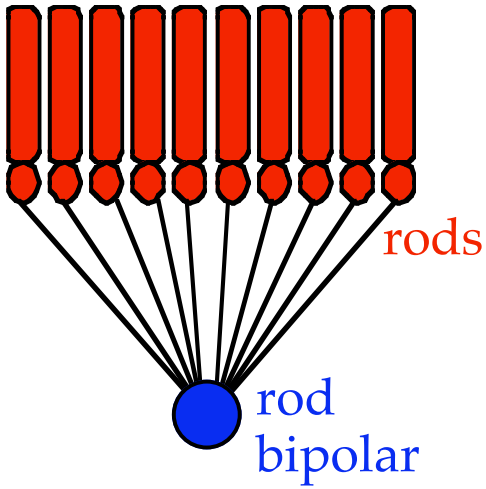


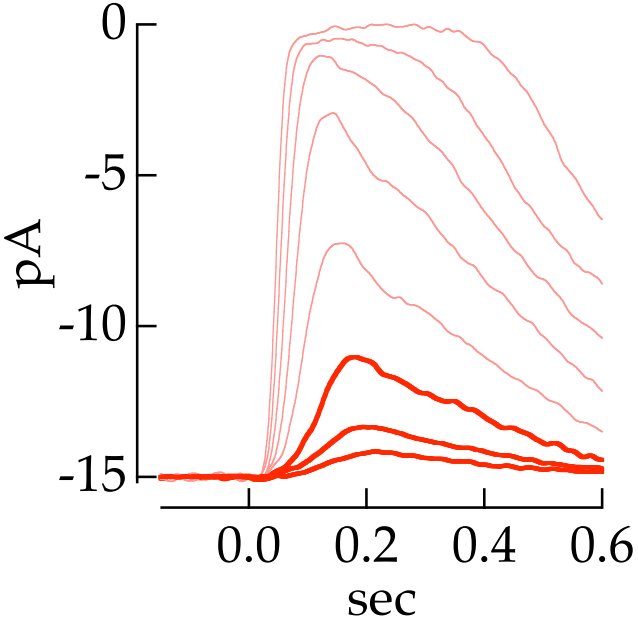


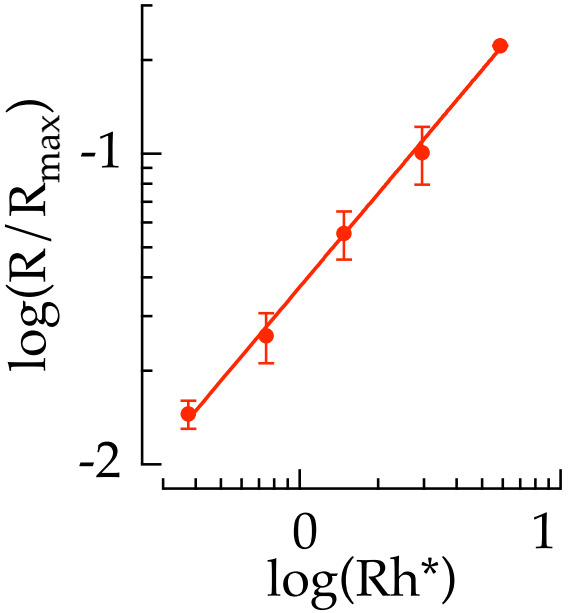


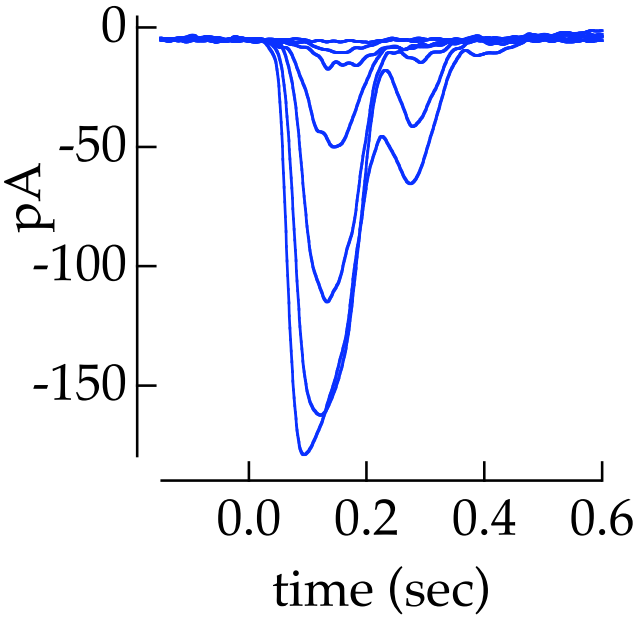
why log-log?

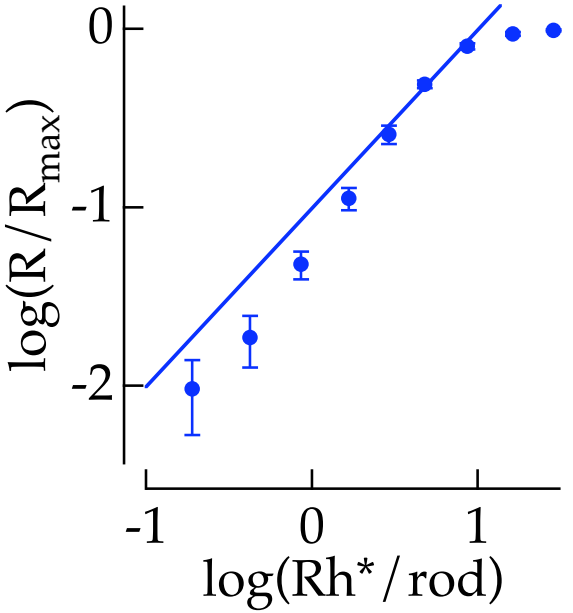
RESPONSES OF ROD BIPOLARS BUT NOT RODS GROW SUPRALINEARLY WITH FLASH STRENGTH

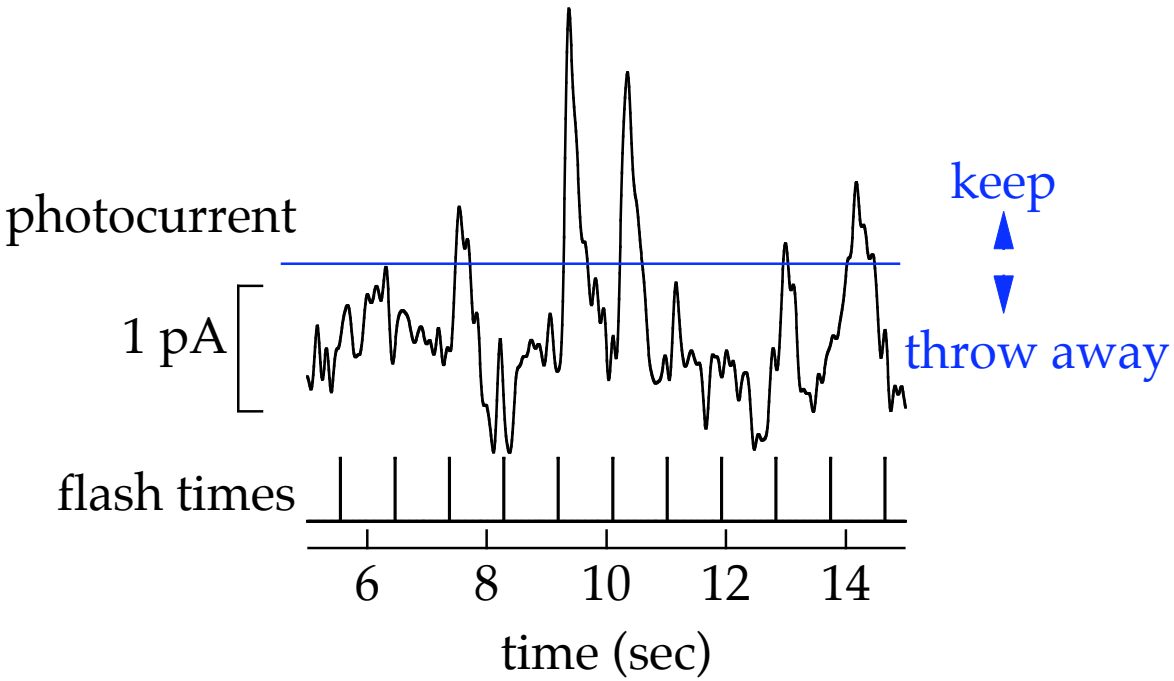






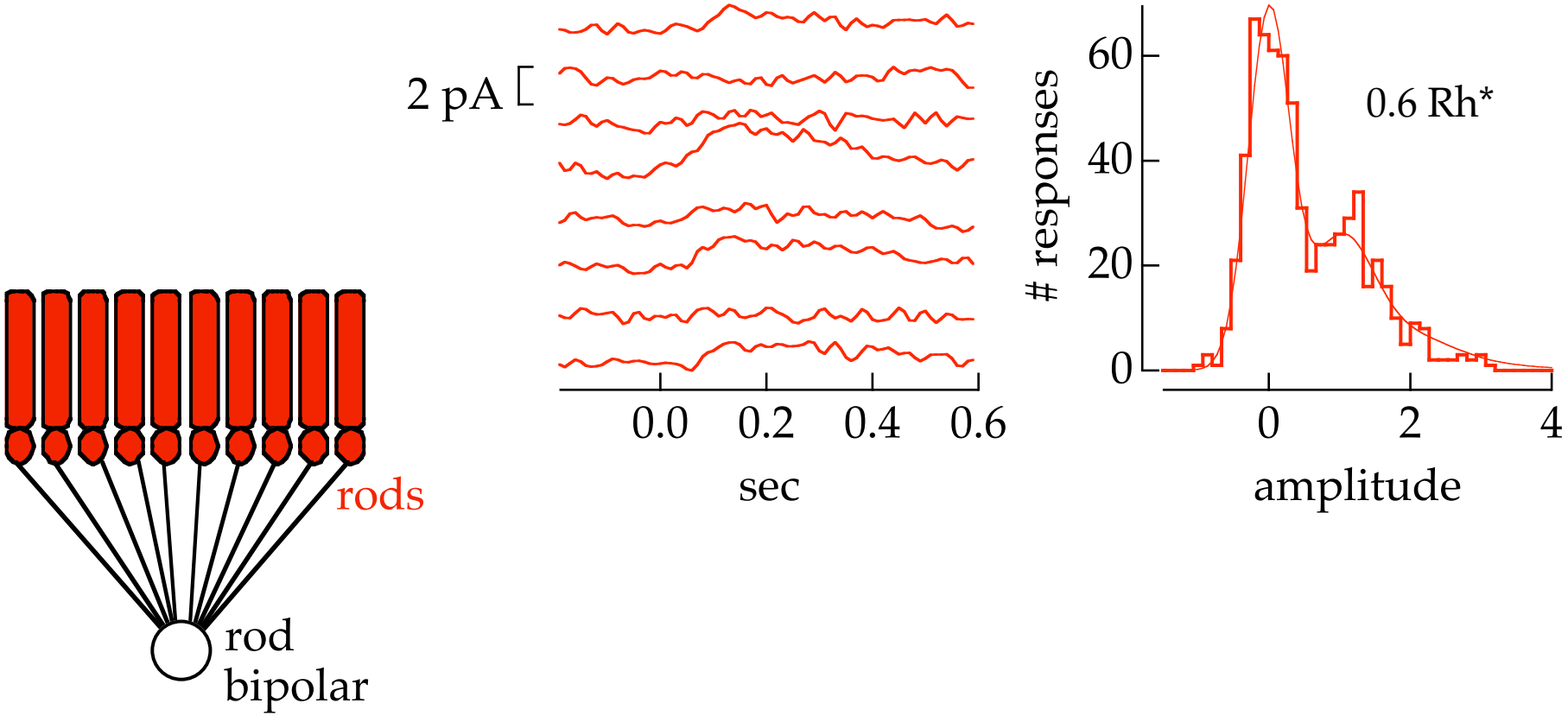




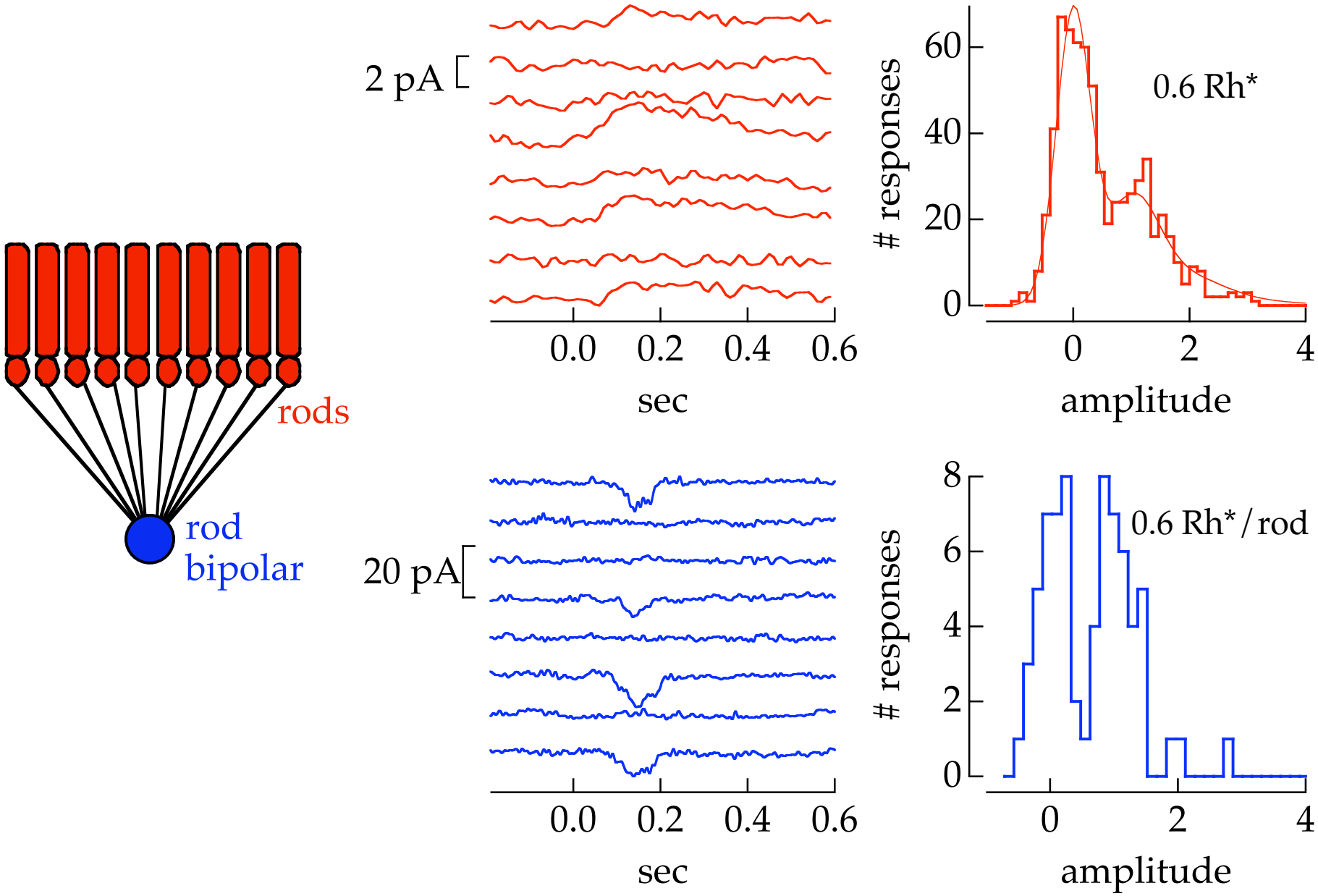


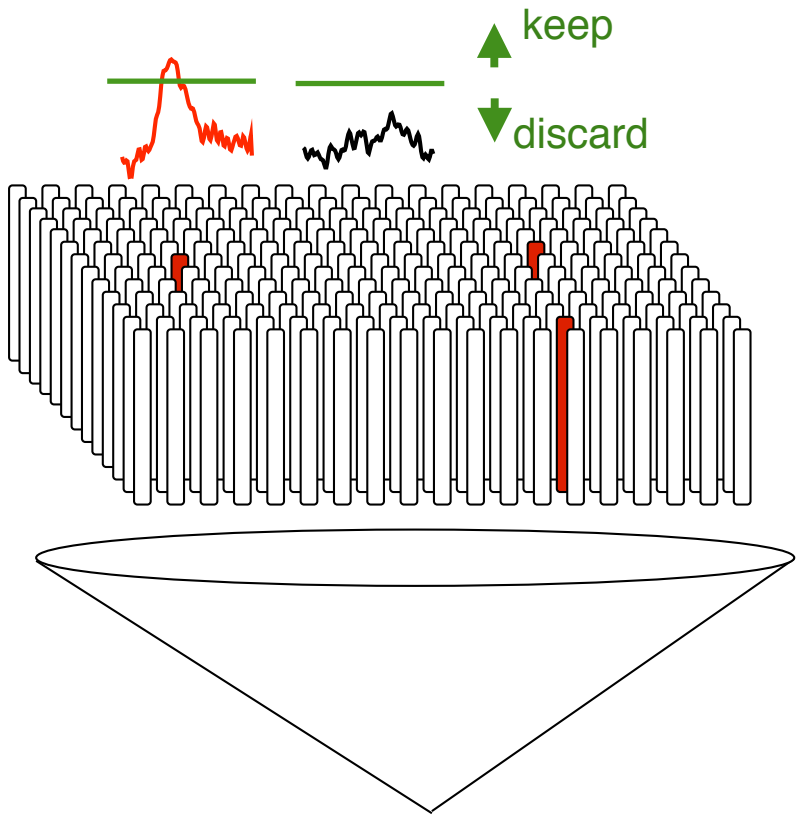
Does rod-rod bipolar signal transfer separate rod signal and noise?

MOUSE ROD SINGLE PHOTON RESPONSES ARE PARTIALLY OBSCURED BY NOISE



ROD BIPOLARS GENERATE DISCRETE RESPONSES TO DIM FLASHES



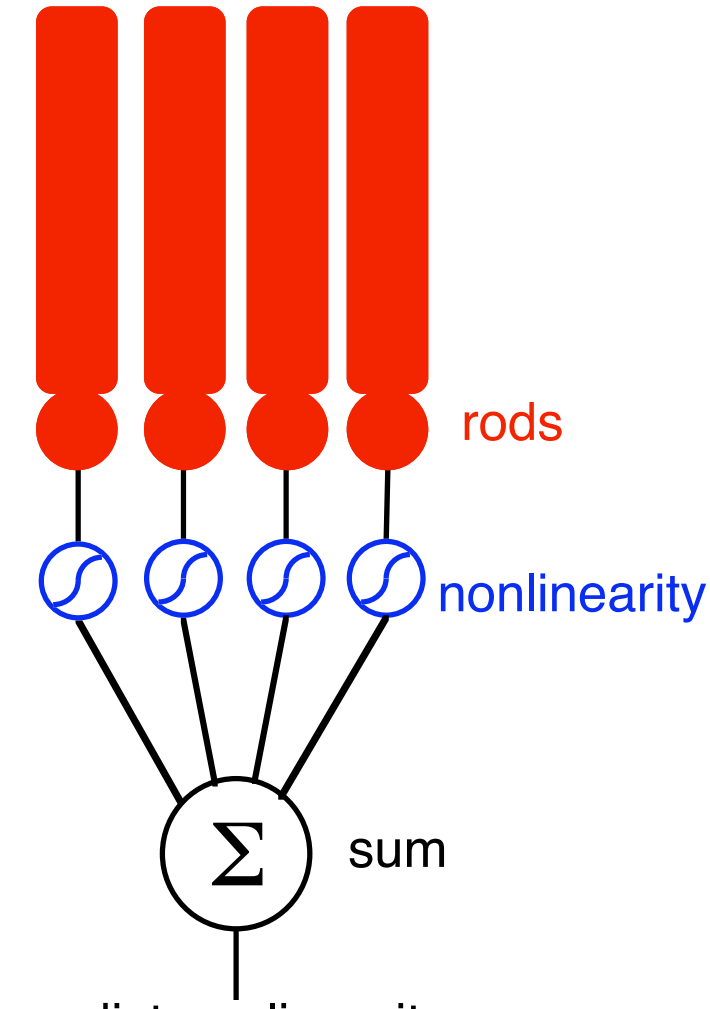


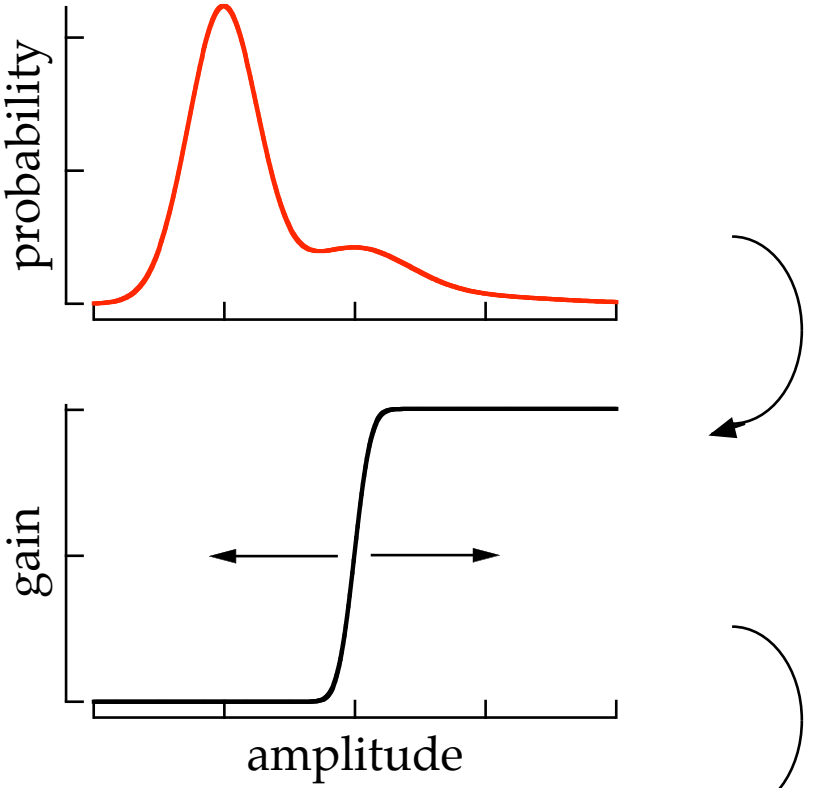
• Mouse rod-rod bipolar signal transfer is nonlinear.

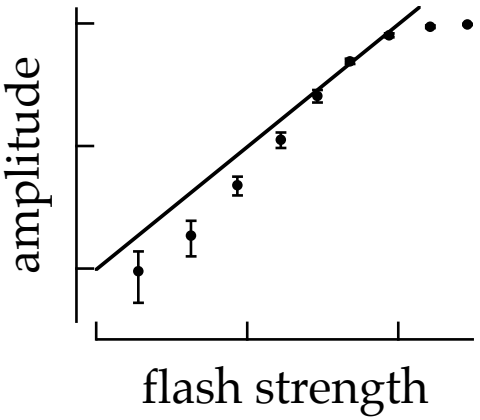
• Nonlinear signal transfer eliminates or severely attenuates majority of rod's single photon responses.

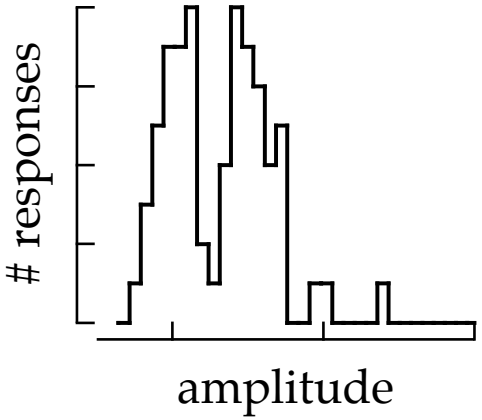
• Rejection of noise more than compensates loss of signal - thus rod bipolars provide near-optimal readout of rod signals near visual threshold.

MODEL FOR ROD-ROD BIPOLAR SIGNAL TRANSFER

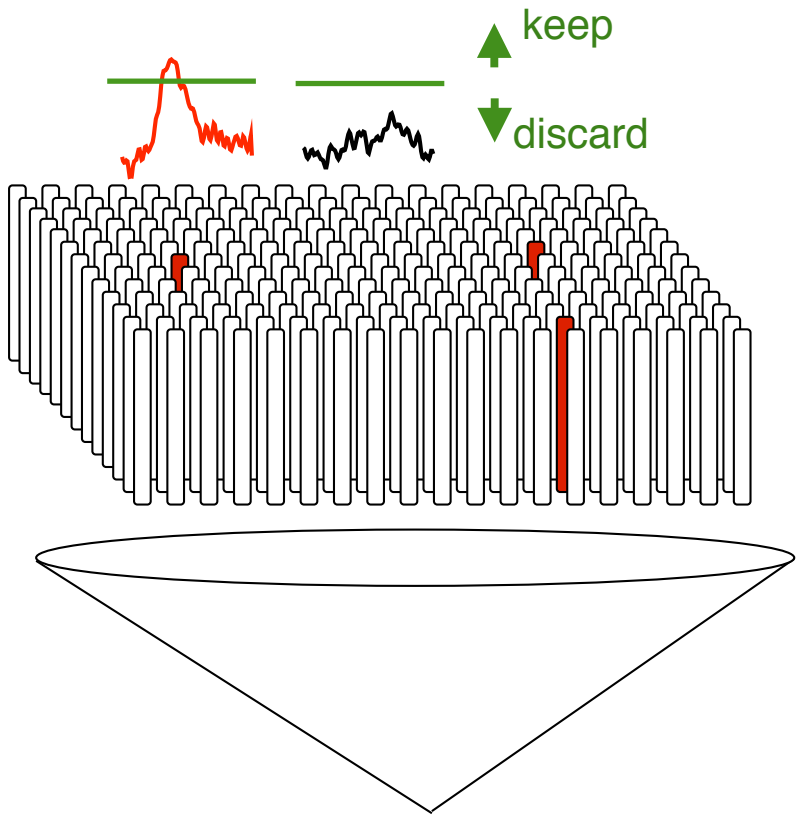








signal and noise distributions
and discrimination



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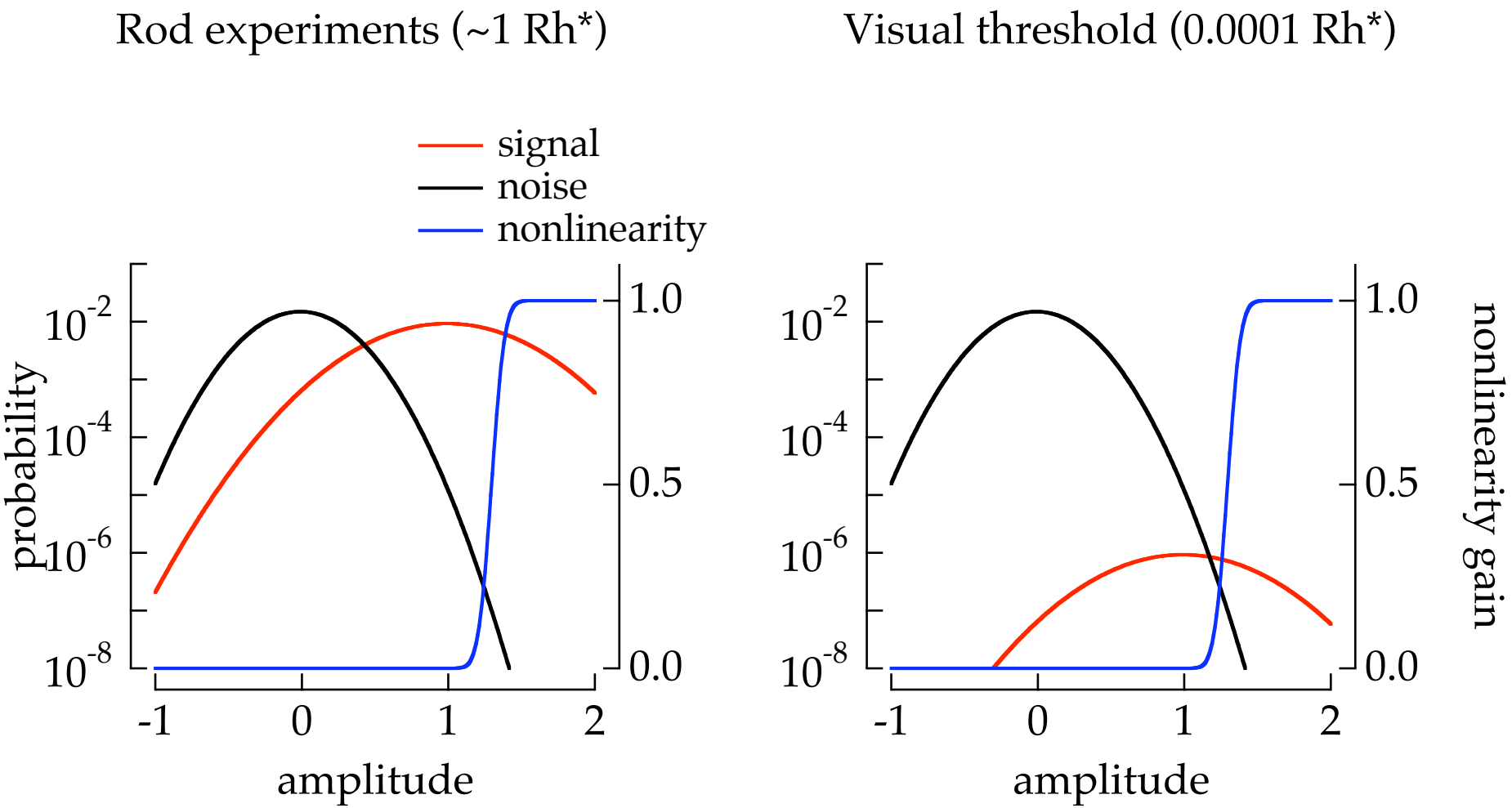
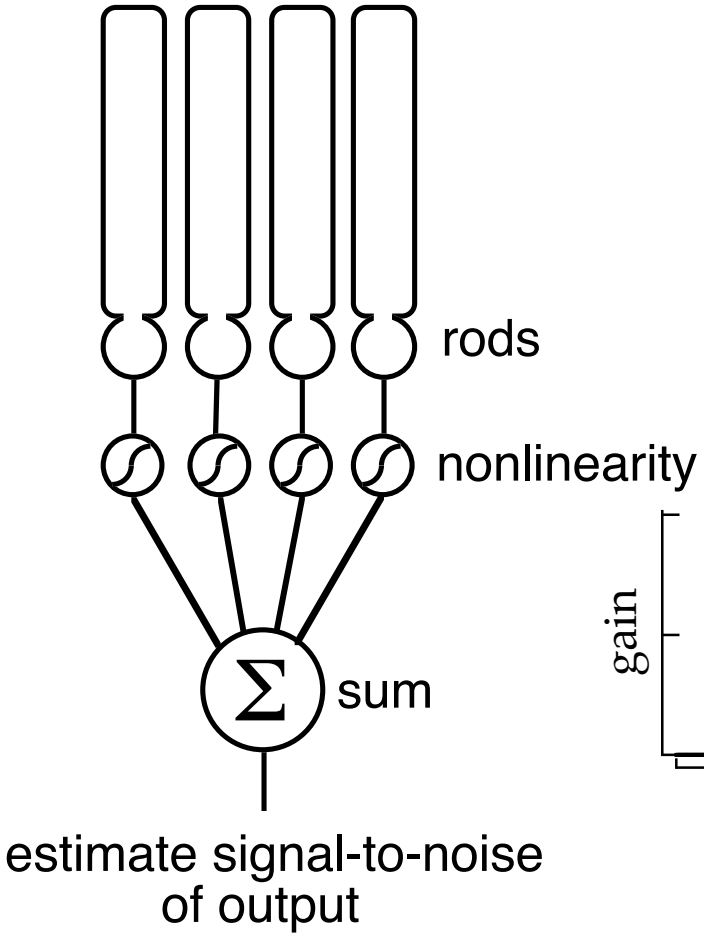
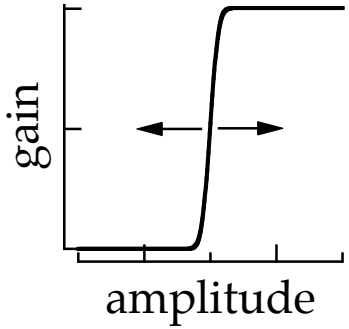
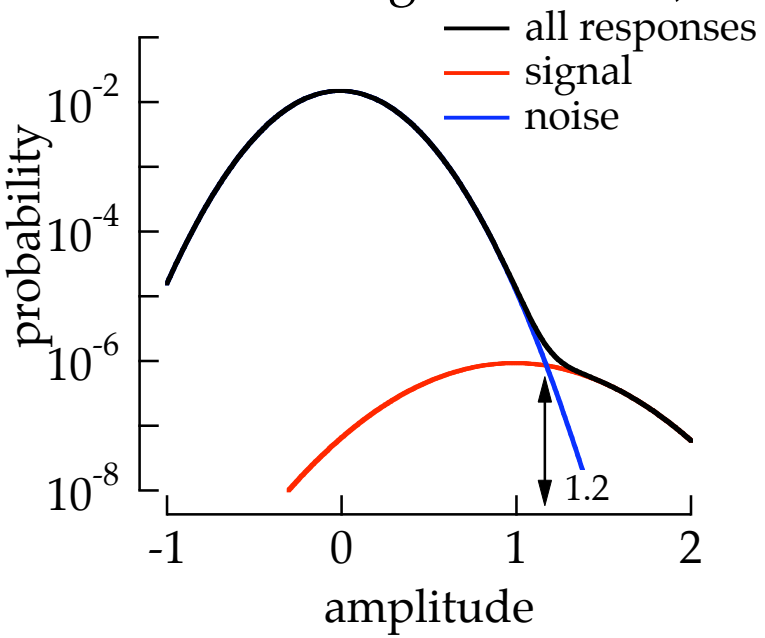
DISTRIBUTION OF ROD RESPONSES AT VISUAL THRESHOLD

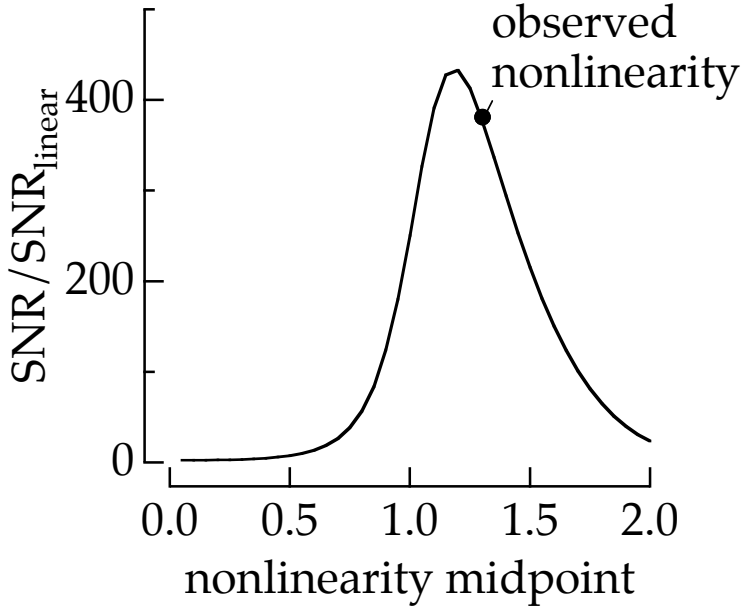


ROD BIPOLAR PROVIDES NEAR OPTIMAL READOUT OF ROD SIGNALS AT VISUAL THRESHOLD (0.0001 Rh*/rod/integration time)

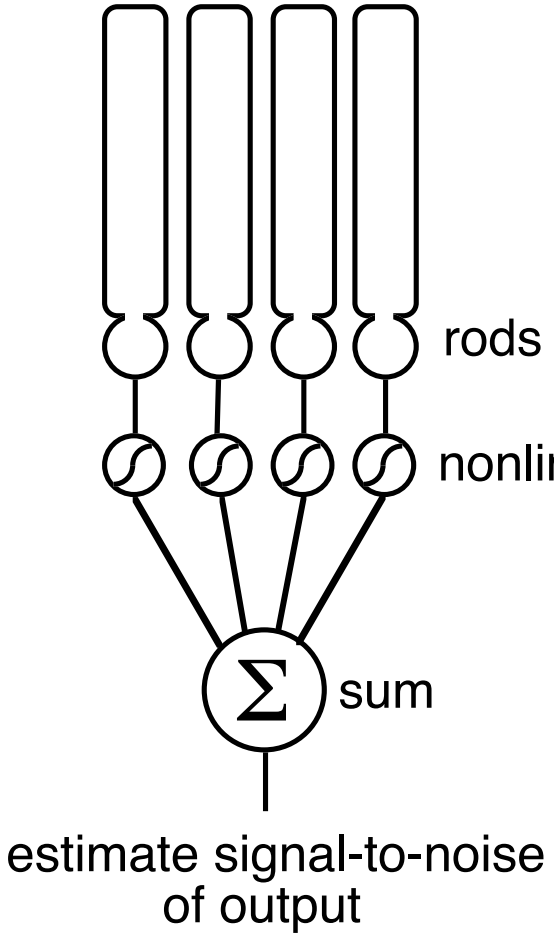


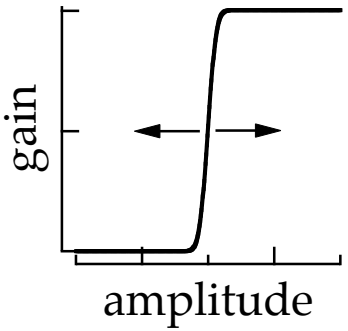


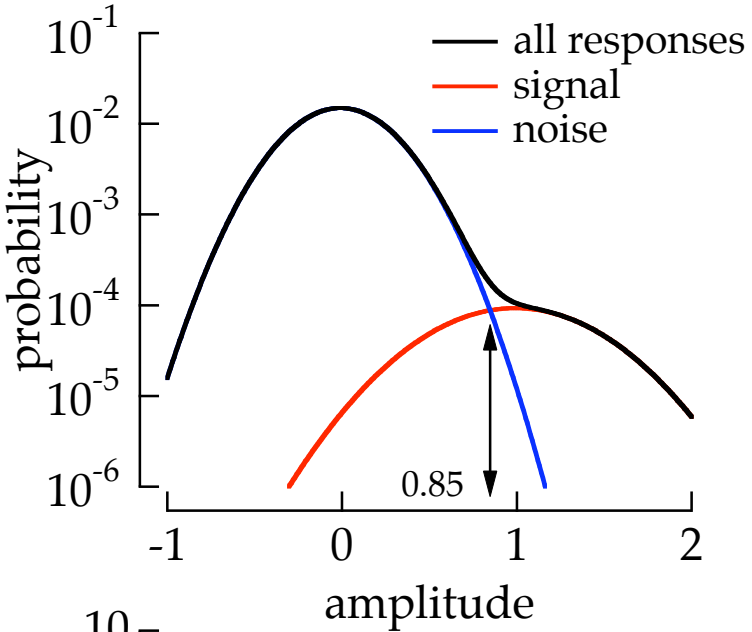


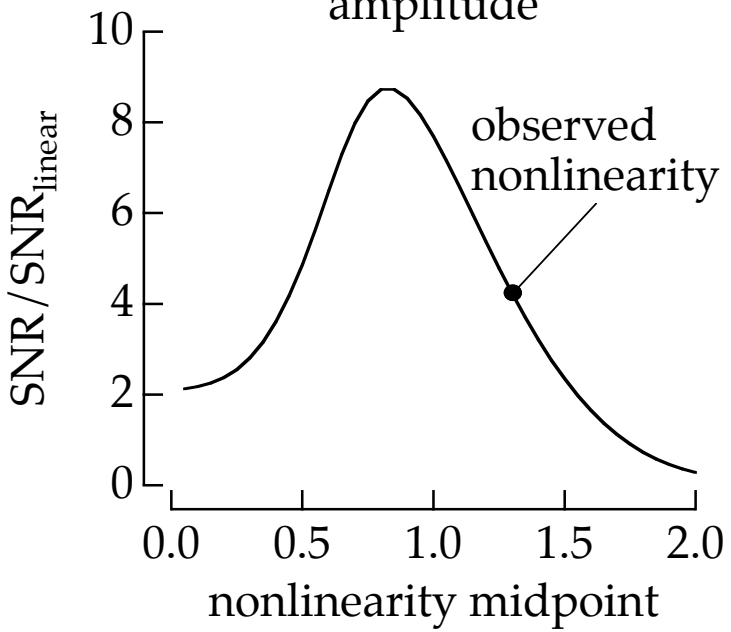


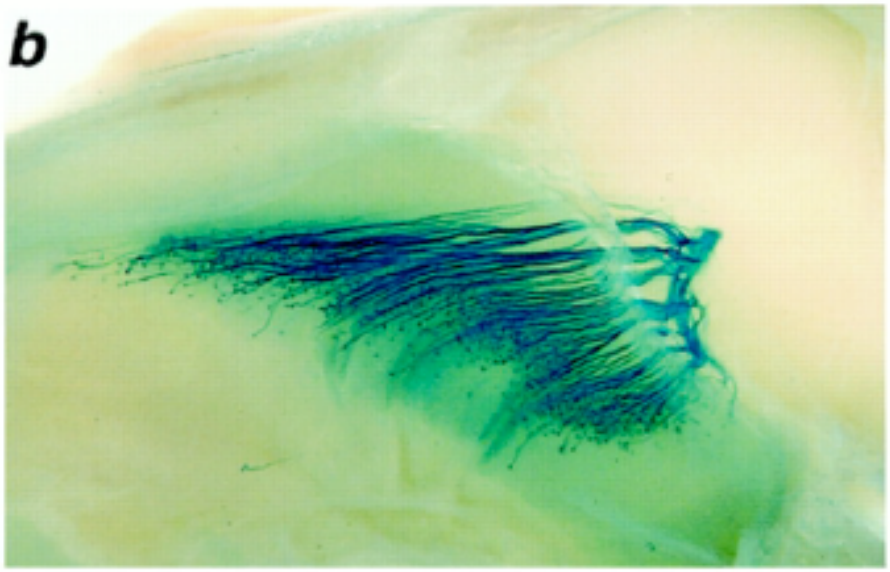
NONLINEAR SIGNAL TRANSFER LIMITS SENSITIVITY WELL ABOVE VISUAL THRESHOLD (0.01 Rh*/rod/integration time)

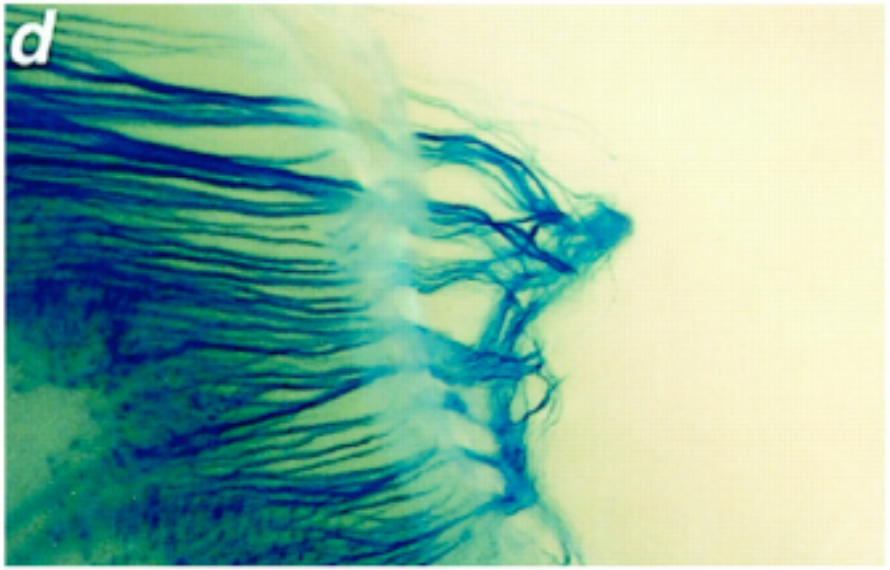


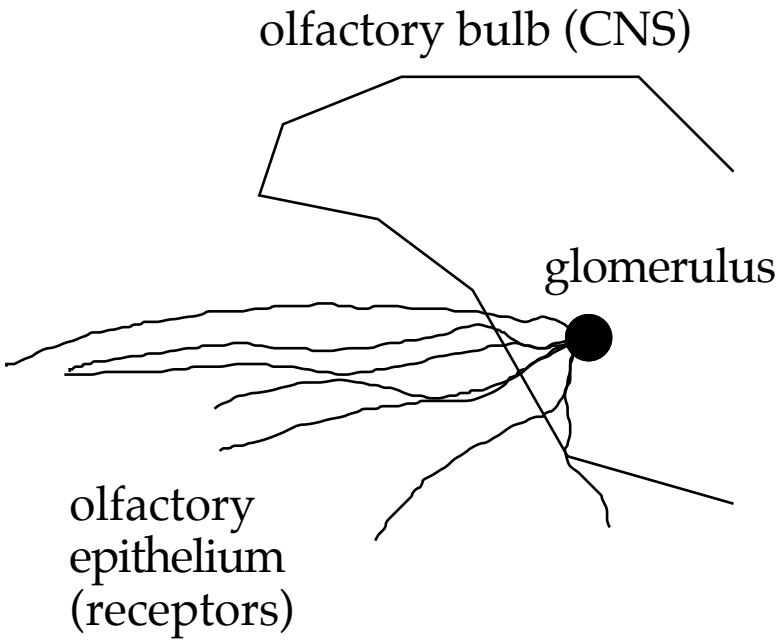












Mombaerts et al, 1996