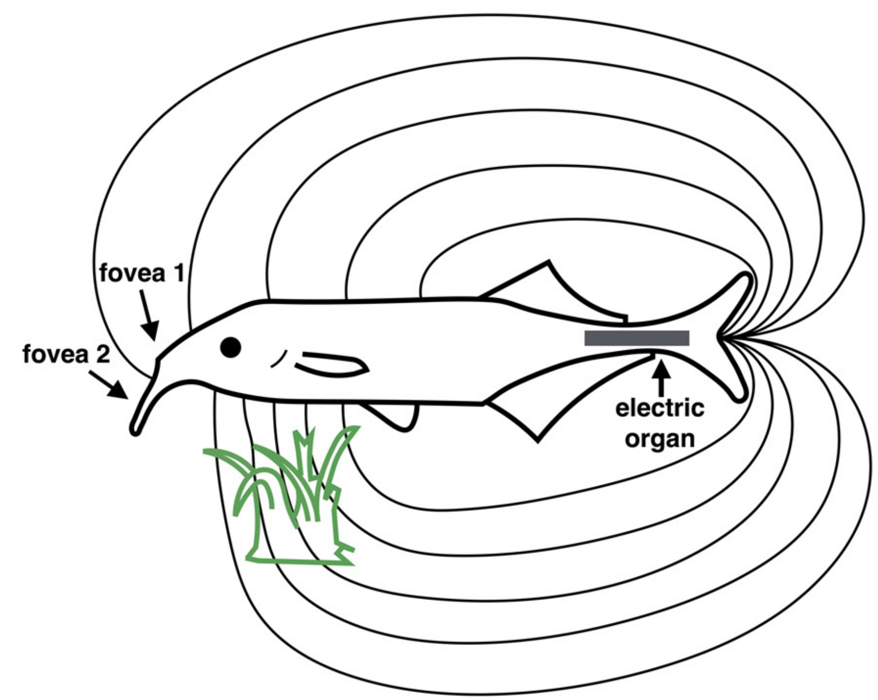

C. elegans


desert ant

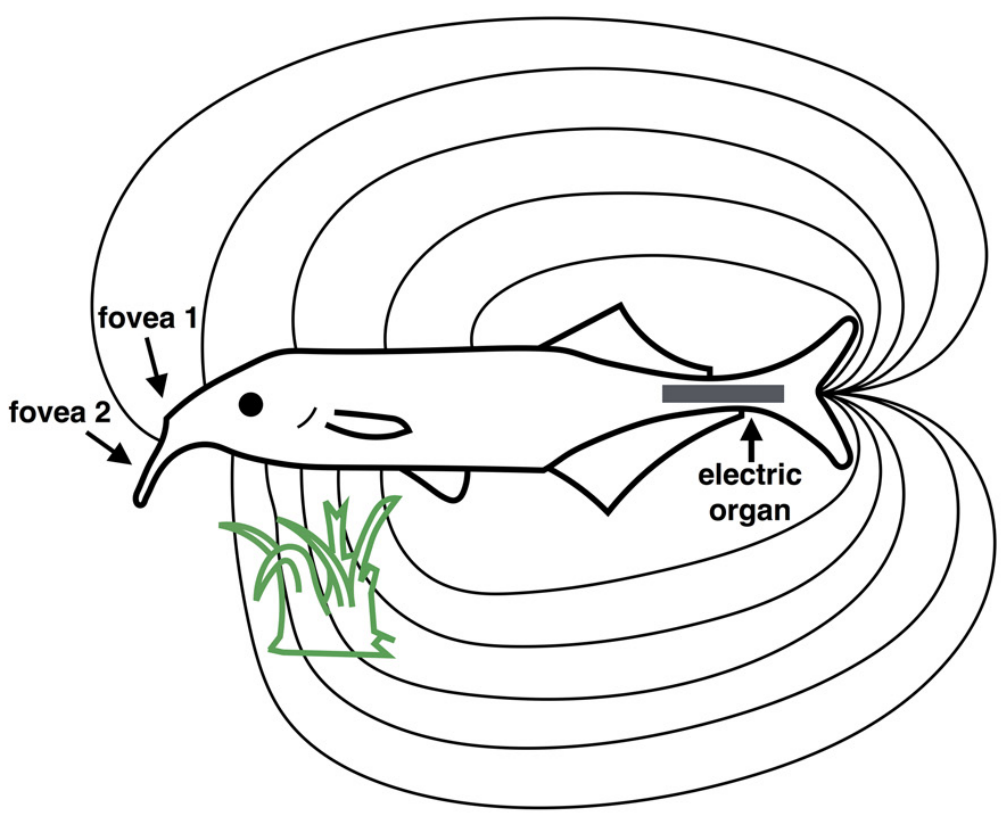

jumping spider


sand wasp

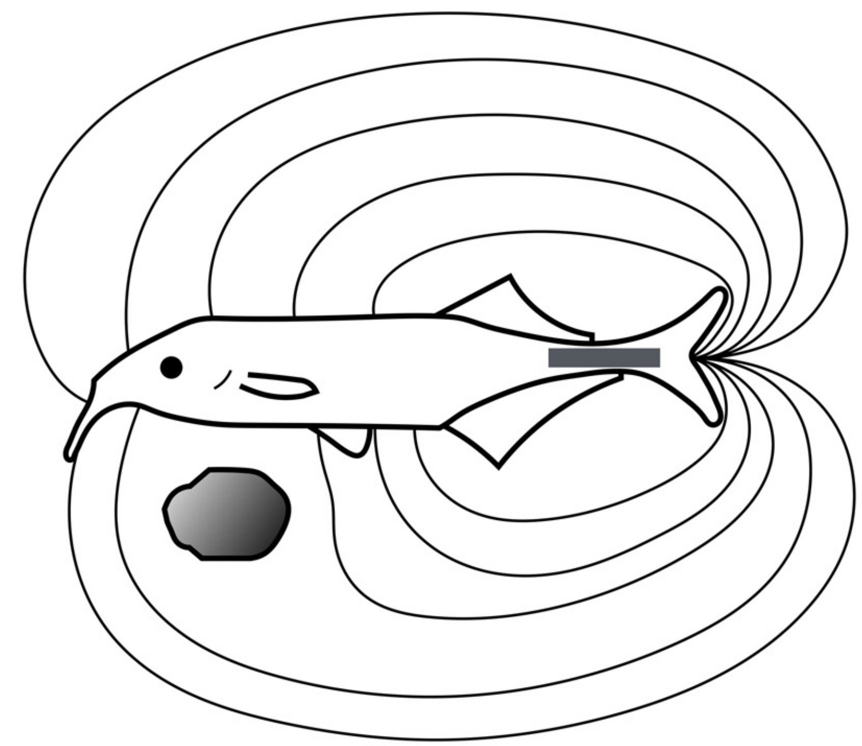


weakly electric fish

Spatial perception in weakly electric fish



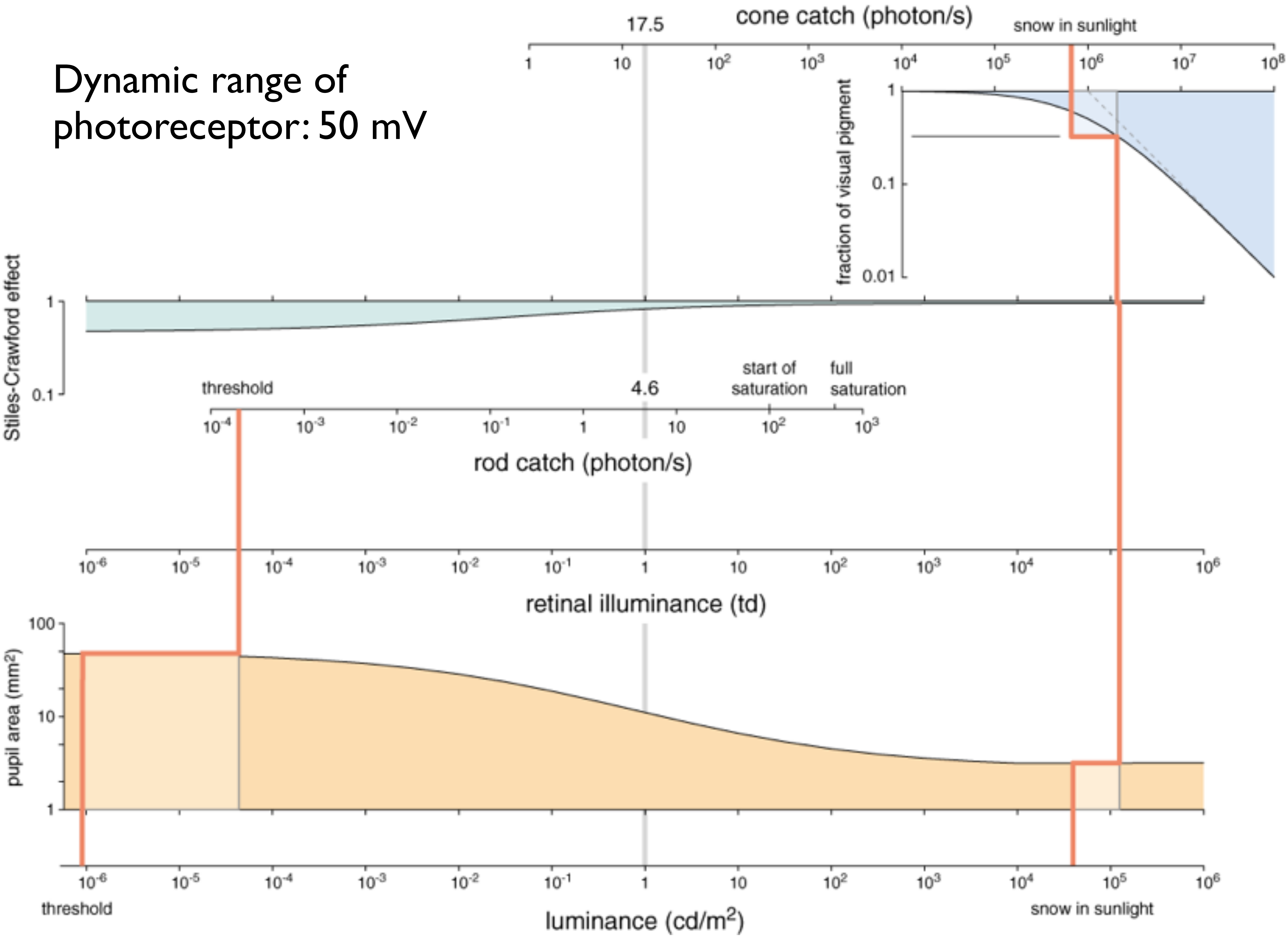
Conductor



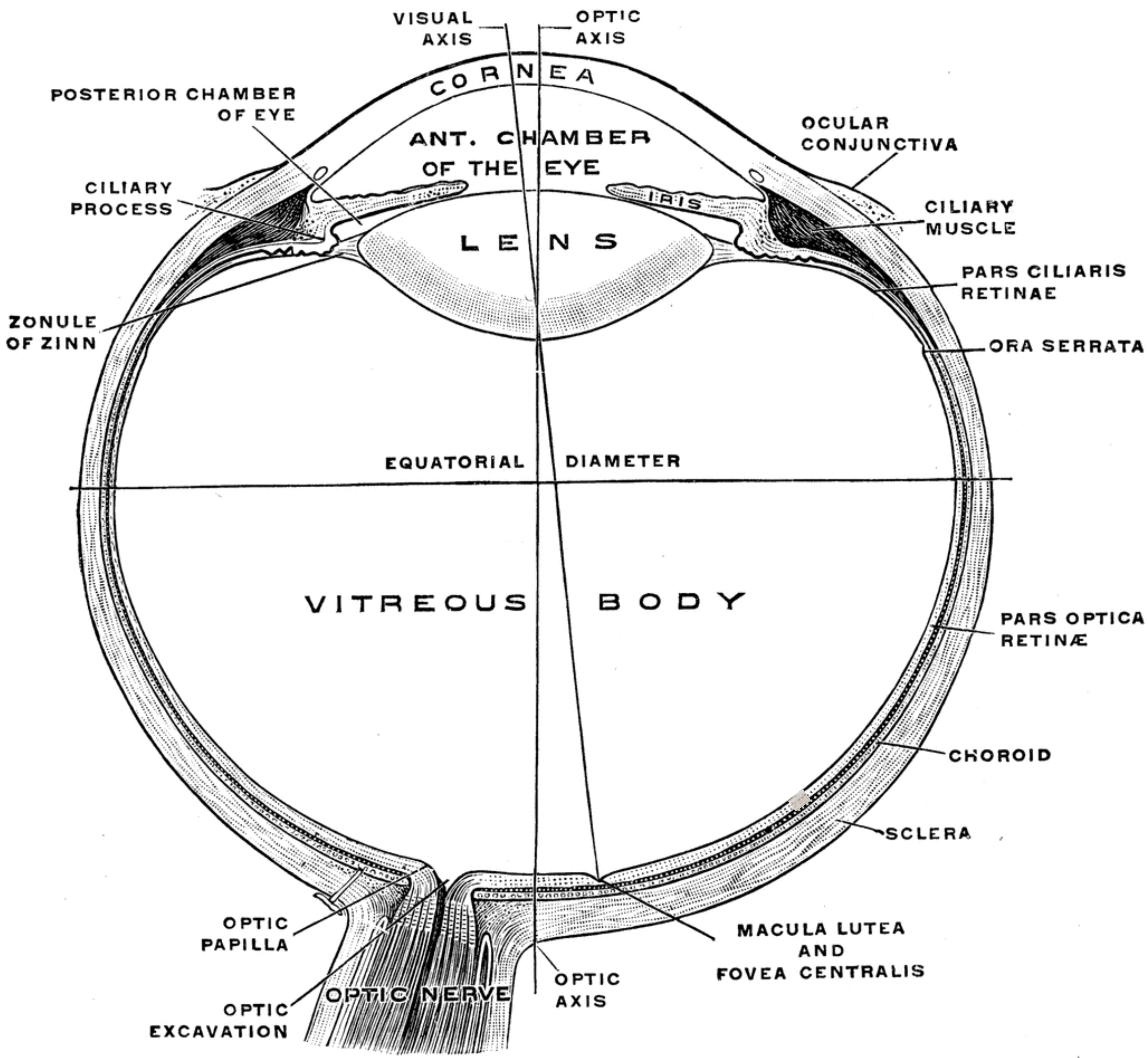
Non-conductor

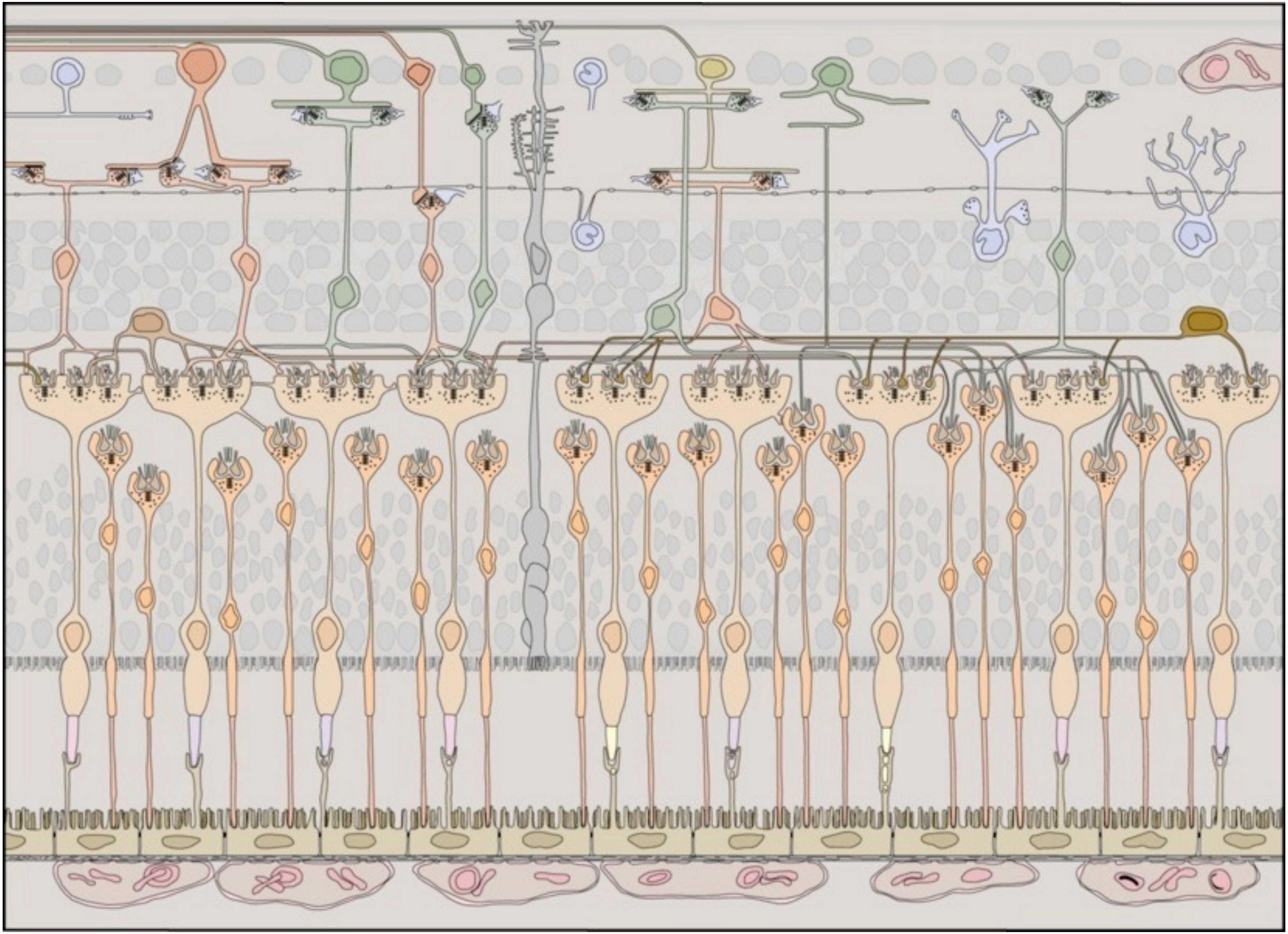
Phototransduction

Dynamic range of photoreceptor: 50 mV

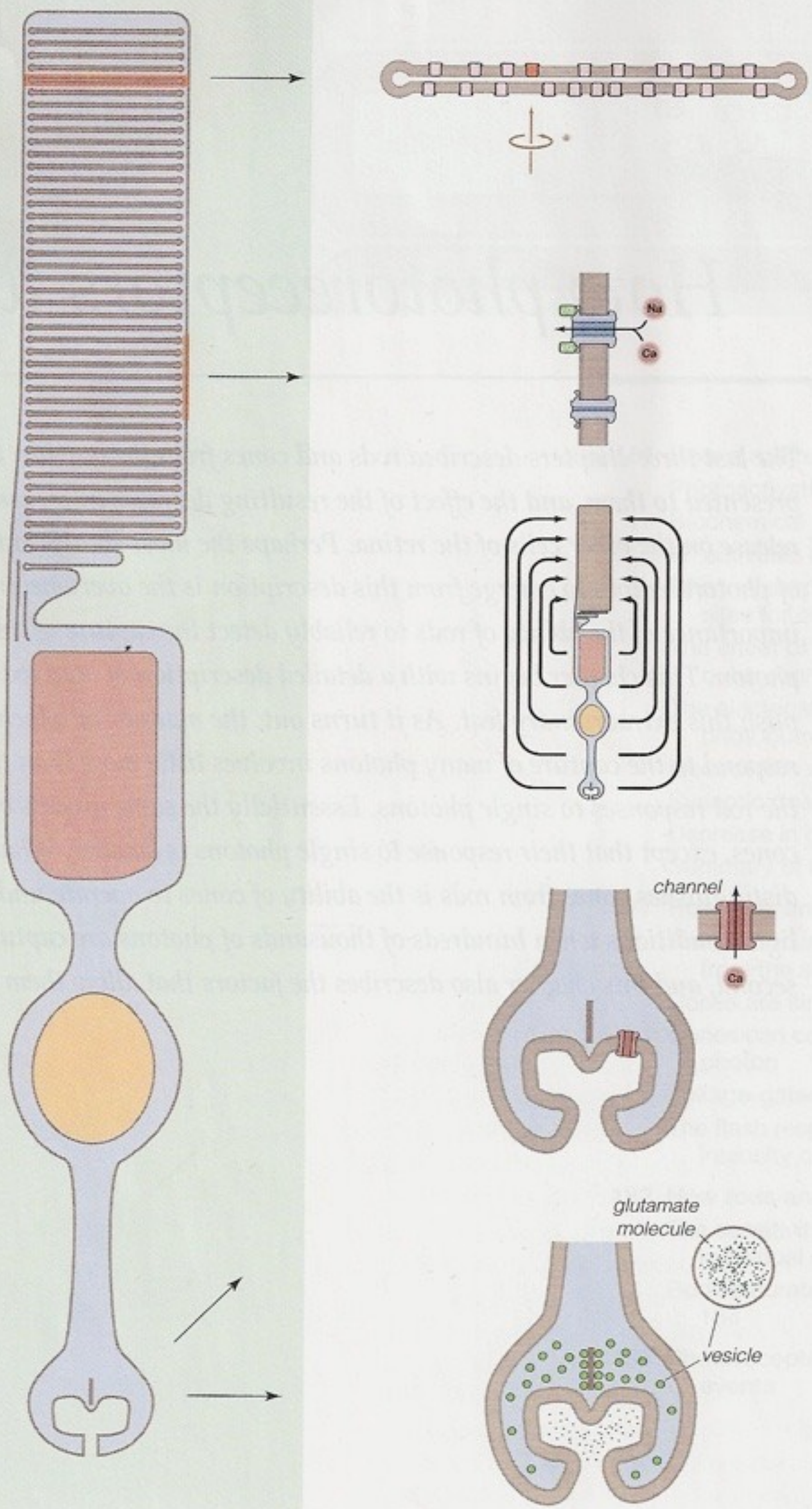


starlight CRT clear blue sky


VISUAL AXIS
OPTIC AXIS
CORNEA
POSTERIOR CHAMBER OF EYE
ANT. CHAMBER OF THE EYE
OCULAR CONJUNCTIVA
CILIARY PROCESS
IRIS
CILIARY MUSCLE
LENS
PARS CILIARIS RETINAE
ZONULE OF ZINN
ORA SERRATA
EQUATORIAL DIAMETER
VITREOUS BODY
PARS OPTICA RETINÆ
CHOROID
SCLERA
OPTIC PAPILLA
MACULA LUTEA AND FOVEA CENTRALIS
OPTIC NERVE
OPTIC AXIS
OPTIC EXCAVATION



Steps in *phototransduction*



Photoactivation:
A photon is absorbed by a visual pigment molecule lying in one of the membranous discs contained in the outer segment.

↓

Biochemical cascade:
In the dark there is a steady movement of positively charged ions (cations) into the outer segment, via ionic channels. The visual pigment molecule, activated by the photon, initiates a cascade of events that ultimately closes these channels.

↓

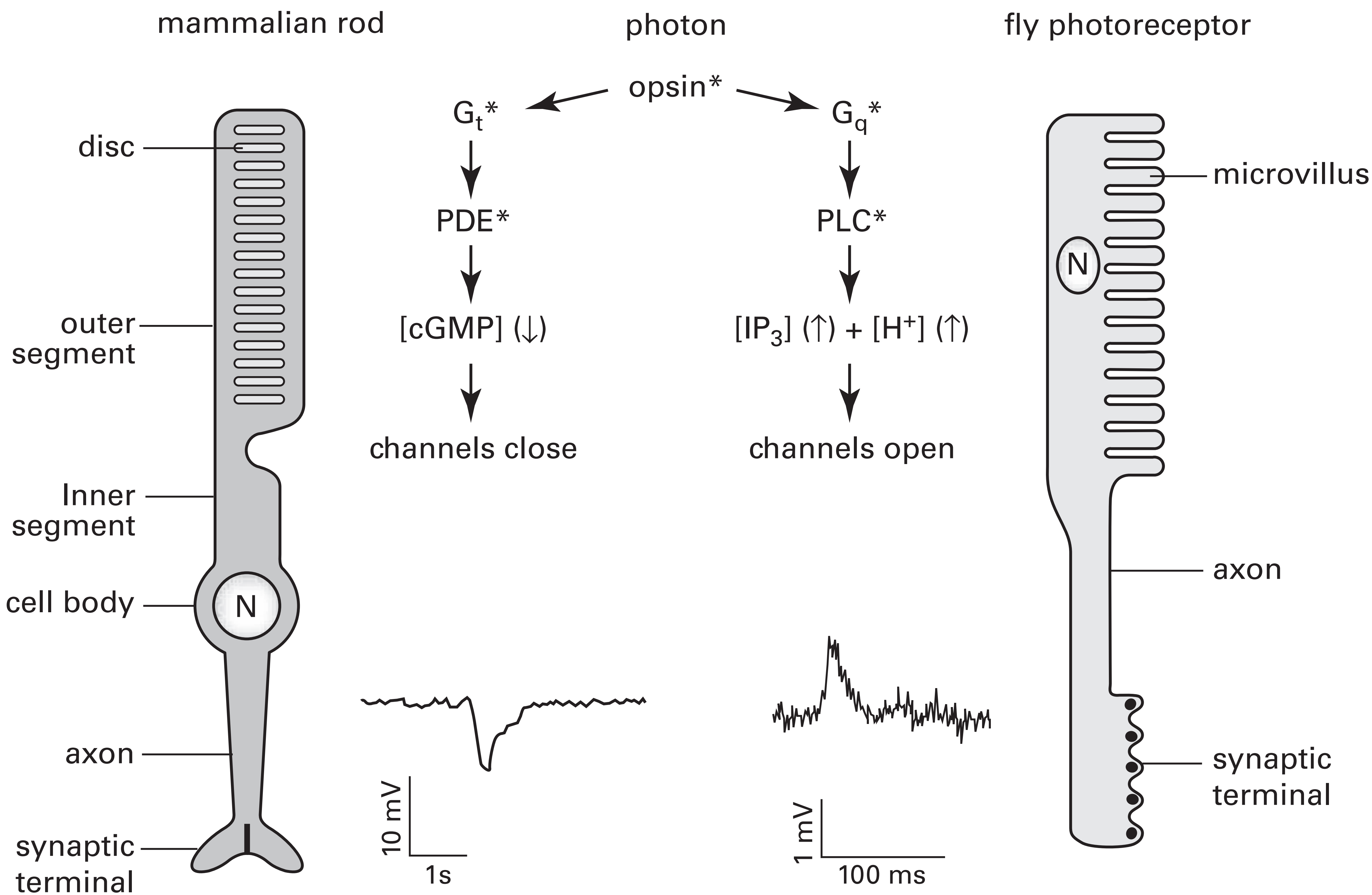
Electrotonic spread:
Normally, the movement of cations into the outer segment is balanced by the outward movement of cations, mainly through the inner segment. The decrease in inward current creates a net outward current, which makes the interior of the cell even more negative. This hyperpolarization of the cell membrane spreads throughout the cell. This is how the information about light absorption spreads to the synaptic terminal.

↓

Synaptic deactivation:
At the synaptic terminal there are calcium channels that open when the voltage across the cell membrane depolarizes and close when it hyperpolarizes. Thus the hyperpolarization of the cell membrane leads to a decrease in the rate of entry of calcium ions. Free calcium ions are continuously being removed from the cell interior, so a decrease in the rate of entry of calcium leads to a decrease in the internal concentration of free calcium ion.

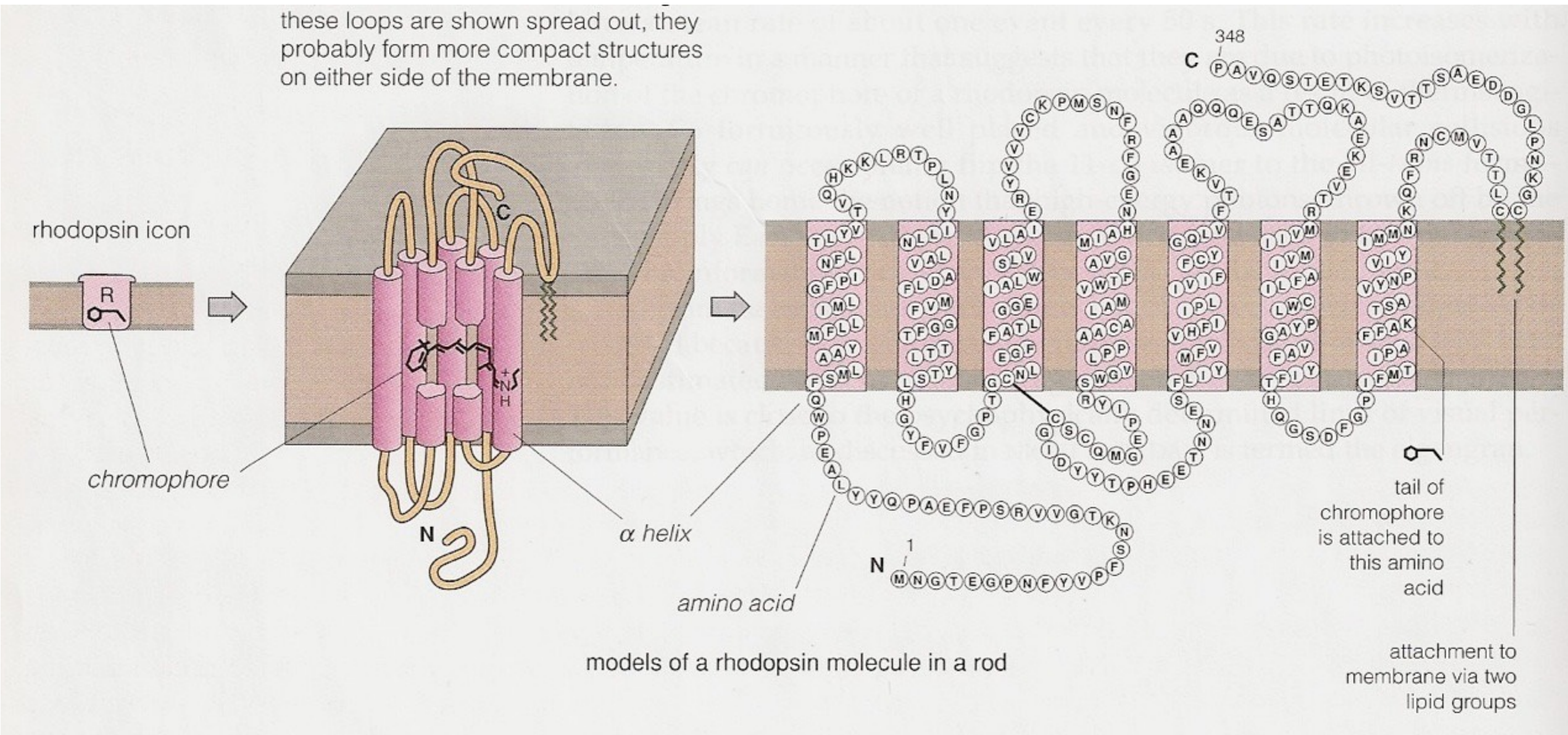
↓

Decrease in glutamate release:
The synaptic terminal contains vesicles that in turn contain glutamate molecules. In the presence of calcium ions, they are continuously released into the synaptic cleft. Thus a decrease in the internal concentration of calcium ions leads to a decrease in the rate of release of glutamate molecules.



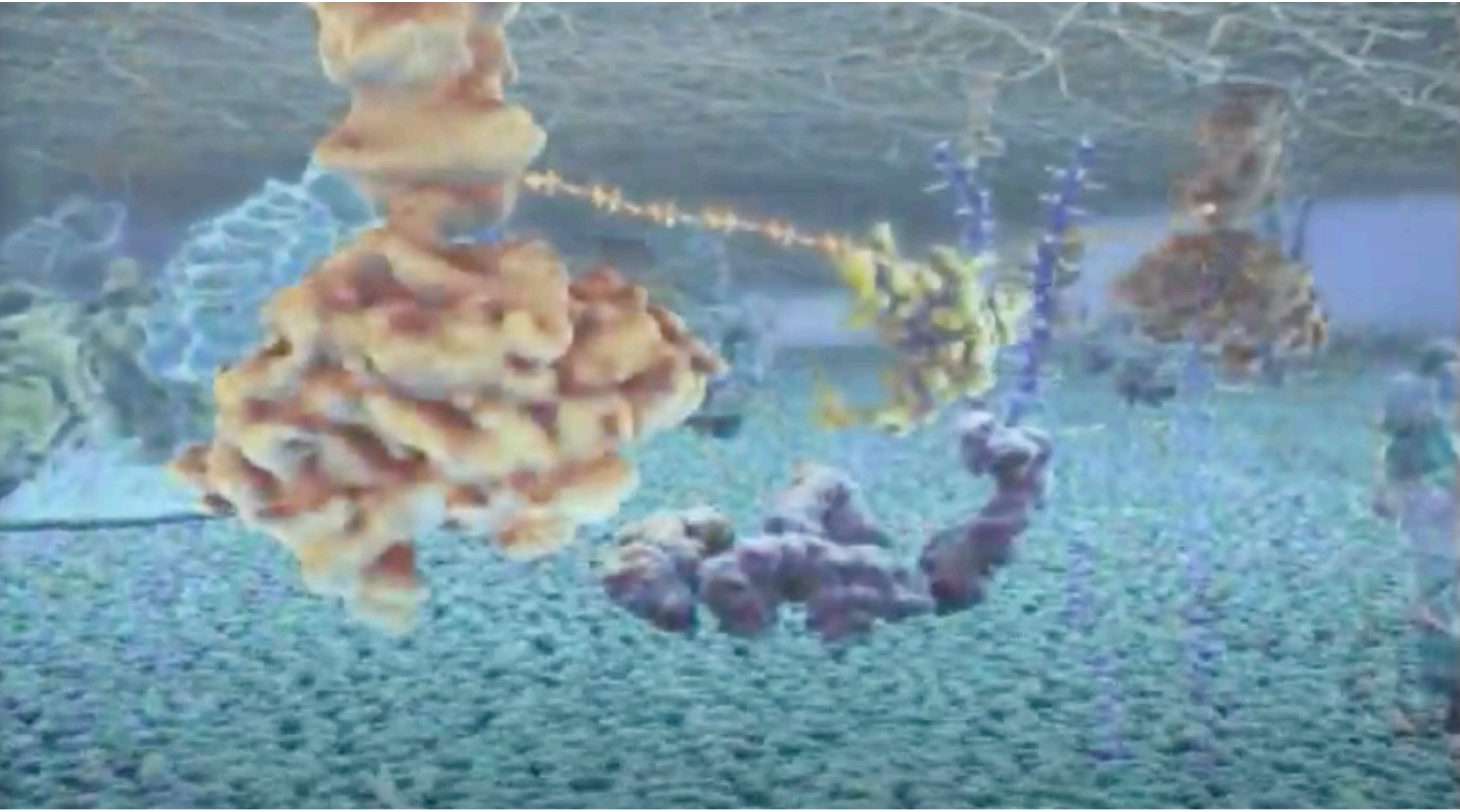
mammalian rod
photon
fly photoreceptor
opsin*
G_t*
G_q*
PDE*
PLC*
[cGMP] (↓)
[IP_3] (↑) + [H^+] (↑)
channels close
channels open
disc
outer segment
Inner segment
cell body
N
axon
synaptic terminal
microvillus
N
axon
synaptic terminal
10 mV
1s
1 mV
100 ms

Rhodopsin molecule

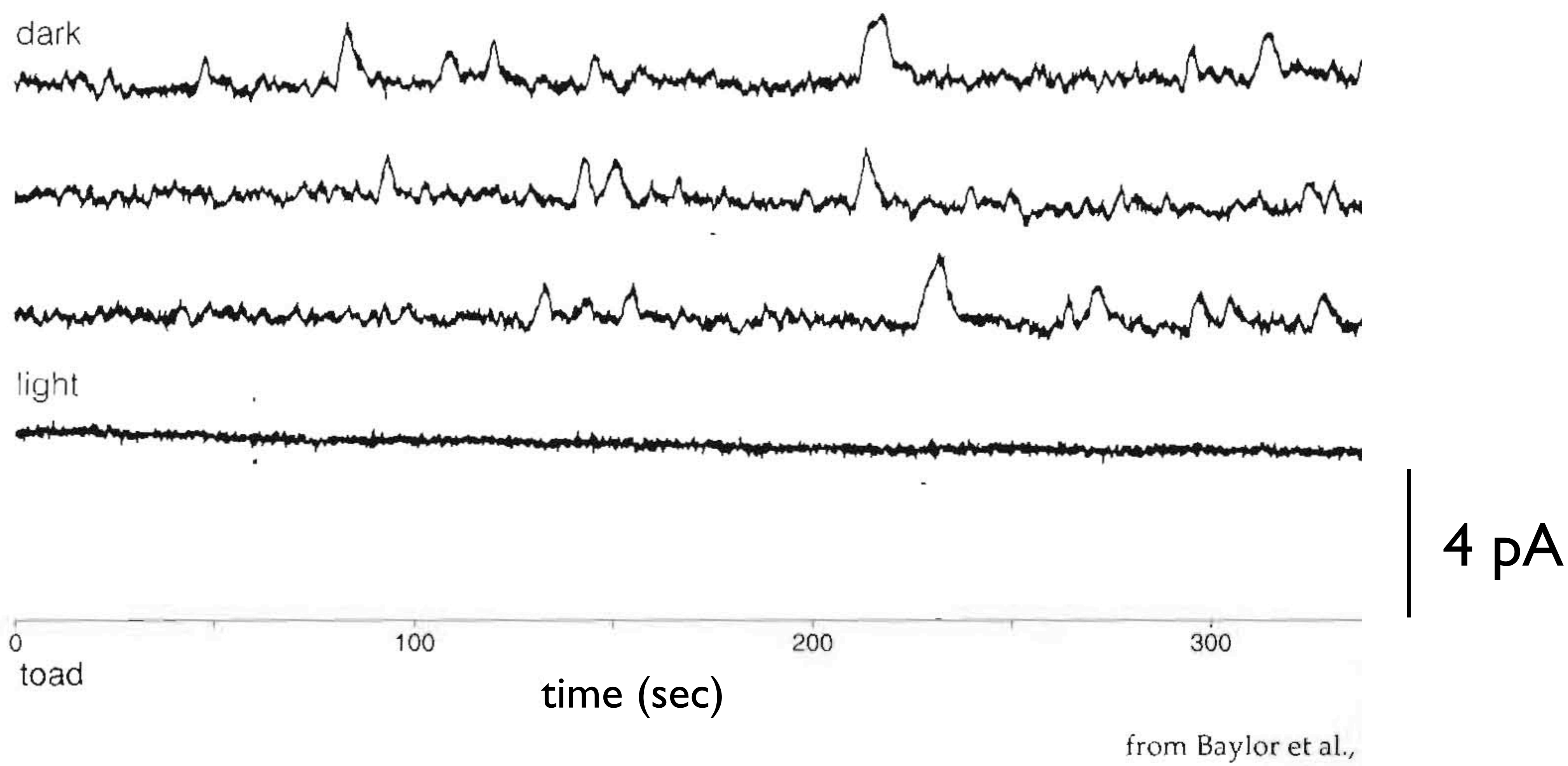


Inner Life of the Cell

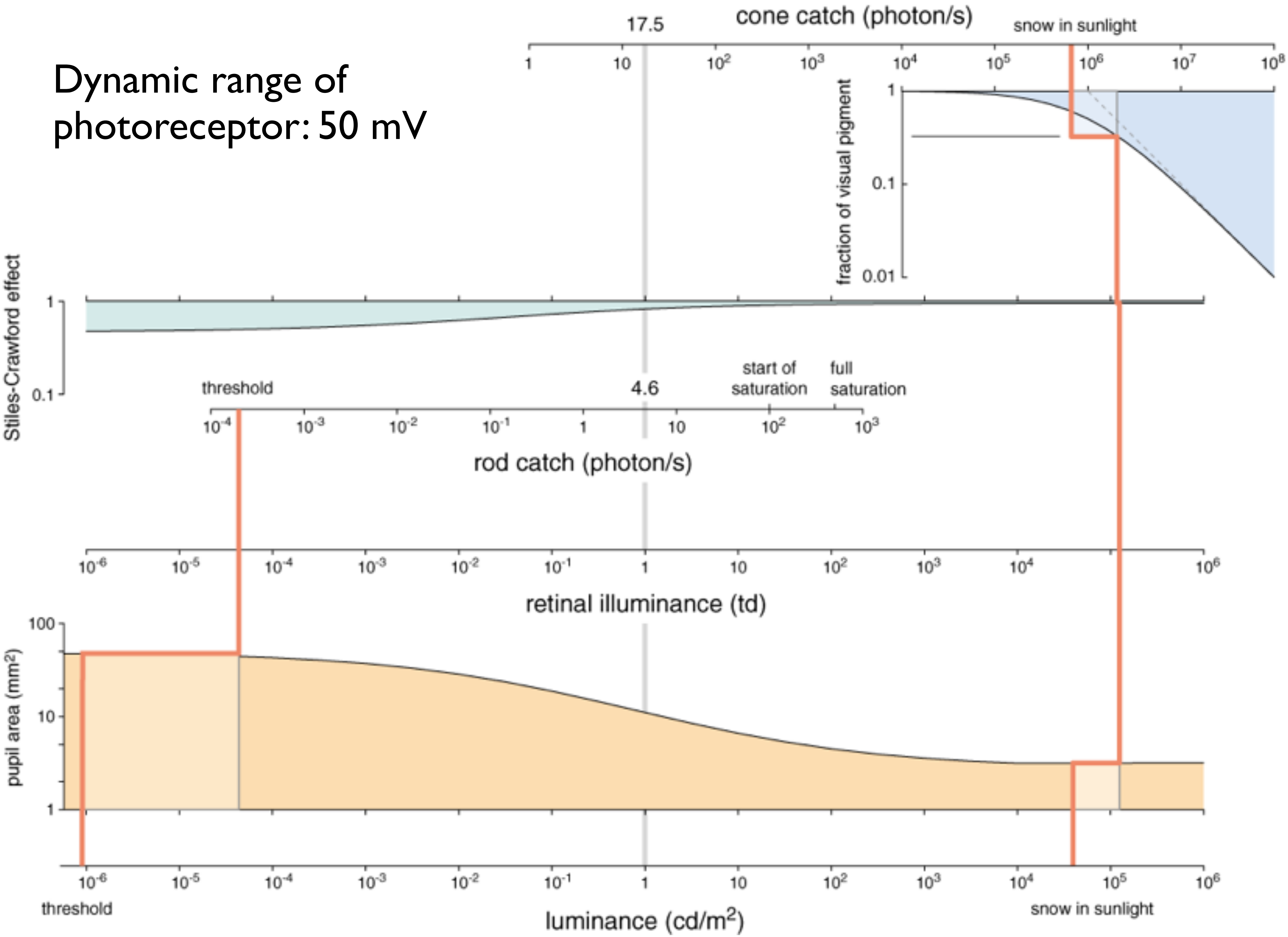
https://www.youtube.com/watch?v=wJyUtbn0O5Y



Spontaneous isomerizations determine lower limit of light detection, or visual threshold



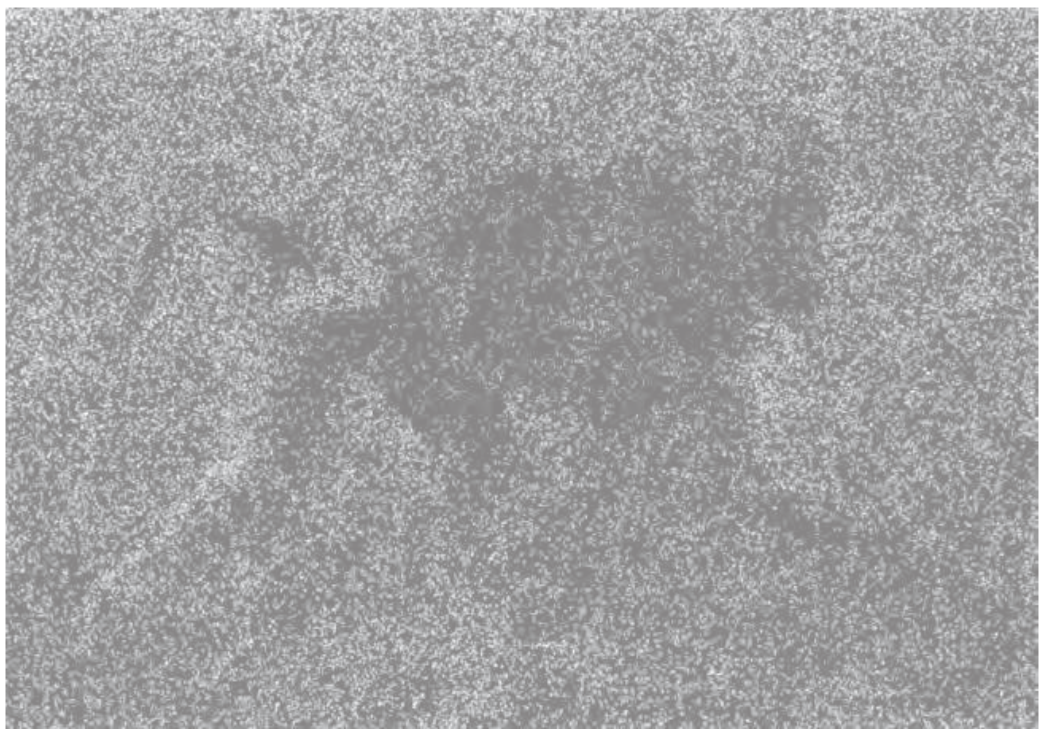
Dynamic range of photoreceptor: 50 mV



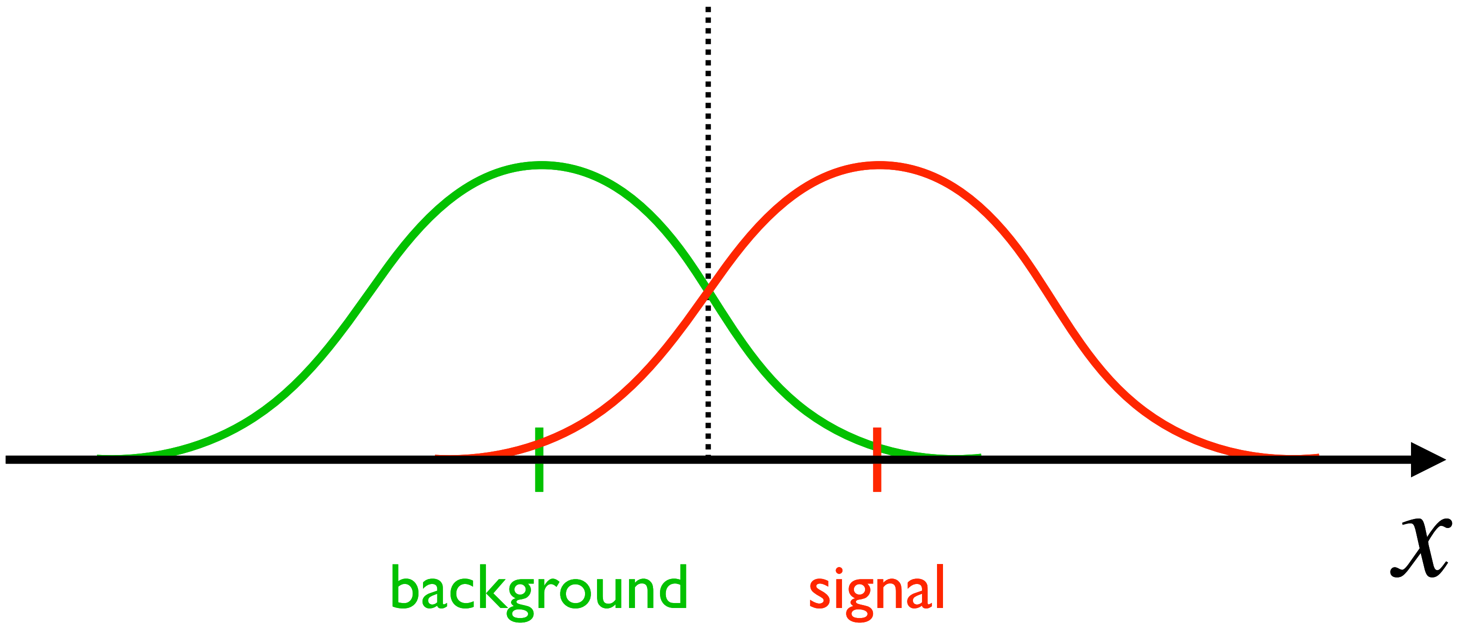
starlight CRT clear blue sky

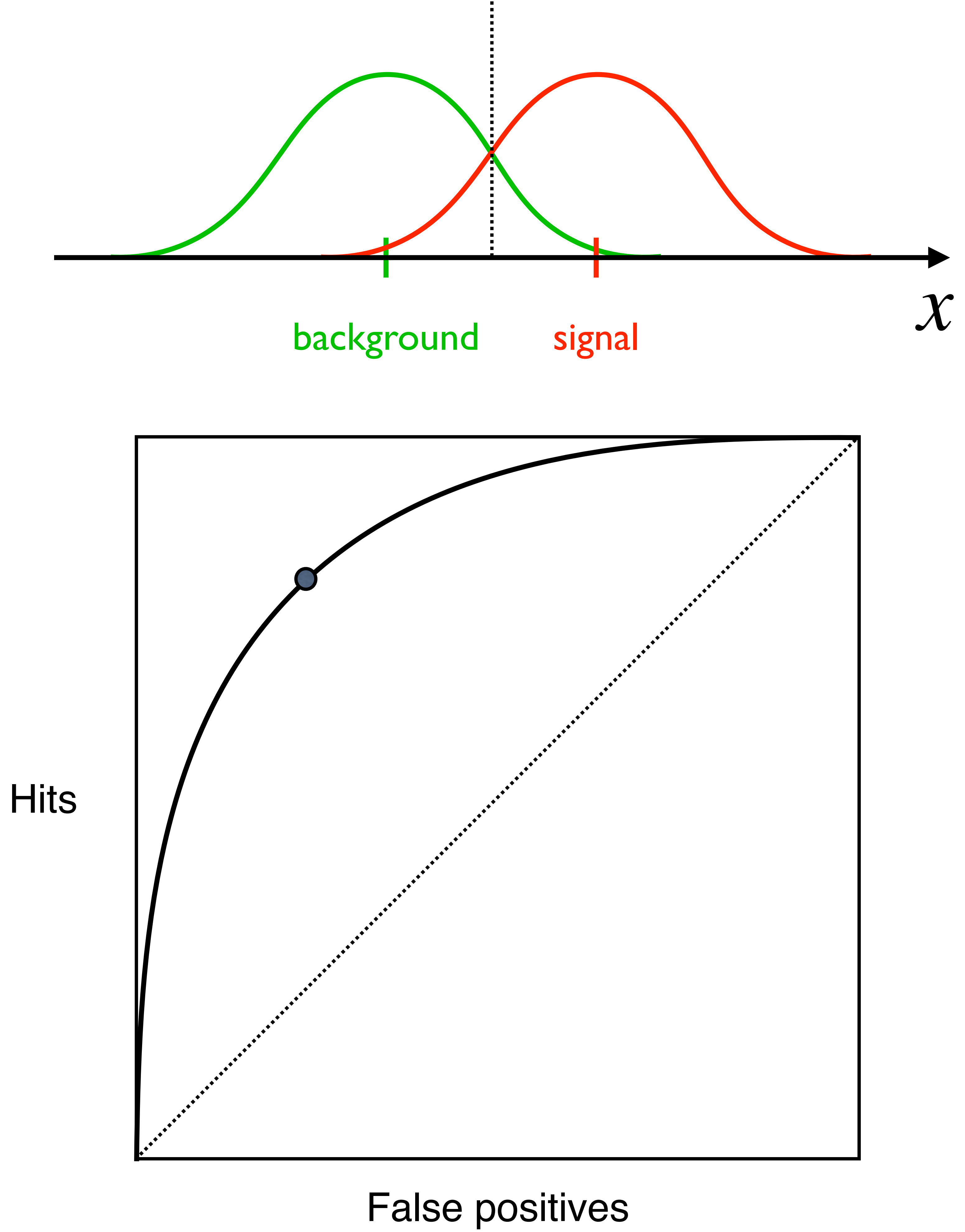
starlight

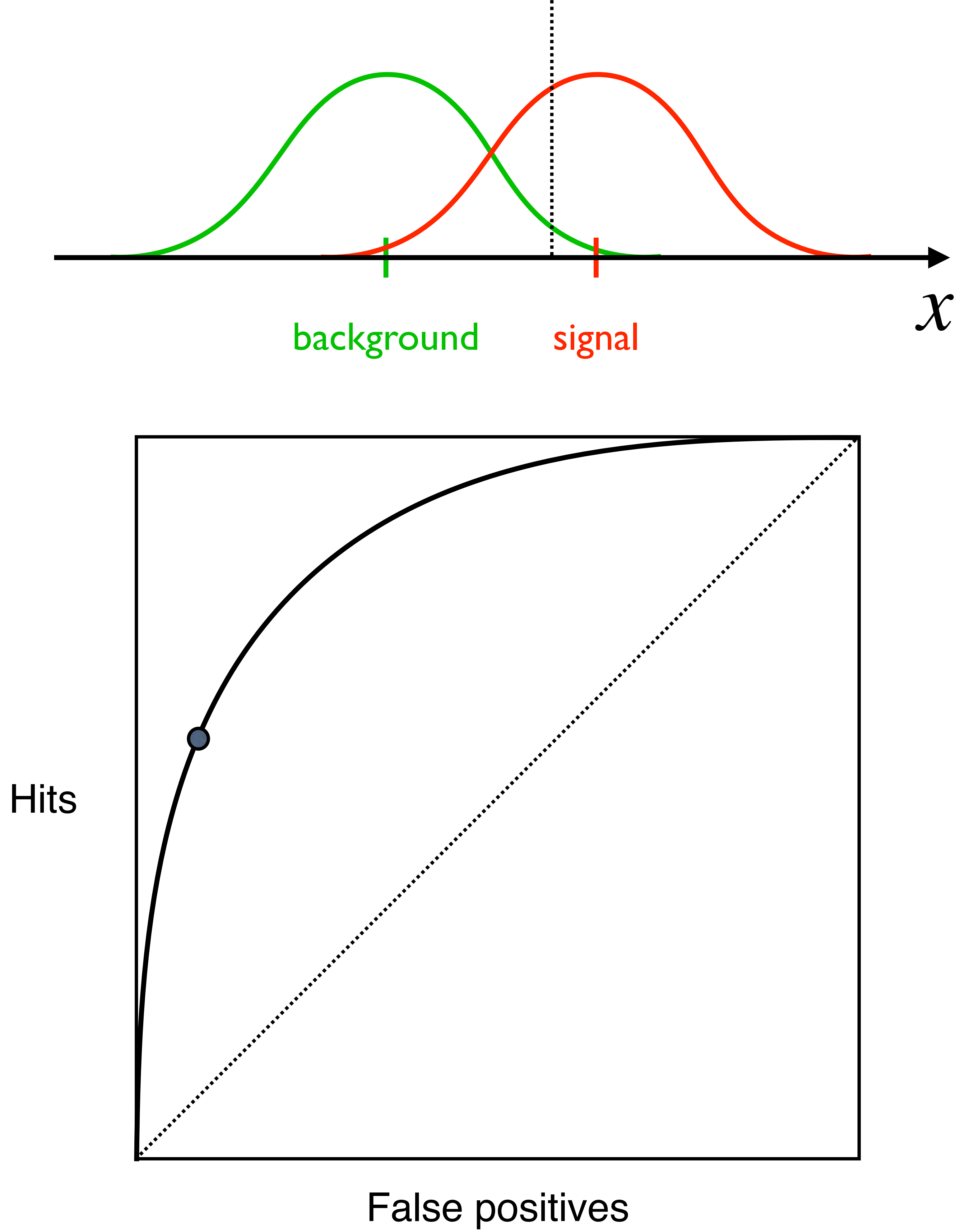
10^{-5}R*/rod/integration time

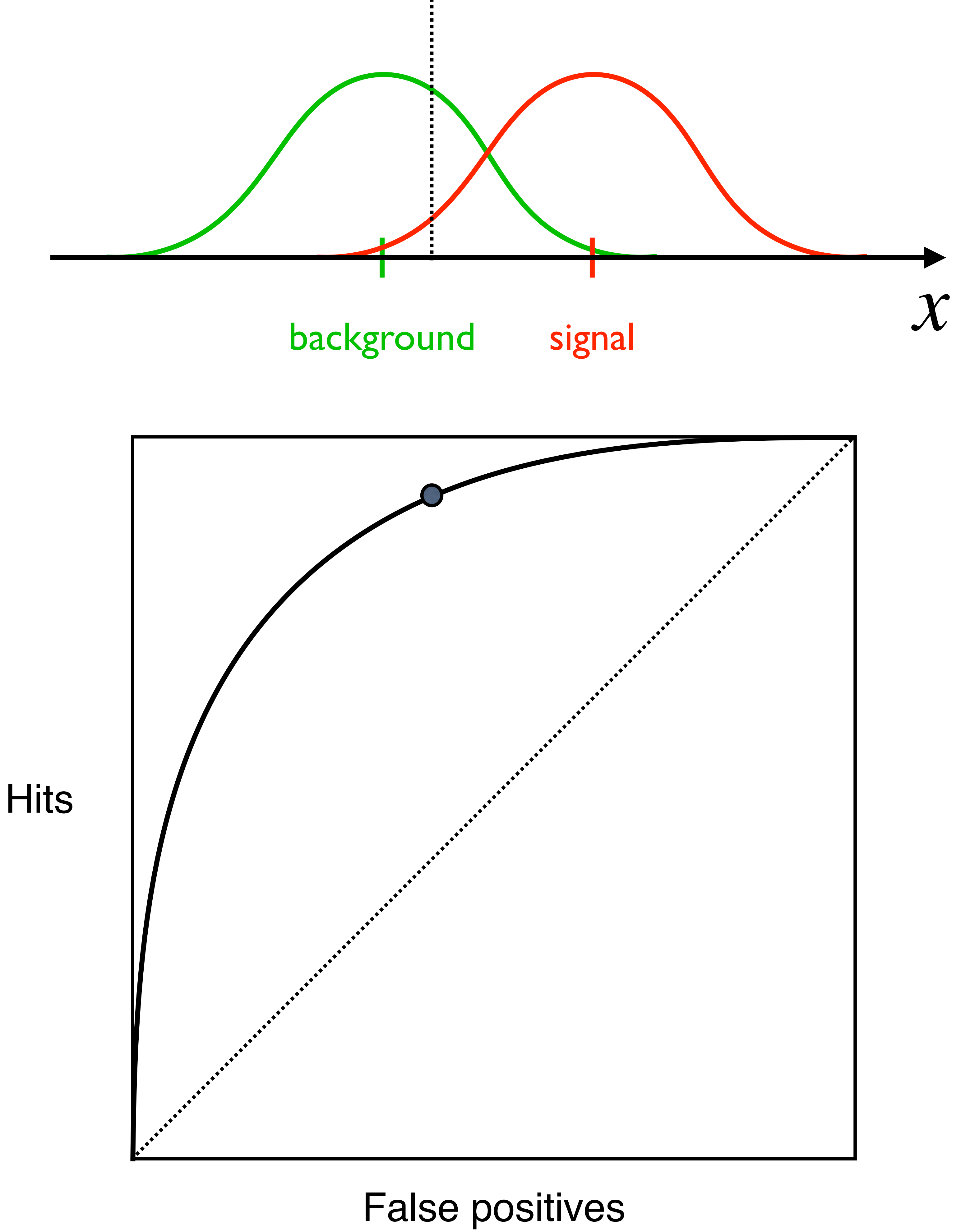


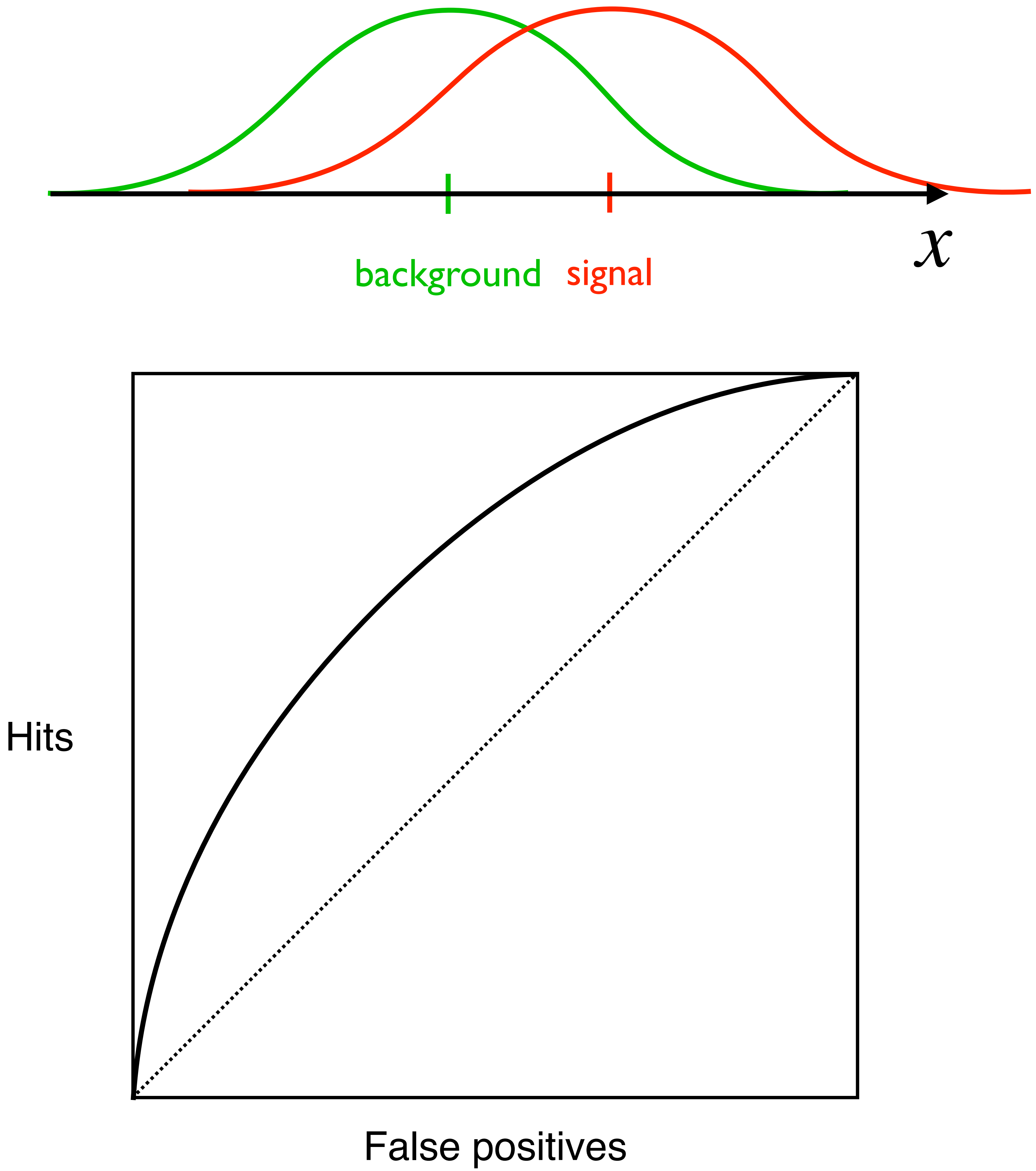
daylight


x
background
signal

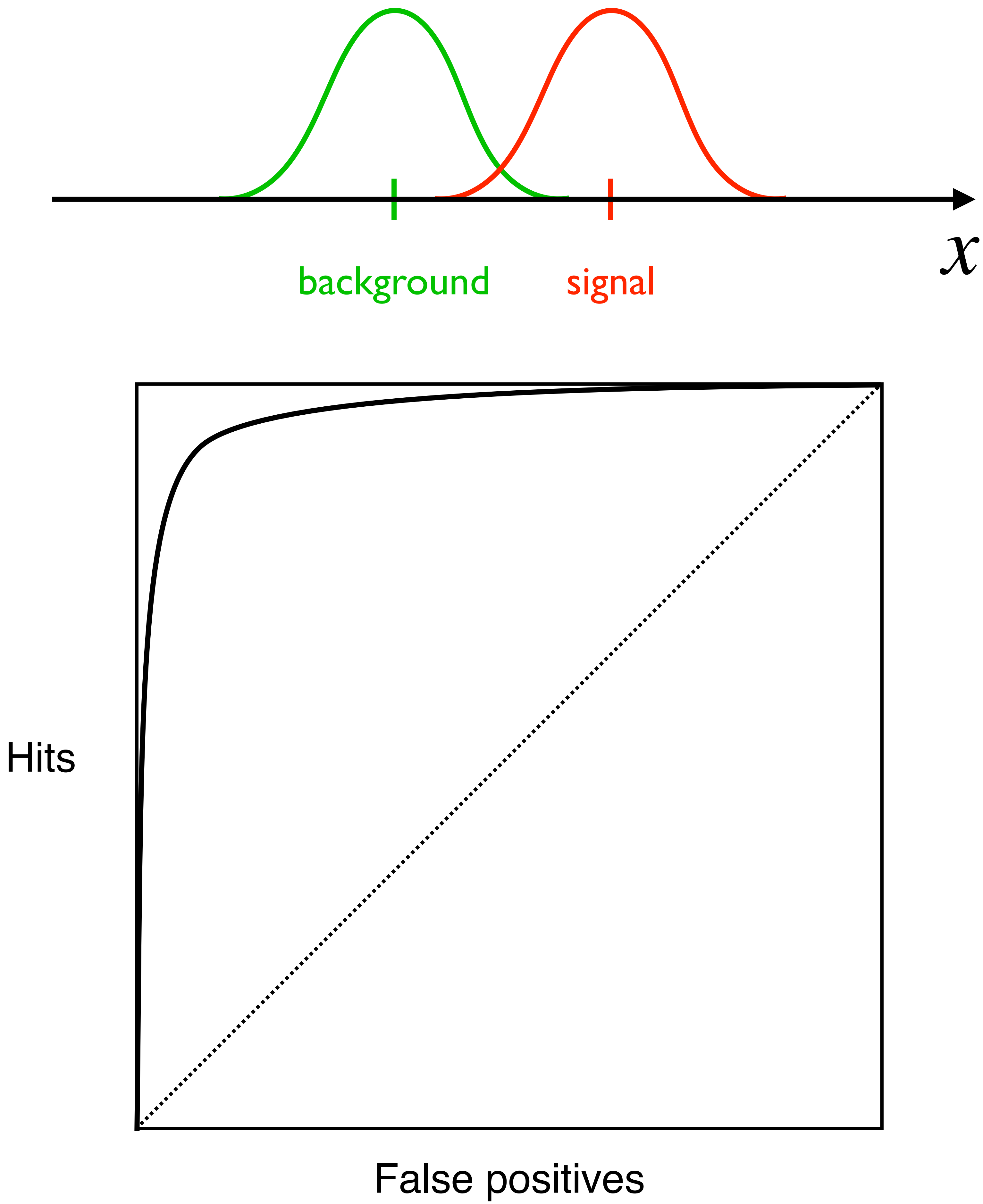

x
background
signal
Hits
False positives


x
background
signal
Hits
False positives


x
background
signal
Hits
False positives

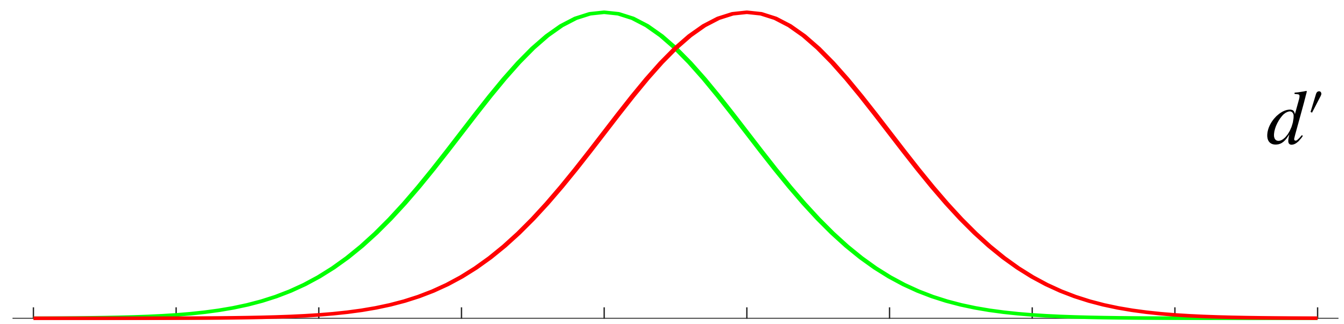


x
background
signal
Hits
False positives

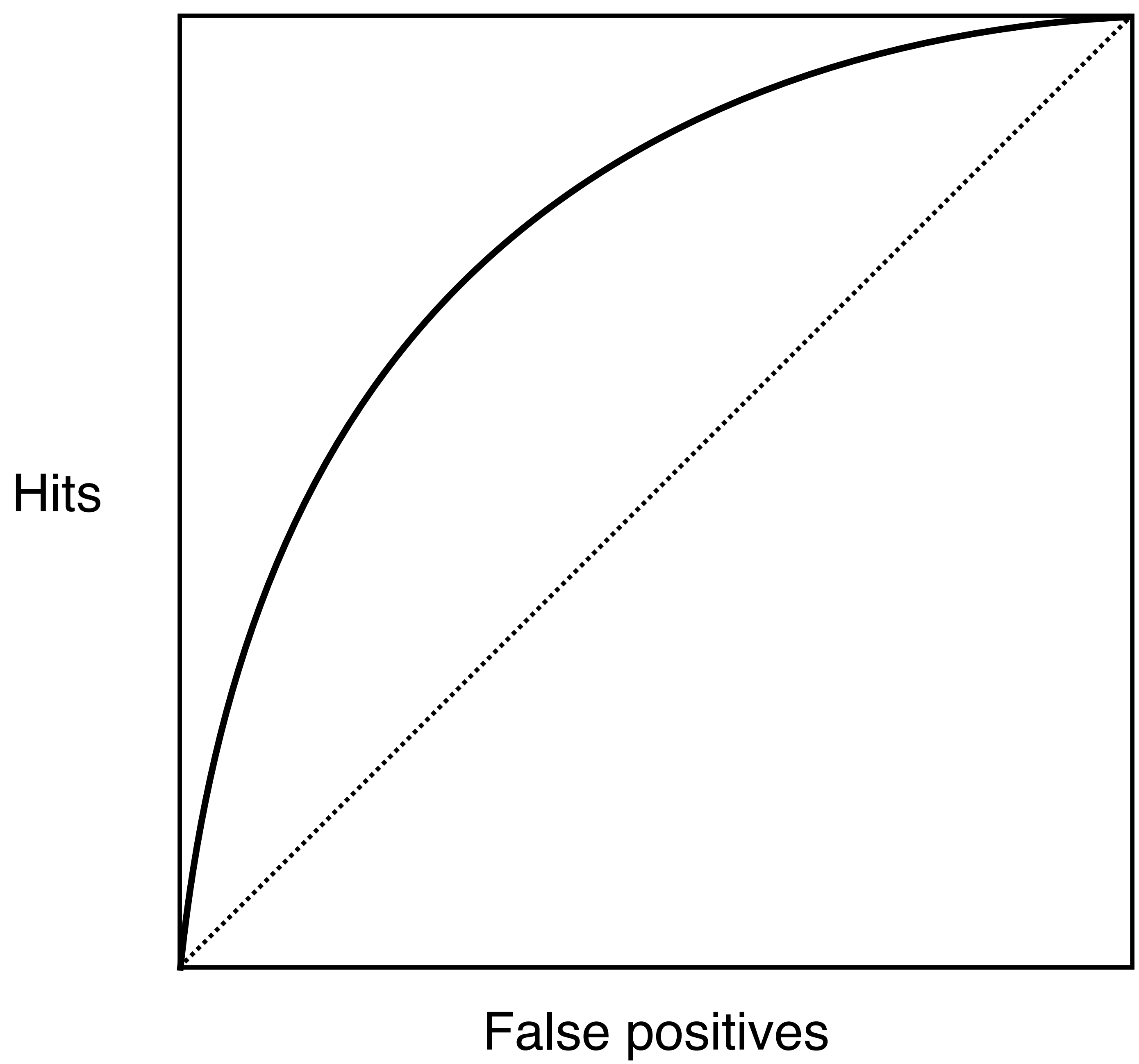


x
background
signal
Hits
False positives

At $d' = 1$, P(correct) ≈ 0.75

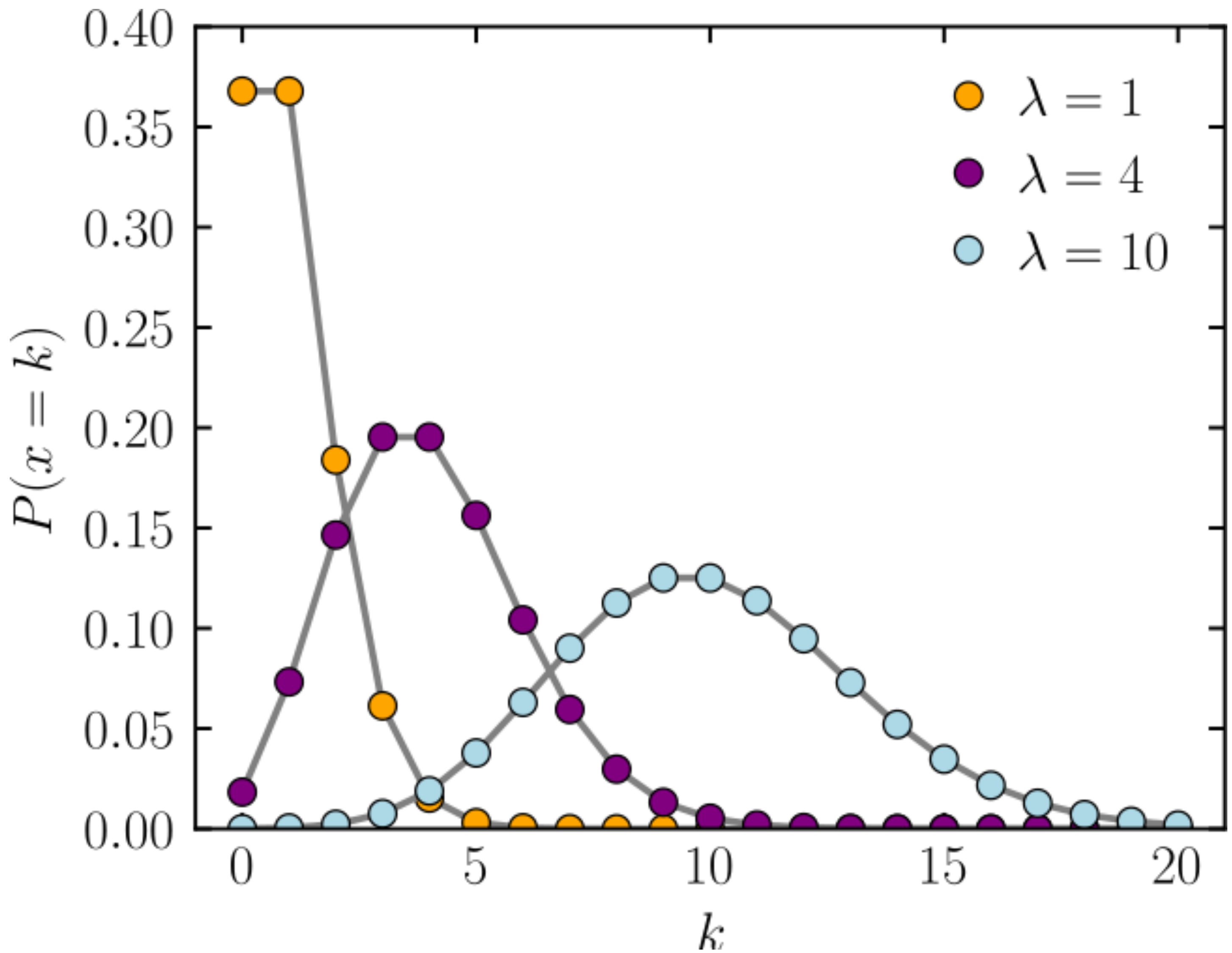


$$d' = \frac{\mu_{\text{signal}} - \mu_{\text{background}}}{\sigma}$$



Poisson distribution

$$P(k) = \frac{\lambda^k \, e^{-\lambda}}{k!}$$



mean = λ

variance = λ

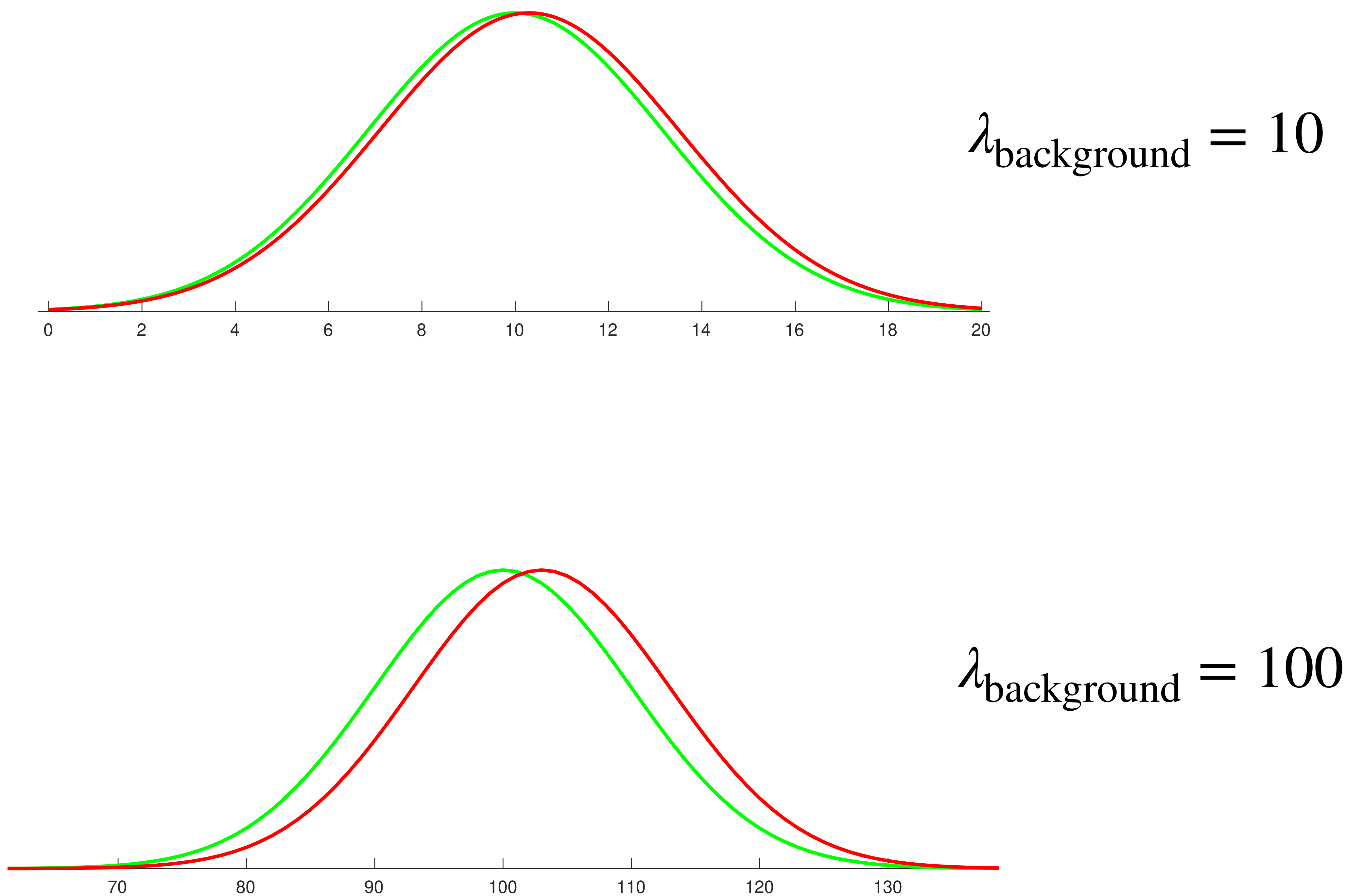
std (σ) = $\sqrt{\lambda}$

At threshold of human vision

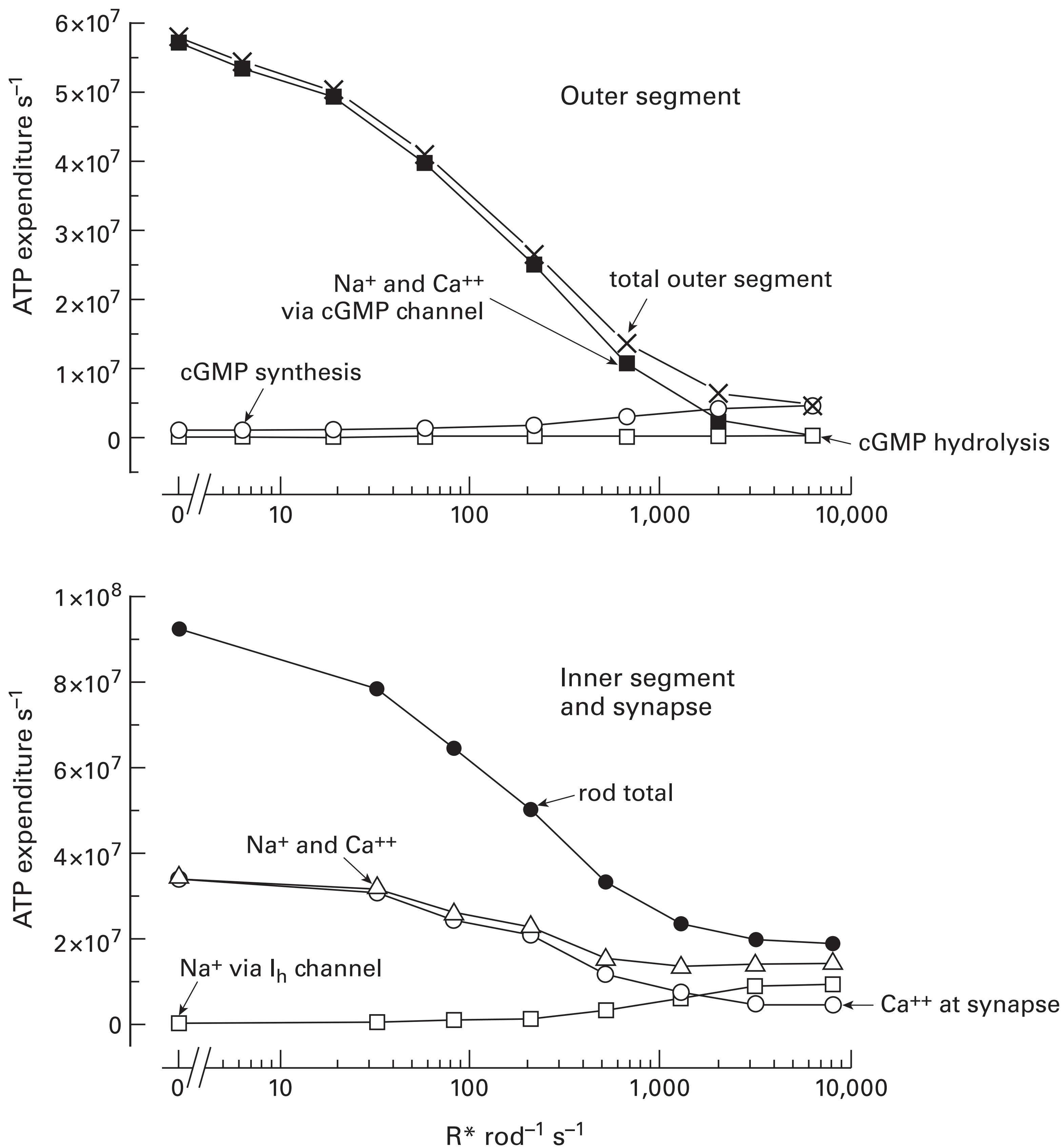
$$\lambda_{\text{background}} = 1/160$$

$$\lambda_{\text{signal}} = 1/160 + 1/5000$$

$$\frac{\lambda_{\text{signal}}}{\lambda_{\text{background}}} = 1.032$$


0
2
4
6
8
10
12
14
16
18
20
$\lambda_{\text{background}} = 10$
70
80
90
100
110
120
130
$\lambda_{\text{background}} = 100$

Energy expenditure as a function of light level



Rod bipolar cells sum thresholded outputs of rods (not linear)
(Sampath, Field, Rieke 2002-2004)