Ohm’s Law: $V = IR$

Power dissipated (Joule heating) =

$$P = I^2R = IV$$

Kirchoff's Loop equation: $$\sum_{closed\,loop} V_i = 0$$

Kirchoff's junction rule: $$\sum_{entering/leaving\ \ junction} I_i = 0$$

Resistors in series: $R_{eq} = R_1 + R_2 + \ldots$

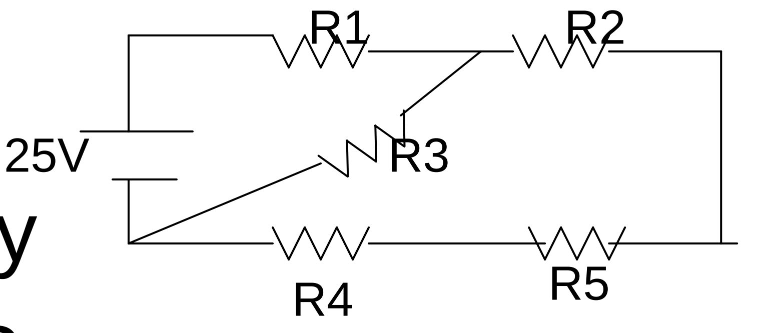
Resistors in parallel: $R_{eq}^{-1} = R_1^{-1} + R_2^{-1} + \ldots$

Capacitors in series: $C_{eq}^{-1} = C_1^{-1} + C_2^{-1} + \ldots$

Capacitors in parallel: $C_{eq} = C_1 + C_2 + \ldots$

Group Problems

1. R combo – all 100 Ω

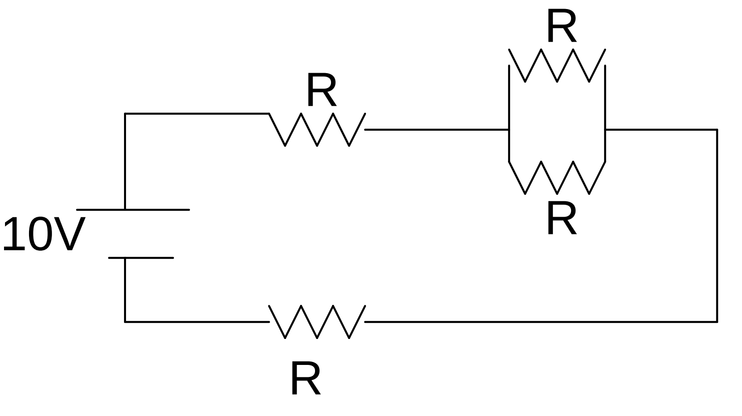


a) Find I from the battery

b) Find I through each R

2. a) Find equivalent R (in terms of R)

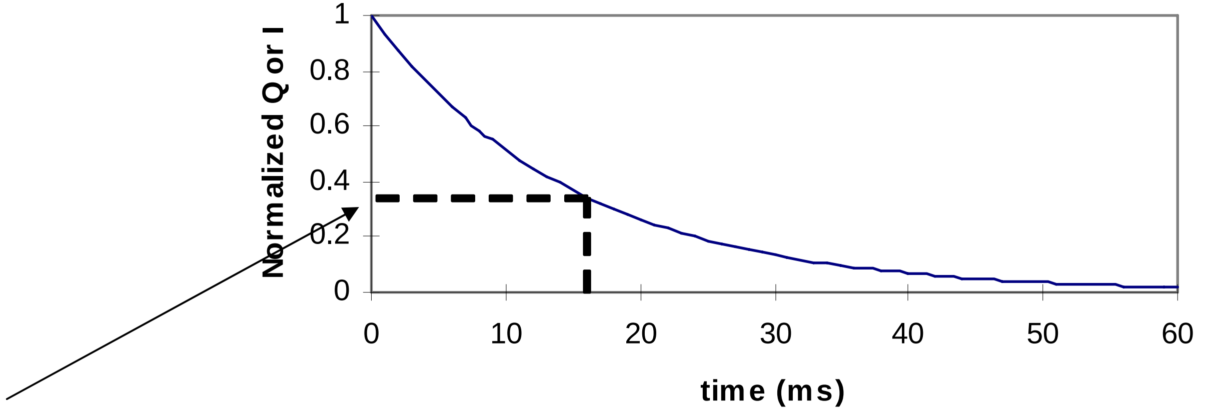
   b) Find the battery current if R = 100 Ω



Simple RC Series circuit

- Discharging: $Q(t) = Q_o exp(-t/RC)$

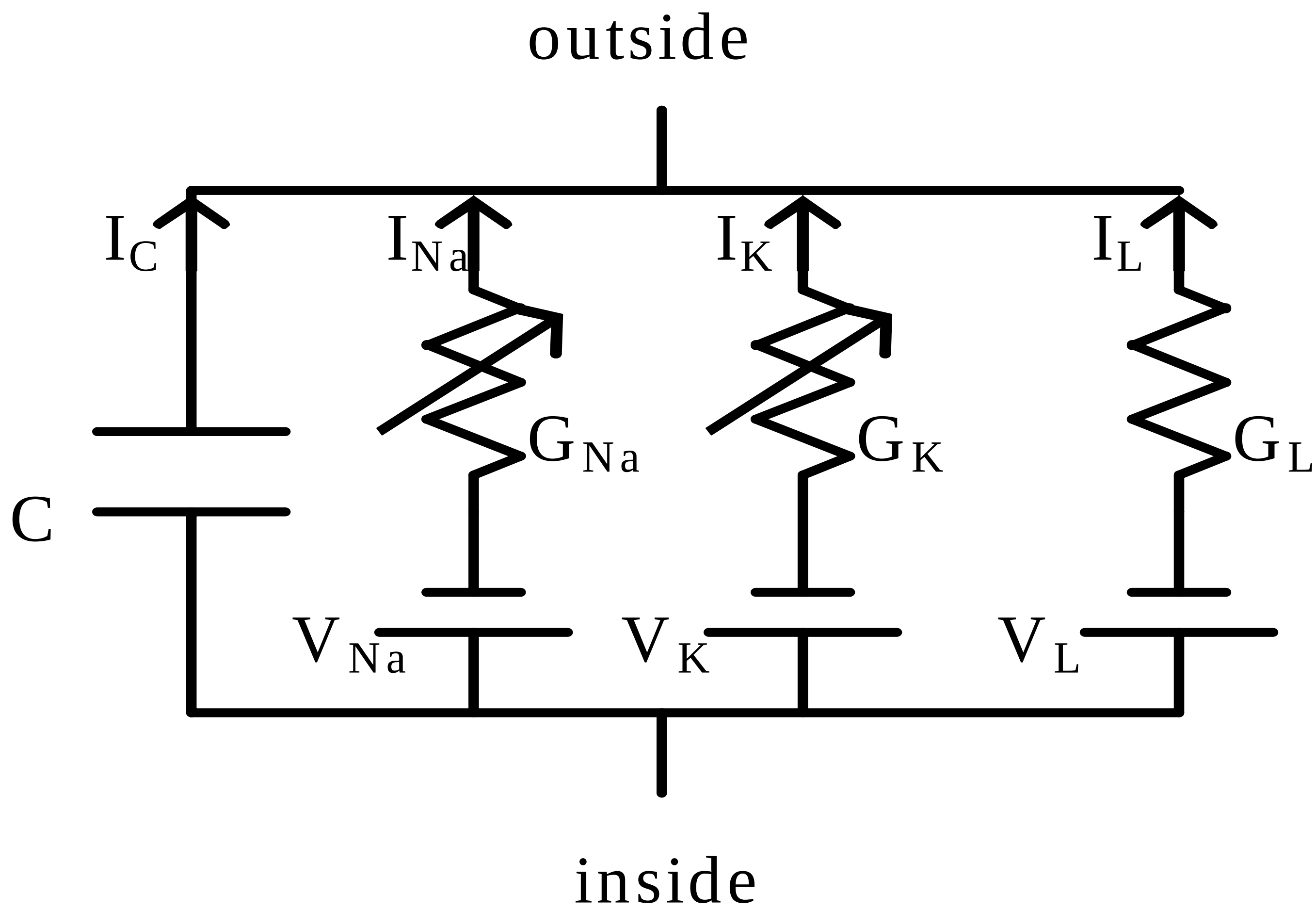
  and $I(t) = I_o exp(-t/RC)$



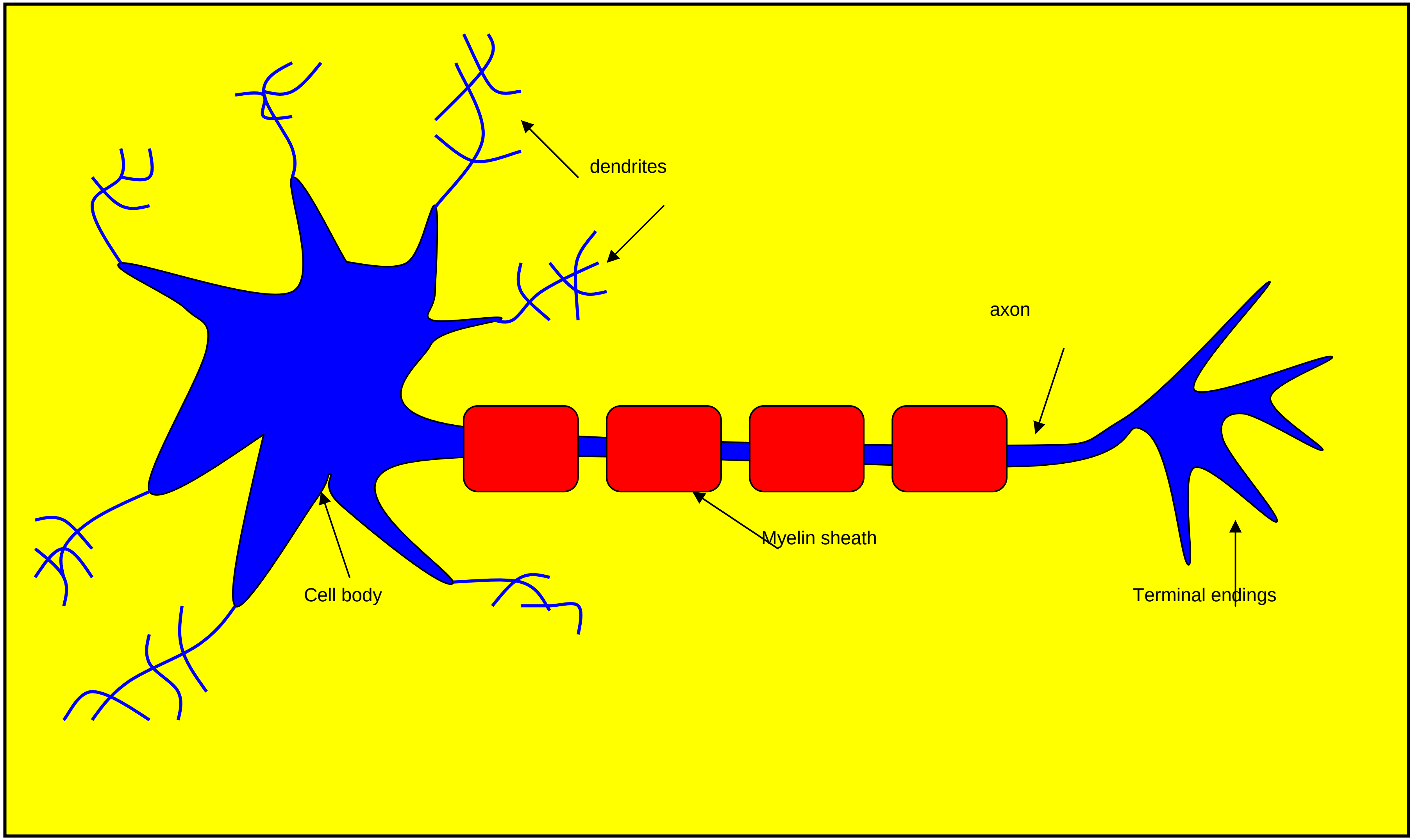
When t = RC = 1 time constant, then
$Q = Q_o exp(-1) = 0.37Q_o$

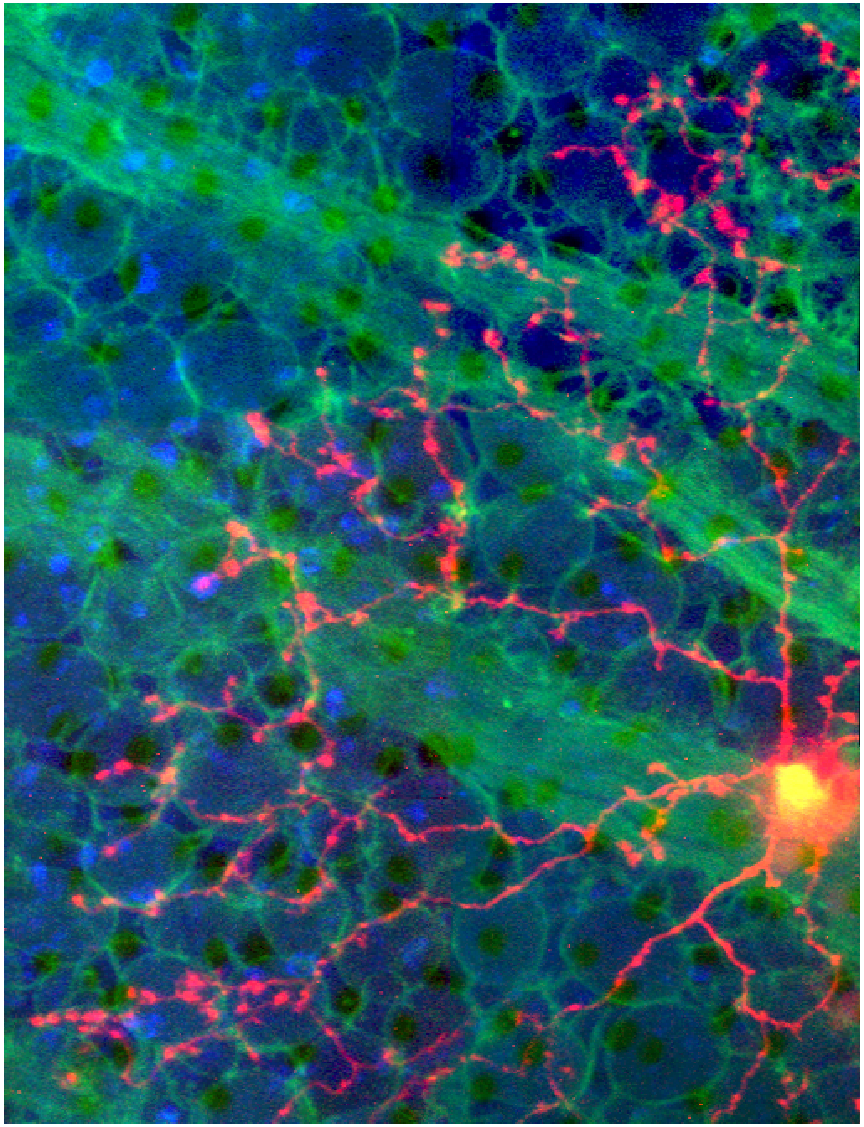
Microscopic Picture of Electric Current

- E field in wire produces forces on free electrons leading to a net drift velocity: $v_{drift} = a\tau$, where a is the acceleration ($a = F/m = eE/m = e(V/L)/m$ where V is the applied voltage across the wire of length L) and τ is the mean-free time between collisions
- Solving for the charge drifting by allows us to compute the current I: $I=[(ne^2\tau/m)(A/L)]V = [1/R]V = GV$, where n is the free charge density, e is the electron charge, A is the wire cross-sectional area, R is the wire's resistance and G is its conductance
- We can also introduce intrinsic parameters: conductivity, $\sigma = ne^2\tau/m$ and resistivity, $\rho = 1/\sigma$ to write $R = \rho L/A$

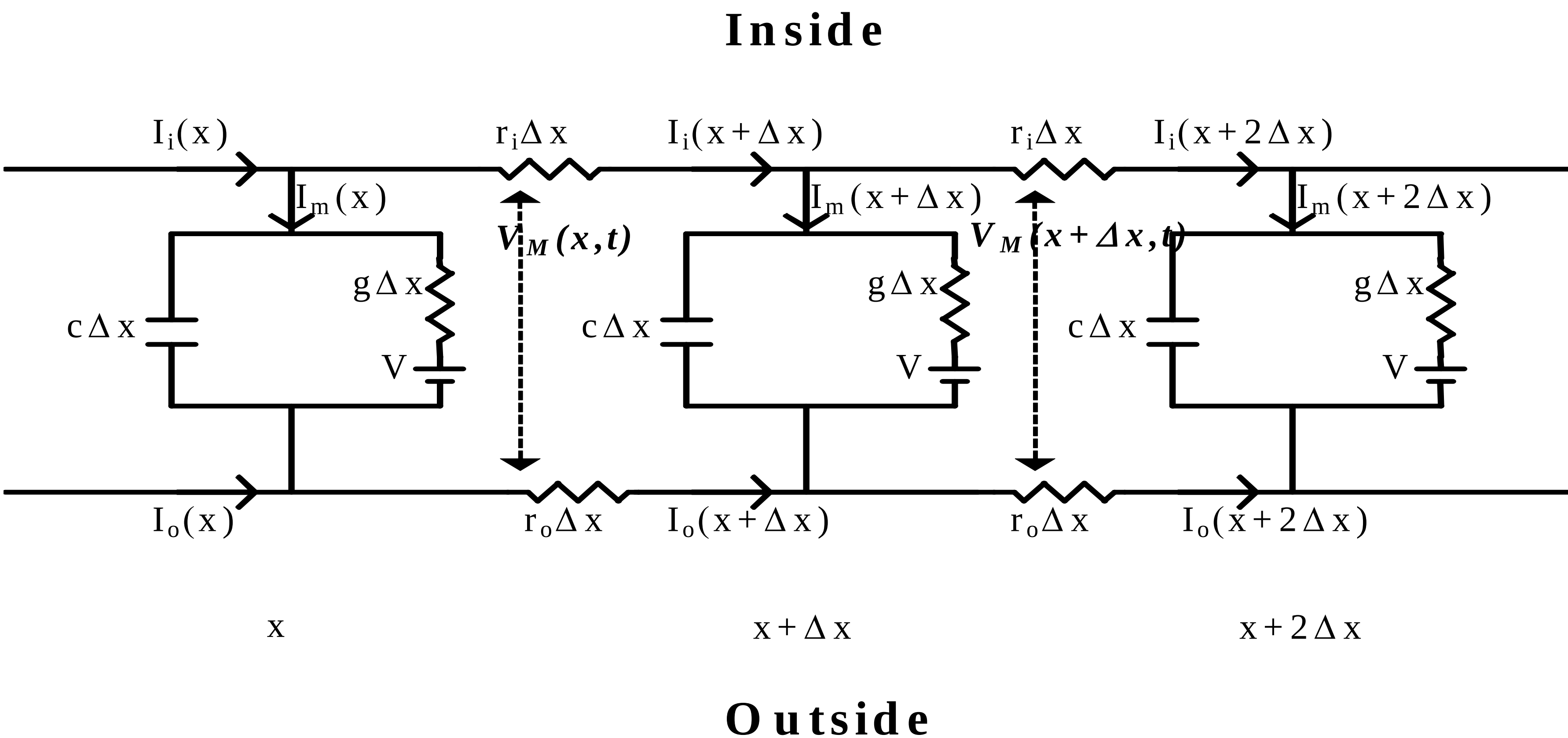


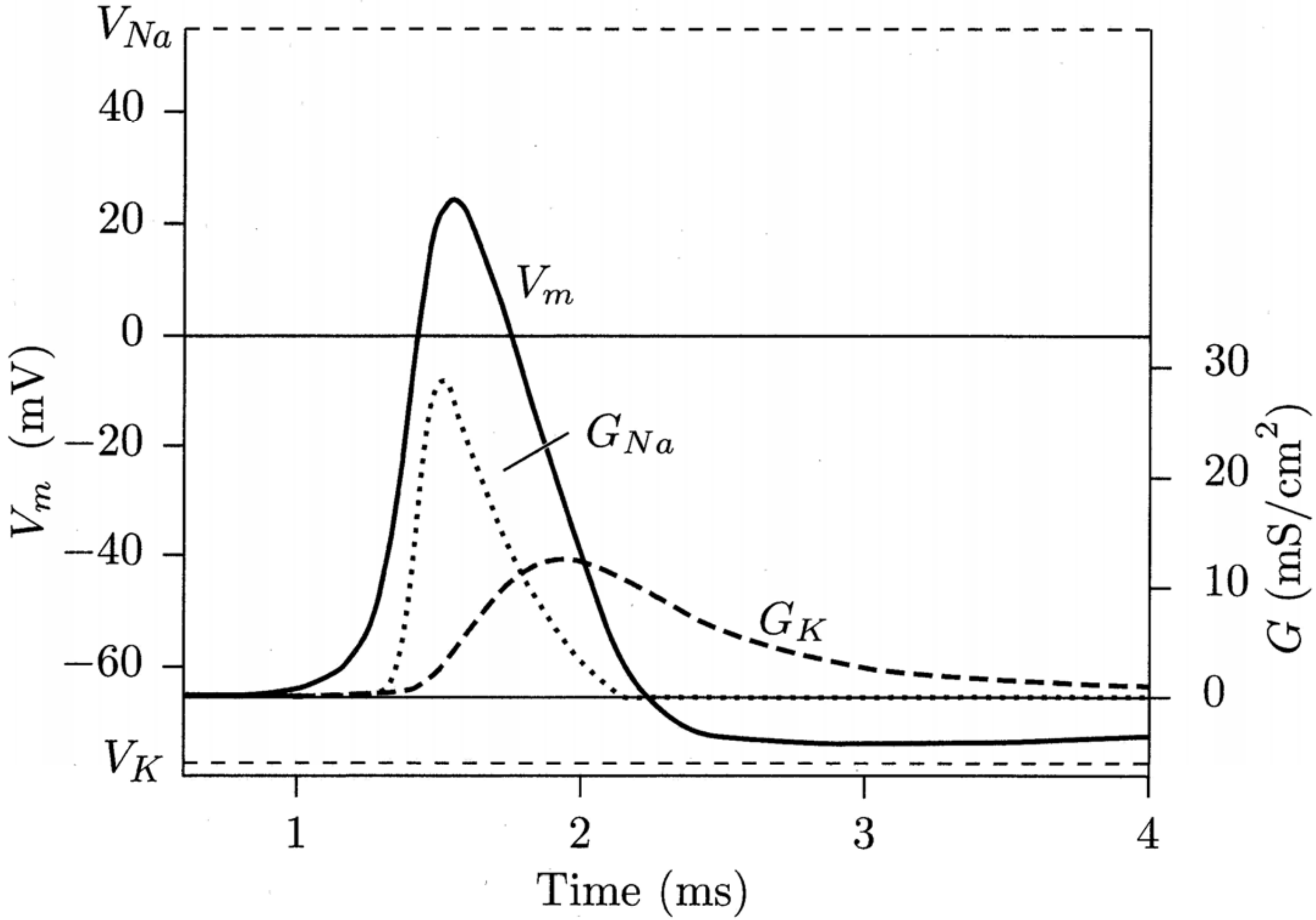
outside
I_C
I_{Na}
I_K
I_L
G_{Na}
G_K
G_L
C
V_{Na}
V_K
V_L
inside


dendrites
axon
Myelin sheath
Cell body
Terminal endings

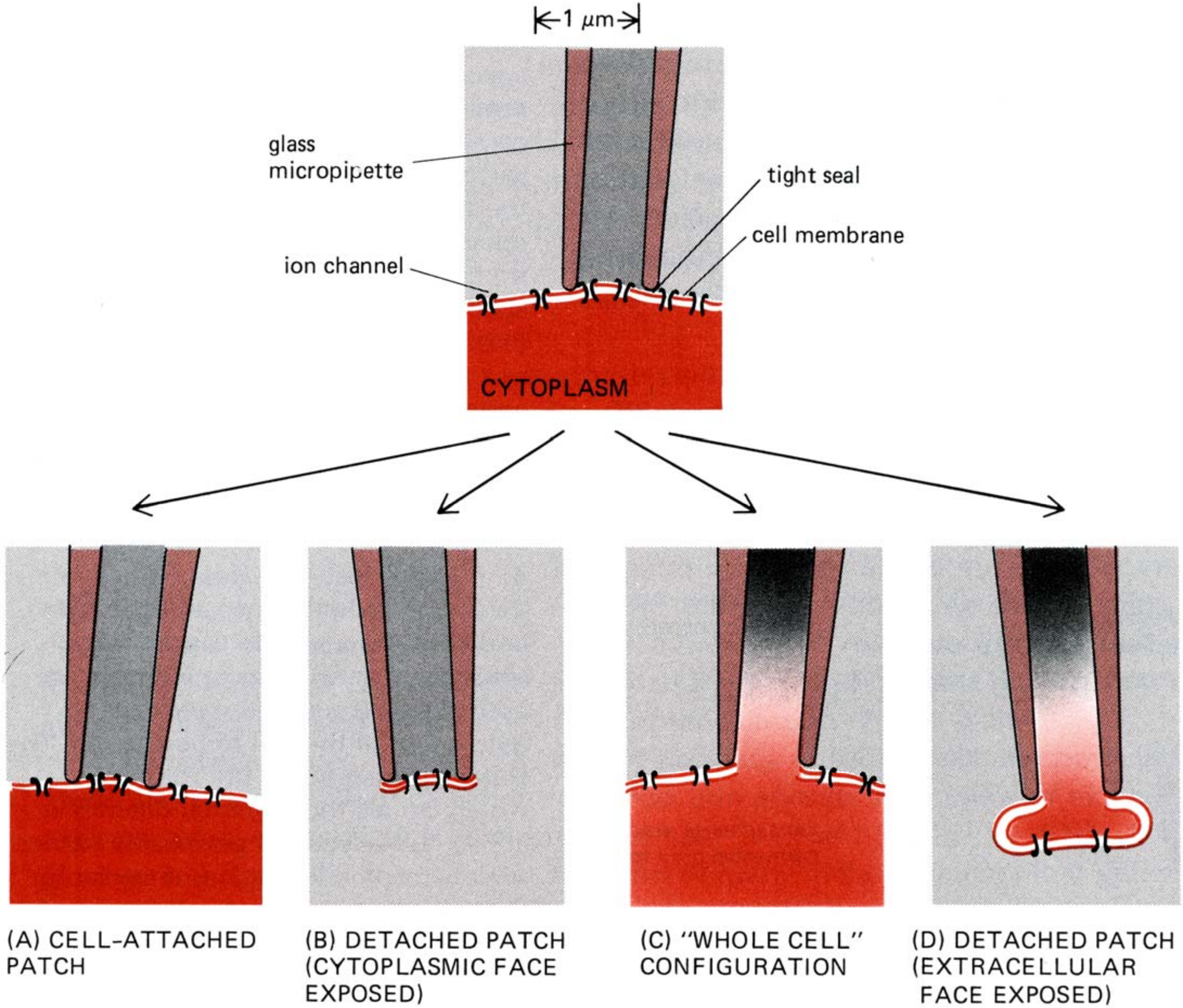


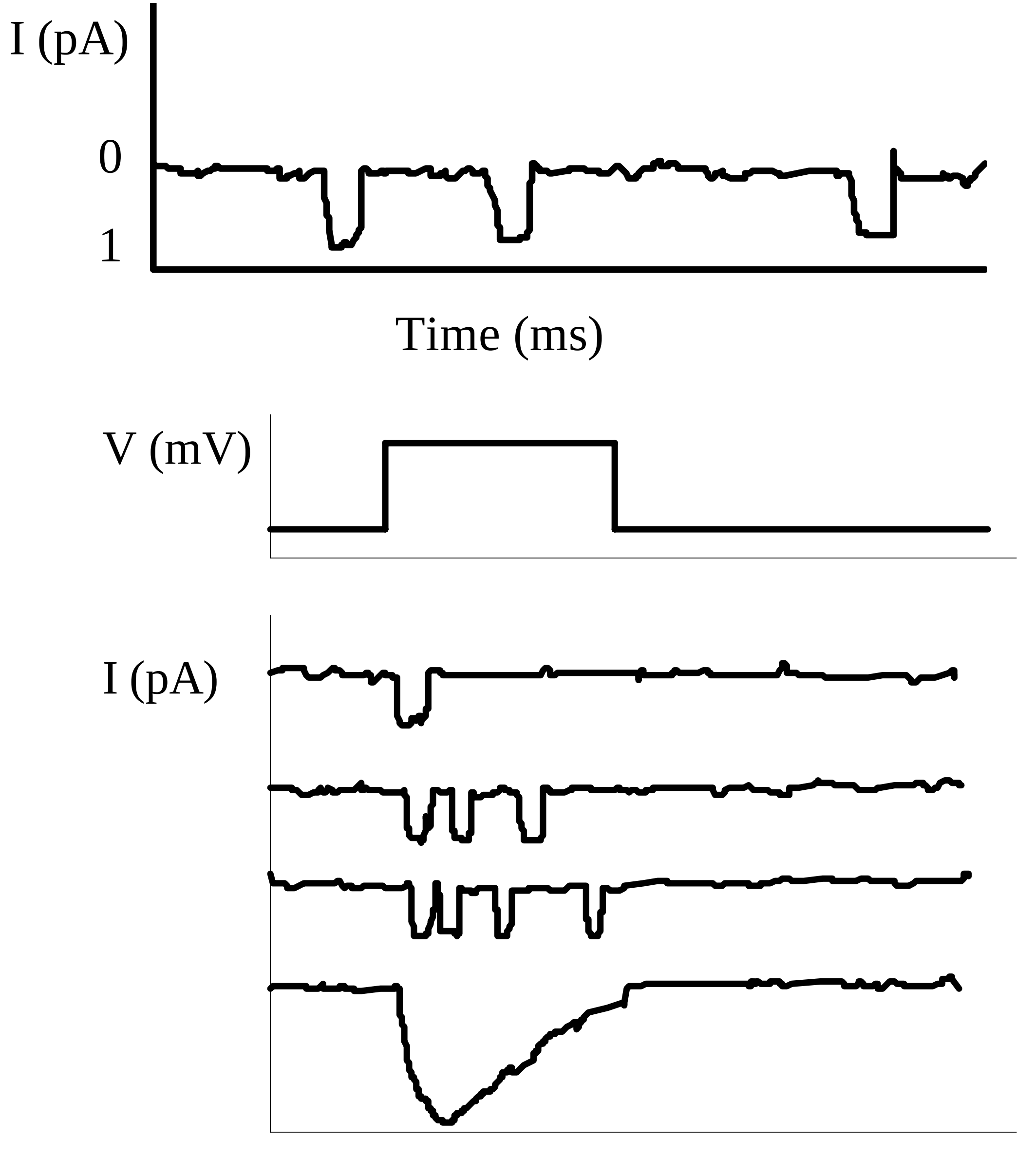
retinal “starburst” cell (red) found in visual processing network, Courtesy of Thomas Euler, Max Planck Institute for Medical Research, Heidelberg


Inside
$I_i(x)$
$r_i \Delta x$
$I_i(x+\Delta x)$
$r_i \Delta x$
$I_i(x+2\Delta x)$
$I_m(x)$
$I_m(x+\Delta x)$
$I_m(x+2\Delta x)$
$V_M(x,t)$
$V_M(x+\Delta x,t)$
$g\Delta x$
$g\Delta x$
$g\Delta x$
$c\Delta x$
$c\Delta x$
$c\Delta x$
V
V
V
$I_o(x)$
$r_o \Delta x$
$I_o(x+\Delta x)$
$r_o \Delta x$
$I_o(x+2\Delta x)$
x
$x+\Delta x$
$x+2\Delta x$
Outside



V_{Na}
40
20
0
−20
−40
−60
V_K
V_m (mV)
V_m
G_{Na}
G_K
30
20
10
0
G (mS/cm^2)
1
2
3
4
Time (ms)


1 μm
glass micropipette
tight seal
cell membrane
ion channel
CYTOPLASM
(A) CELL-ATTACHED PATCH
(B) DETACHED PATCH (CYTOPLASMIC FACE EXPOSED)
(C) "WHOLE CELL" CONFIGURATION
(D) DETACHED PATCH (EXTRACELLULAR FACE EXPOSED)



I (pA)
0
1
Time (ms)
V (mV)
I (pA)
Time (ms)