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EU ADVANCED COURSE IN COMPUTATIONAL NEUROSCIENCE

An IBRO Neuroscience School

(30 July - 24 August 2001)

"Is the Striatum a Competitive Network?"

presented by:

Charles J. WILSON

University of Texas at San Antonio
Division of Life Sciences
6900 N. Loop, 1604 W.
San Antonio, TX 78249
U.S.A.

C. J. Wilson

Is the Striatum a Competitive Network?

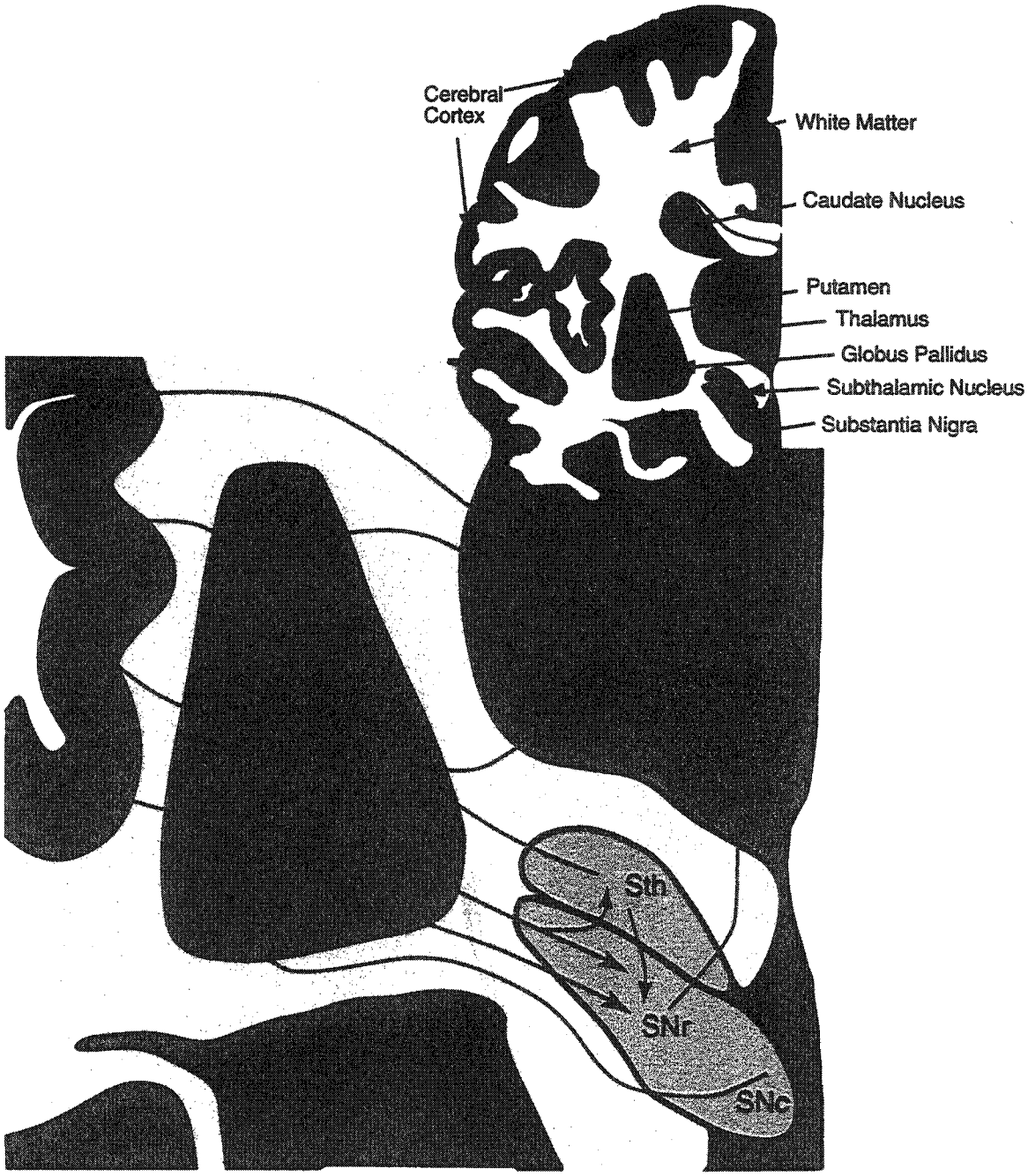
References:

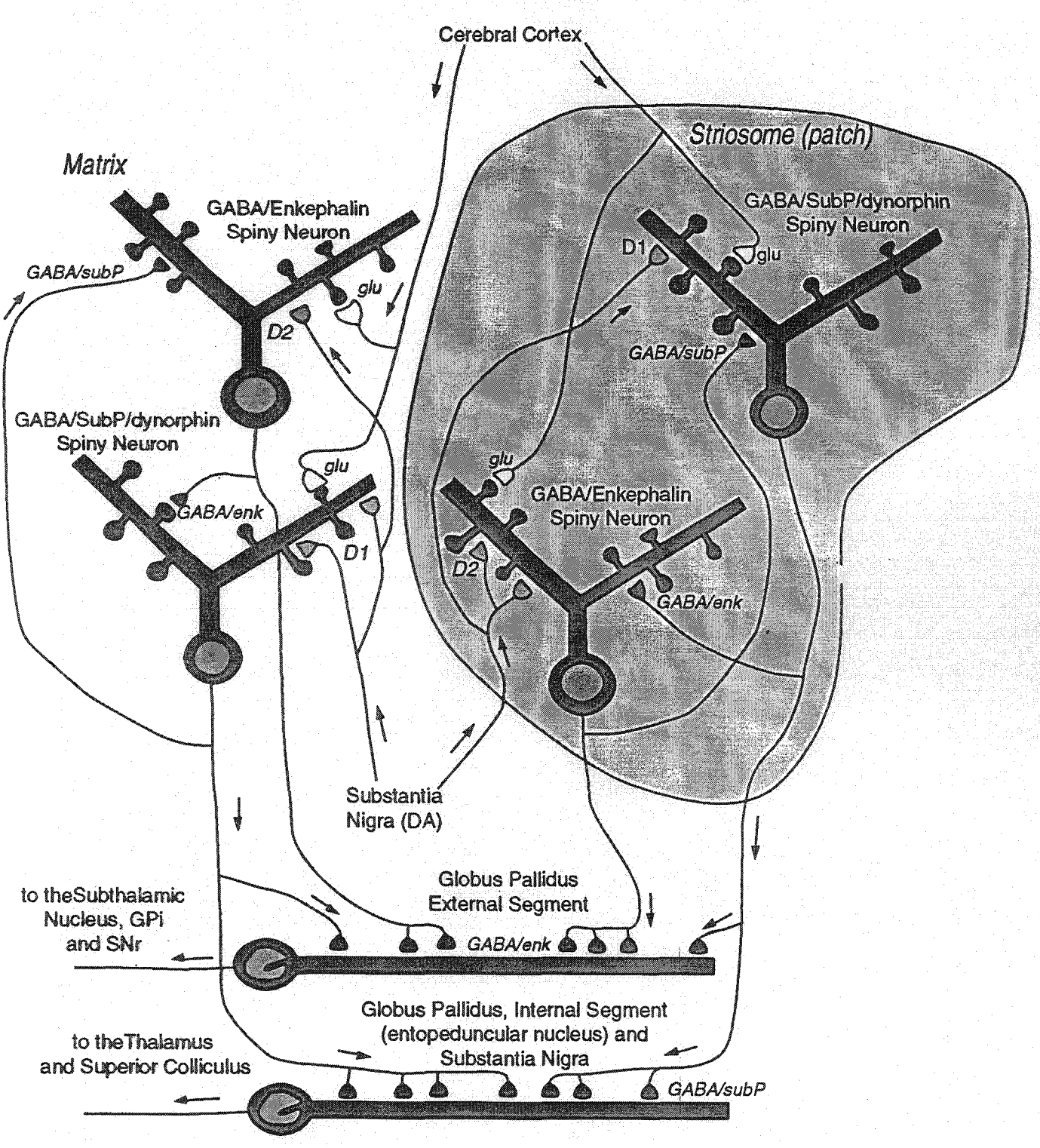
Ingham, C.A., Hood, S.H., Taggart, P. and Arbuthnott, G.A. J Neurosci. 18: 4732-4743, 1998

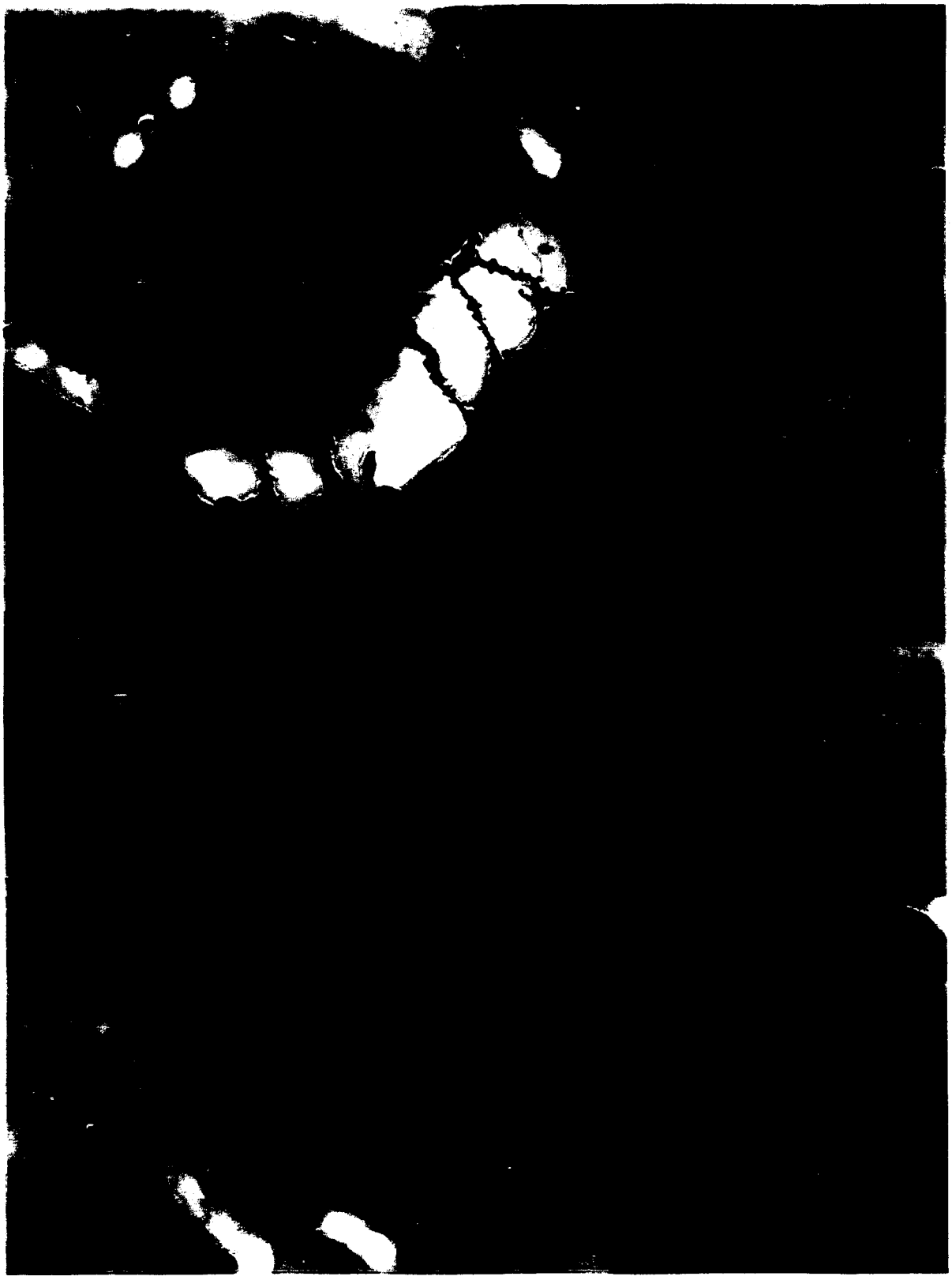
Oorschot, D.E. J. Comp. Neurol. 366: 580-599, 1996

Wickens, J. A Theory of the Striatum, Pergammon Press, Oxford, 1993

Kincaid, A.E., Zheng, T. and Wilson, C.J. J. Neurosci, 18: 4722-4731

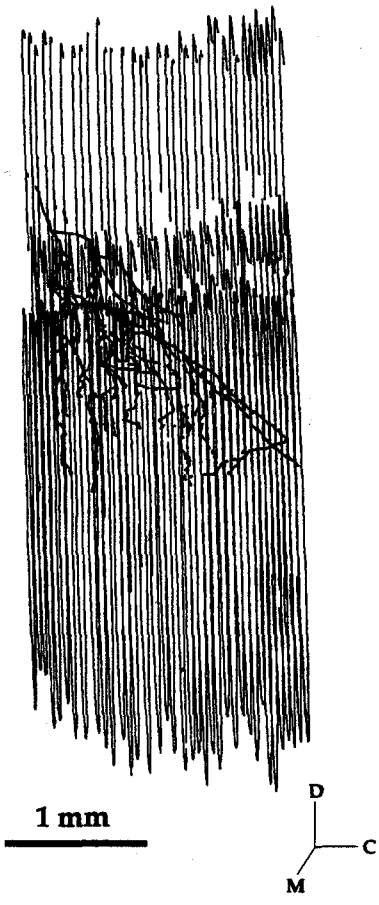

Cerebral Cortex
White Matter
Caudate Nucleus
Putamen
Thalamus
Globus Pallidus
Subthalamic Nucleus
Substantia Nigra
Sth
SNr
SNc


Cerebral Cortex
Striosome (patch)
Matrix
GABA/Enkephalin
Spiny Neuron
GABA/subP
glu
D2
GABA/SubP/dynorphin
Spiny Neuron
D1
glu
GABA/subP
GABA/SubP/dynorphin
Spiny Neuron
glu
GABA/enk
D1
glu
GABA/Enkephalin
Spiny Neuron
D2
GABA/enk
Substantia
Nigra (DA)
to theSubthalamic
Nucleus, GPi
and SNr
Globus Pallidus
External Segment
GABA/enk
Globus Pallidus, Internal Segment
(entopeduncular nucleus) and
Substantia Nigra
to theThalamus
and Superior Colliculus
GABA/subP

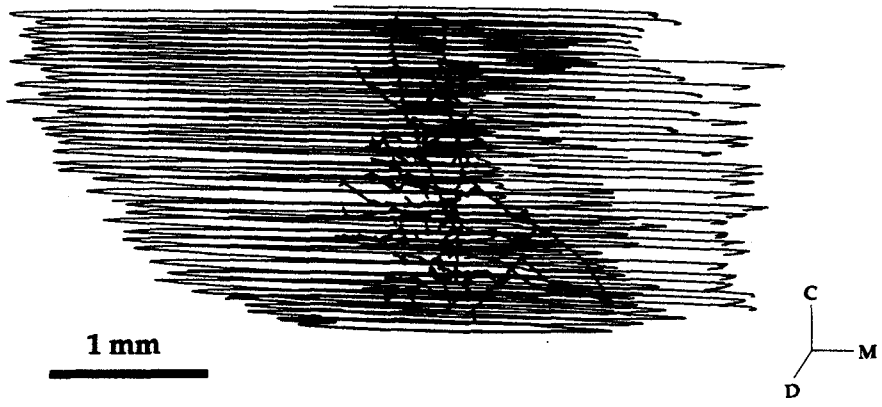


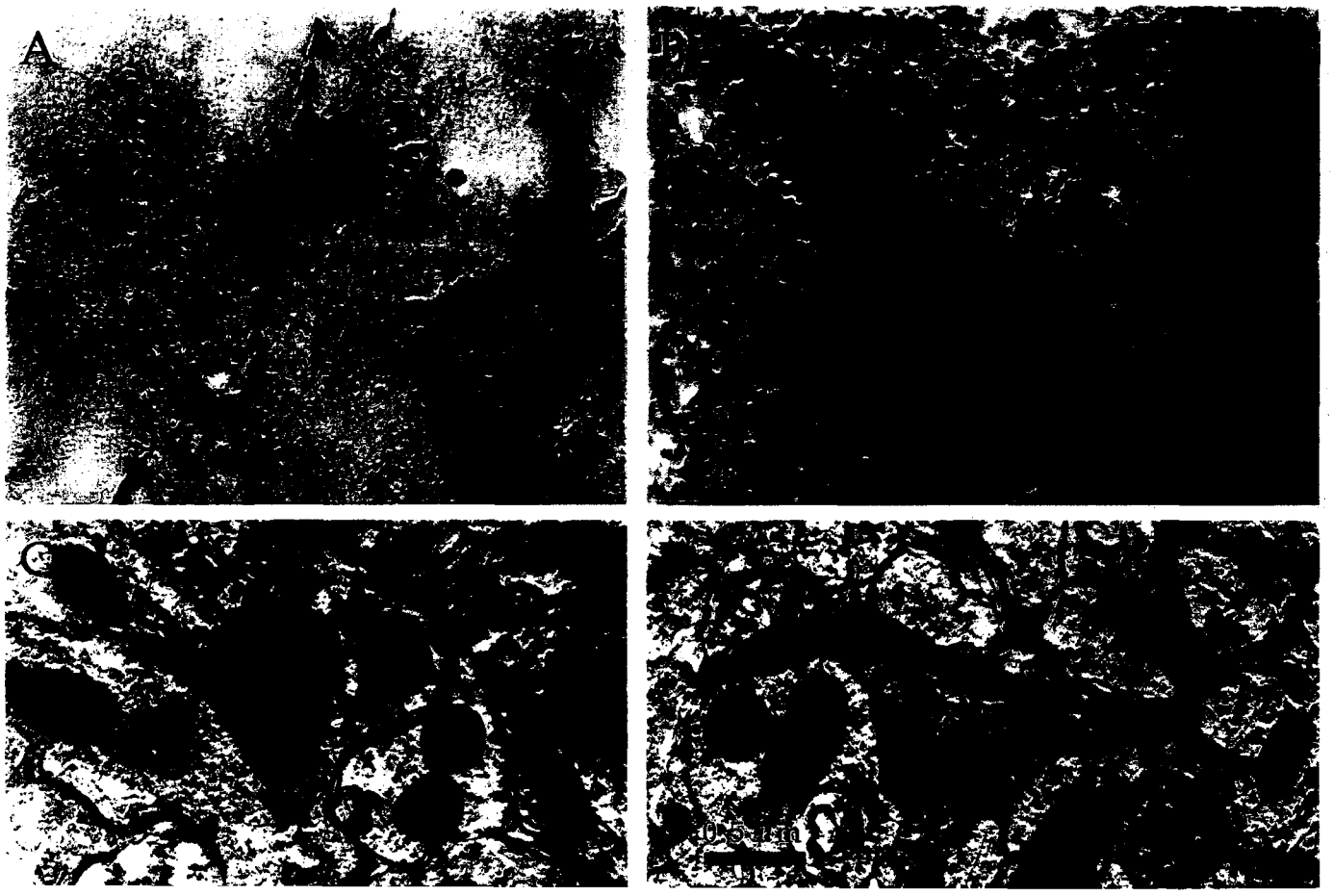
A Frontal View

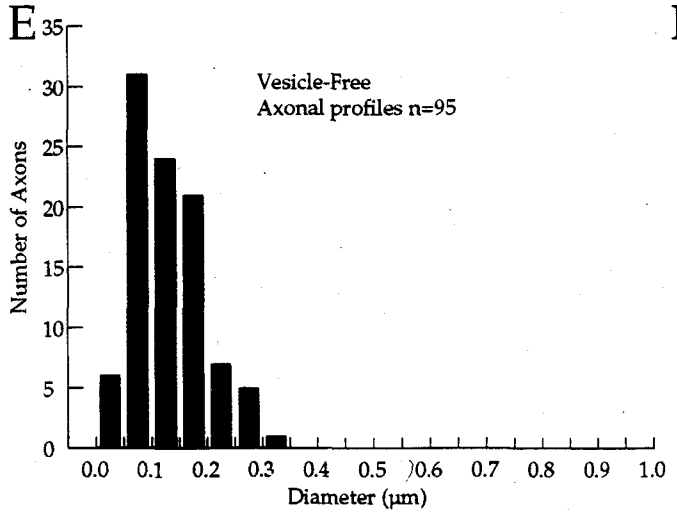
C Sagittal View

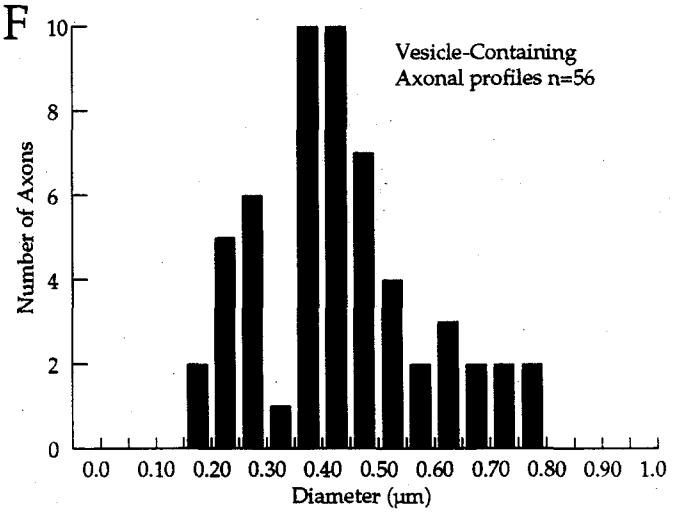


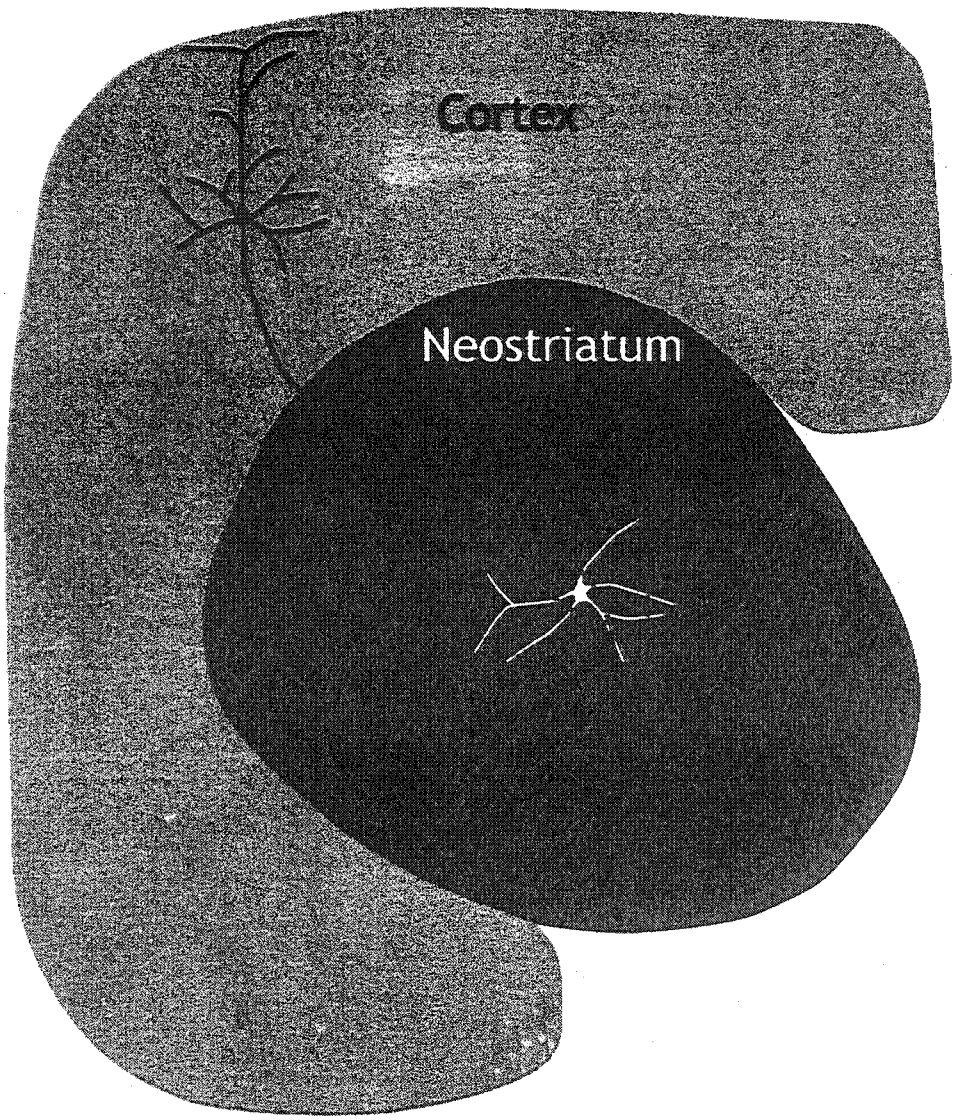
B Horizontal View

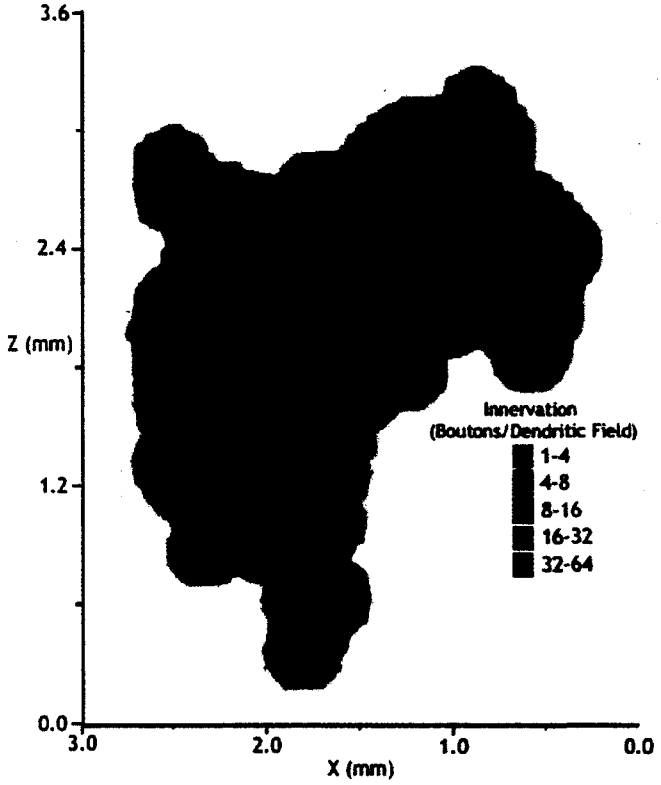


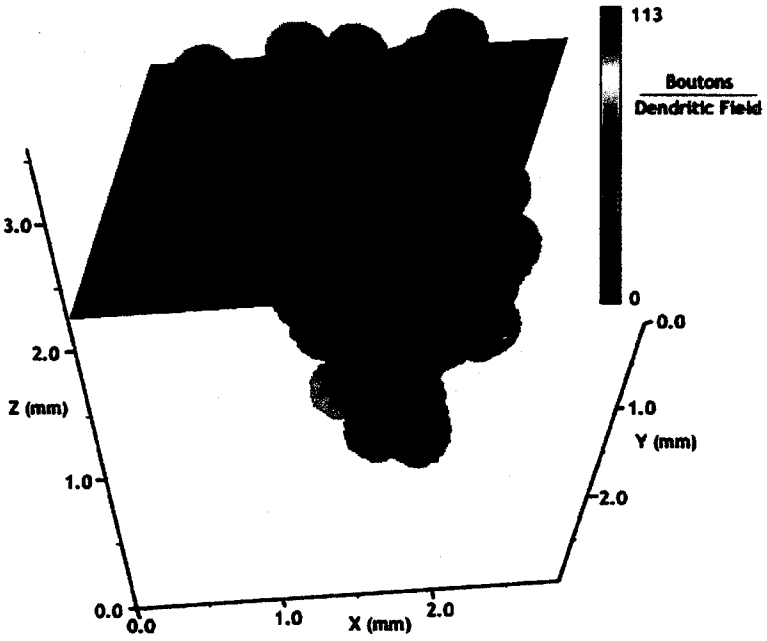

A
B
C
D
0.5 µm


E
Vesicle-Free
Axonal profiles n=95
Number of Axons
0
5
10
15
20
25
30
35
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Diameter (µm)

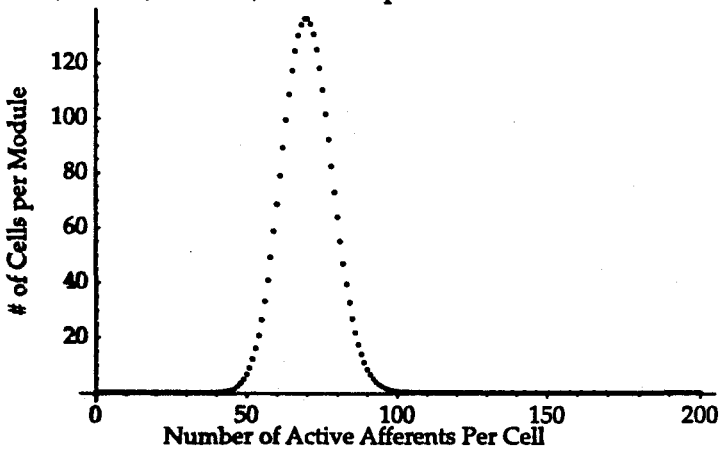

F
Vesicle-Containing
Axonal profiles n=56
Number of Axons
0
2
4
6
8
10
0.0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.0
Diameter (µm)


Cortex
Neostriatum

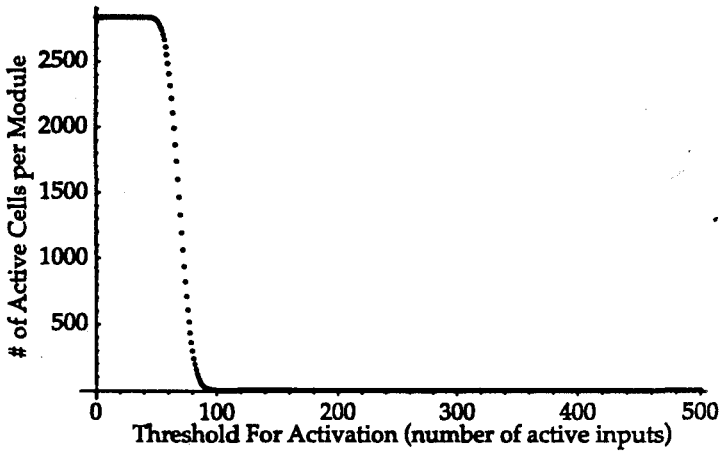

3.6
2.4
1.2
0.0
Z (mm)
3.0
2.0
1.0
0.0
X (mm)
Innervation
(Boutons/Dendritic Field)
1-4
4-8
8-16
16-32
32-64


113
Boutons
Dendritic Field
0
3.0
2.0
1.0
0.0
Z (mm)
0.0
1.0
2.0
X (mm)
0.0
1.0
2.0
Y (mm)

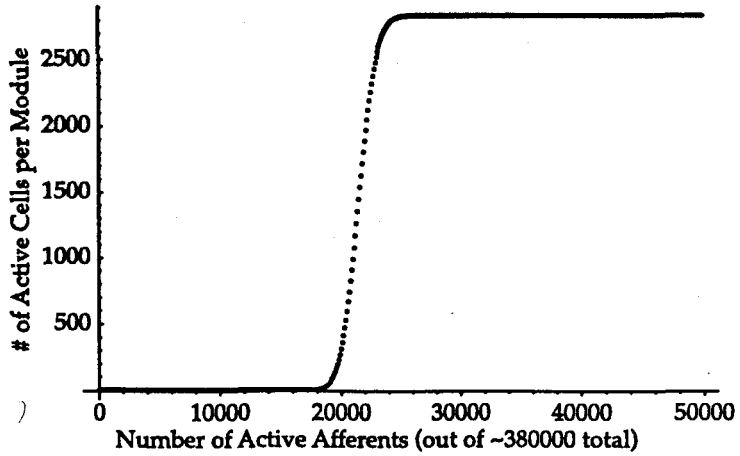
A. The number of neurons in a module receiving k inputs when 5000 (of ~380,000 total) cortical inputs to the module are activated.



B. The number of striatal neurons activated by activation of 5000 corticostriatal neurons for various striatal thresholds



C. Number of striatal neurons activated given a threshold of 300 active inputs, as cortical input is raised from 0 to 50000 (out of 380000)



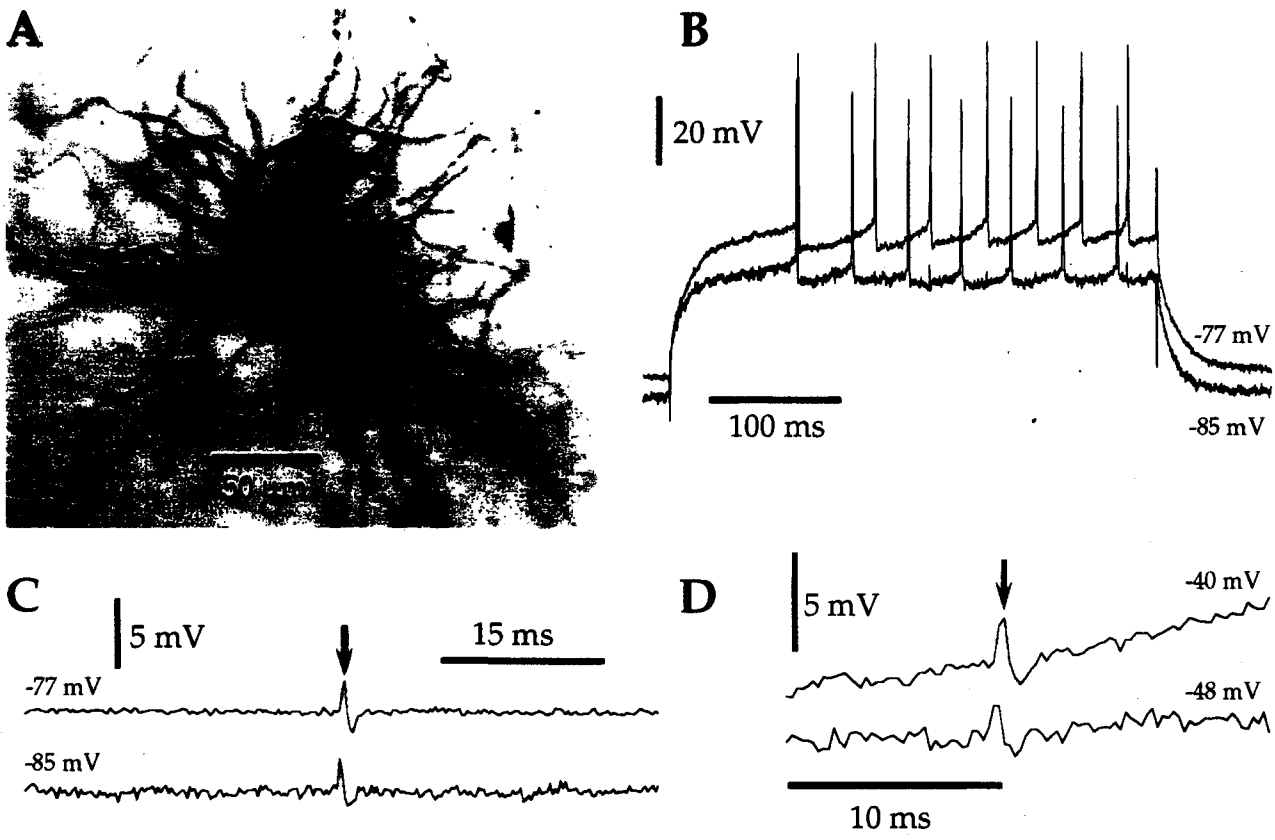

A
B
20 mV
-77 mV
100 ms
-85 mV
C
5 mV
15 ms
-77 mV
-85 mV
D
5 mV
-40 mV
-48 mV
10 ms

TABLE 2 Measurements of corticostriatal connectivity within the volume of one projection neuron's dendritic tree.

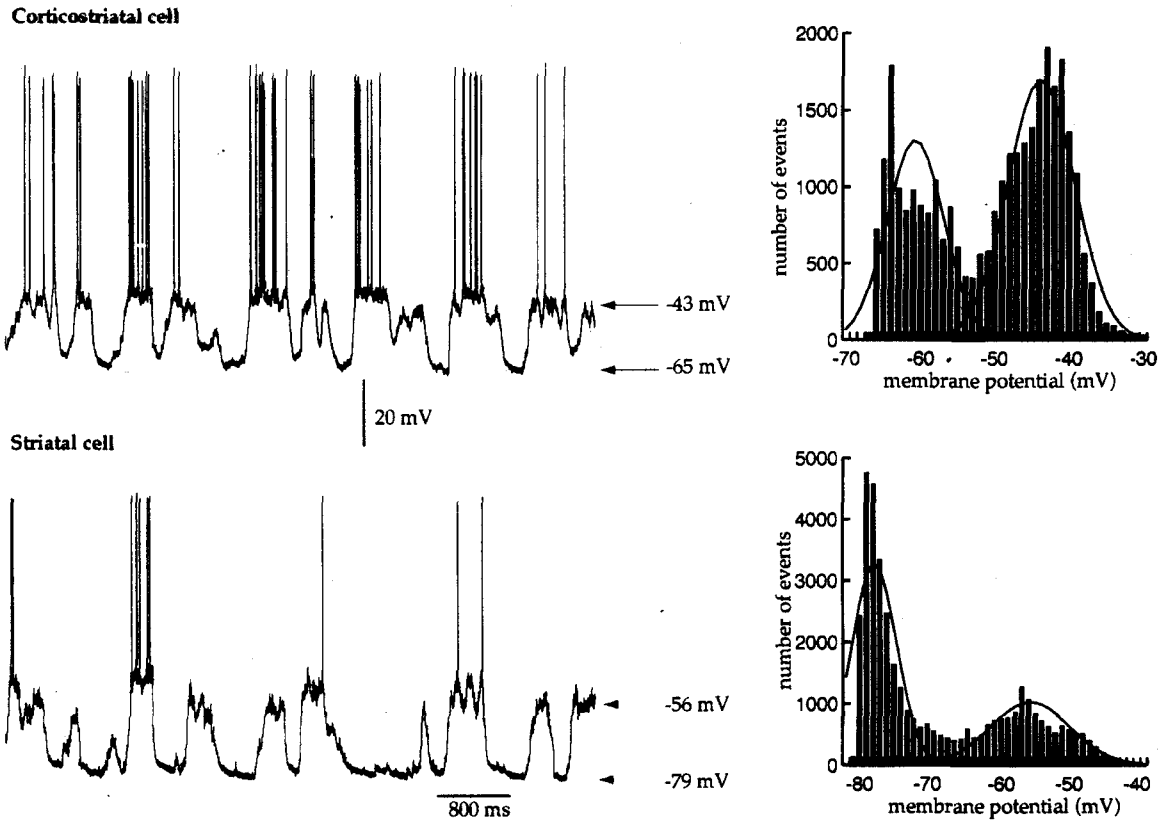
Volume of one dendritic tree[a]	0.0335mm^2
Number of neuronal somata in that volume[b]	2845
Total asymmetric synapses[c]	30.5x10^6
Total corticostriatal synapses[d]	15.25x10^6
Asymmetric synapses per cell	10720
Corticostriatal synapses per cell	5360
Average synapses formed per axon	40
Number of corticostriatal axons participating	381180

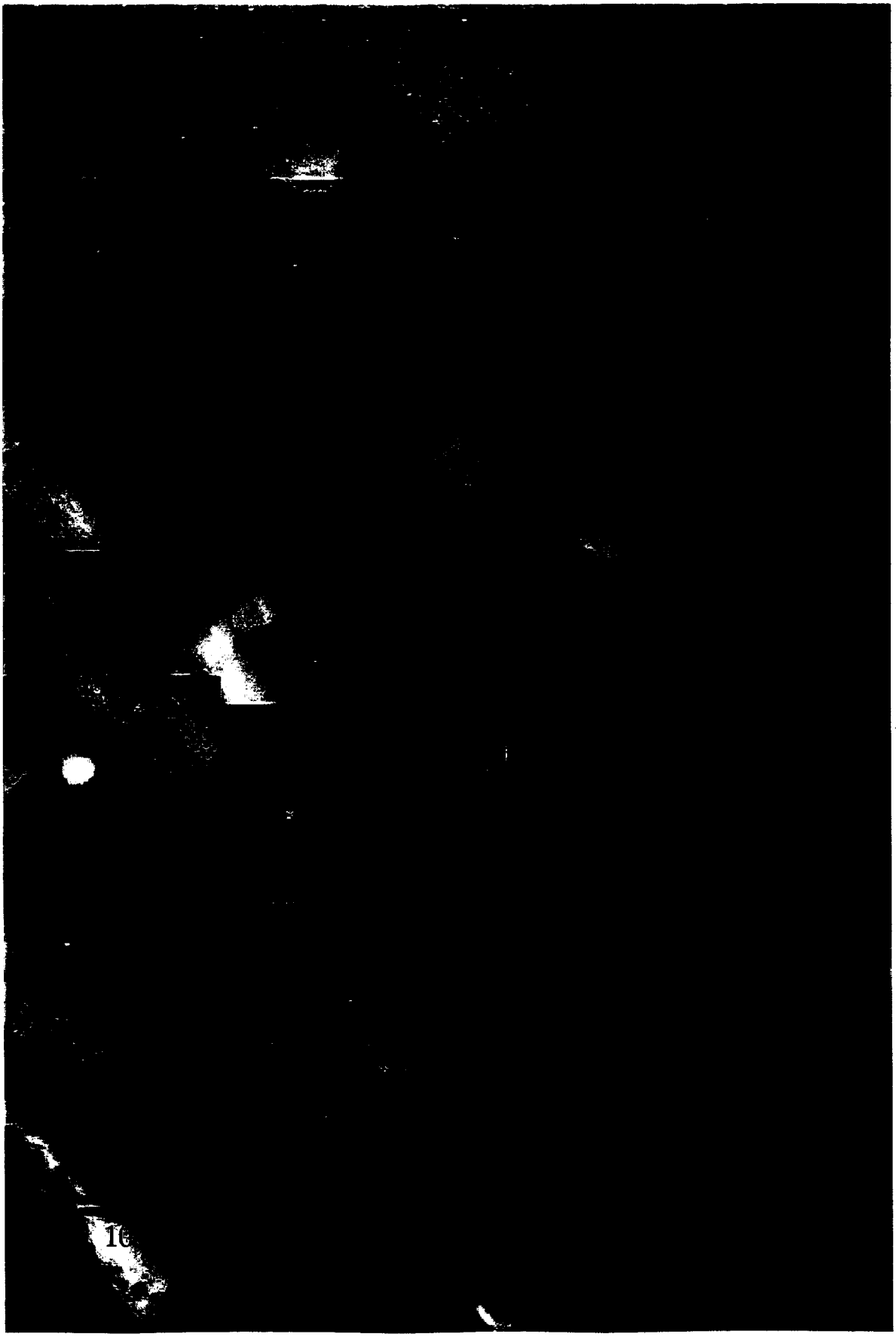
a. Based on a spherical dendritic tree of 400 μm diameter. b. Based on Oorschot, 1996. c. Based on Ingham et al., 1996. d. Based on the assumption that corticostriatal inputs form half of the total asymmetric synapses.

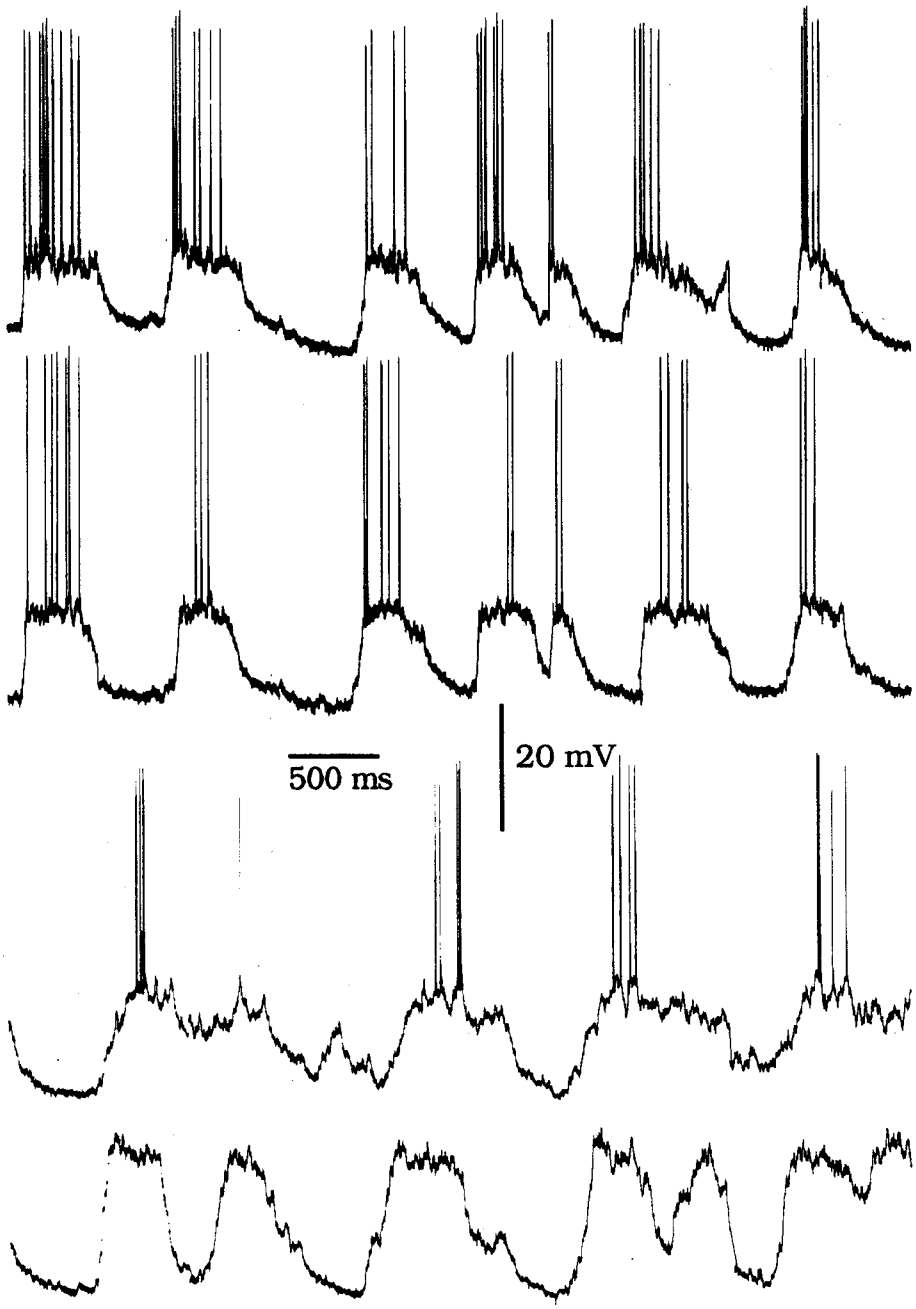
TABLE 3 Corticostriatal statistics assuming 4 different examples of connectivity rules

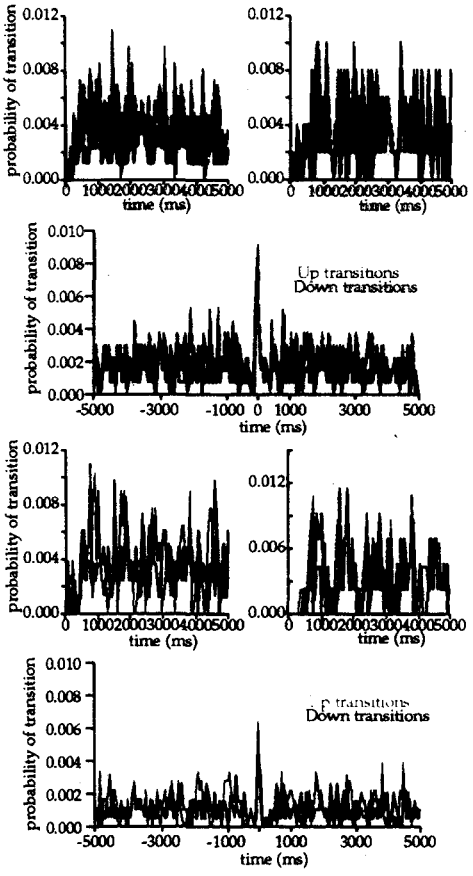
	Non-selective	Growth Rule	Affinity Groups	Totally Selective
Number of spiny cells contacted by 1 axon	40	10	10	1
Average number of synapses per axon per contacted cell	1	4	4	40
Percent of total number of spiny neurons in the volume of one dendritic field contacted by one axon	1.4%	0.35%	0.35%	0.035%
Average number of axons shared by 2 spiny neurons	75.3	4.7	1300	0.0
Percent of total population of cortical axons shared by a randomly selected pair of spiny neurons	1.4%	0.09%	0.34%	0.0%
Average number of cortical cells innervating each spiny cell	5360	1340	1340	134
Average number of spiny cells within the volume of one dendritic field shared by a randomly selected pair of cortical neurons	0.55	0.035	0.97	0.00035
Chances that two randomly selected cortical axons arborizing in the same volume converge onto a given spiny neuron	0.02%	3.4%	0.35%	0.035%

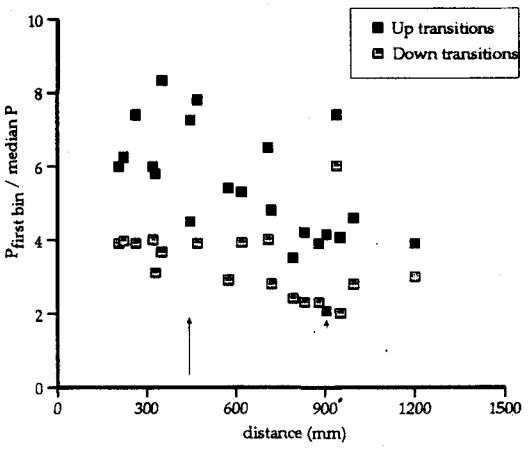
All calculations are for contacts within the volume of one spiny neuron, as in Table 2. Nonselective: Axons contact any spiny neurons in the volume with constant probability. Growth Rule: Axons contact any spiny neuron, but make multiple synapses per contacted neuron (calculations are for 4 synapses per neuron). Affinity Groups: Axons and spiny neurons are divided into subsets and only make synapses within their groups. Group sizes were adjusted to average 4 synapses per contacted neuron (284 groups) for comparison with the Growth Rule.

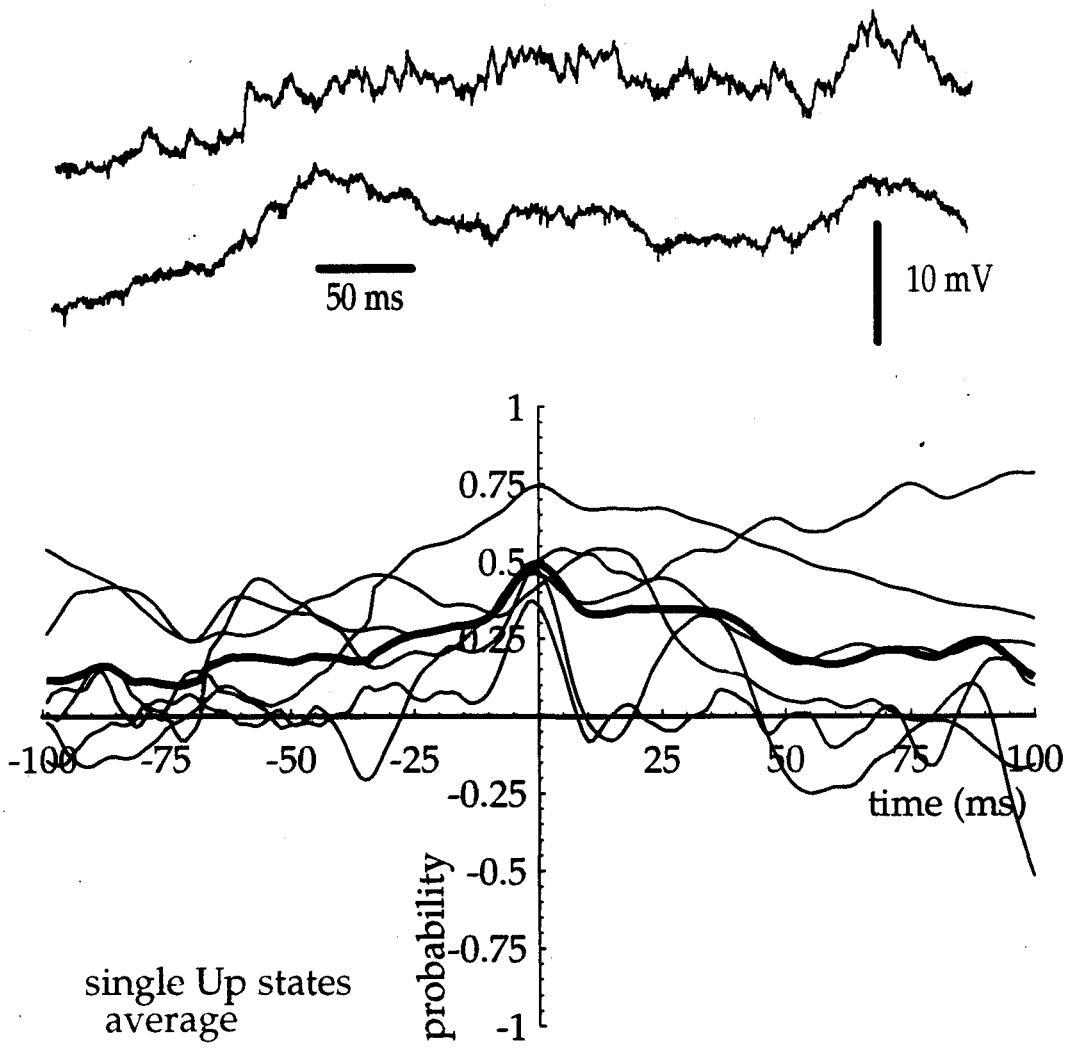

Corticostriatal cell
-43 mV
-65 mV
20 mV
Striatal cell
-56 mV
-79 mV
800 ms
number of events
membrane potential (mV)
number of events
membrane potential (mV)




500 ms
20 mV


probability of transition
time (ms)
Up transitions
Down transitions


Up transitions
Down transitions
P first bin / median P
distance (mm)


50 ms
10 mV
1
0.75
0.5
0.25
-0.25
-0.5
-0.75
-1
-100
-75
-50
-25
25
50
75
100
time (ms)
probability
single Up states
average