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EU ADVANCED COURSE IN COMPUTATIONAL NEUROSCIENCE

An IBRO Neuroscience School

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"Models of Subthalamo-Pallidal Oscillations and their Suppression"

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.

These are preliminary lecture notes, intended only for distribution to participants.

C. J. Wilson

Models of subthalamo-pallidal oscillations and their suppression.

References:

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Functional and pathophysiological models of the basal ganglia
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Current Opinion in Neurobiology 1996, 6:751-758.

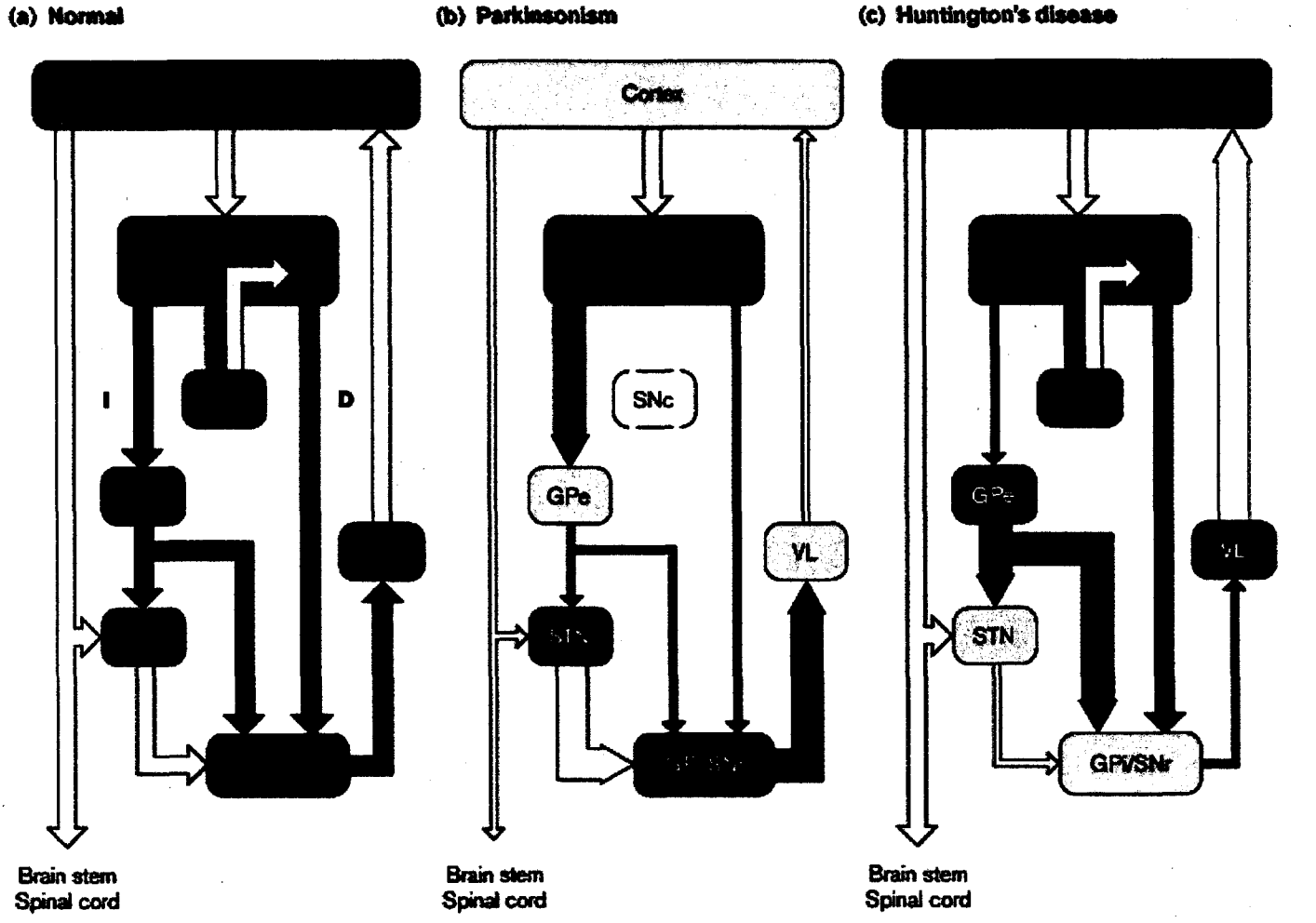

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Figure 1 Schematic diagram of the basal-ganglia– thalamocortical circuity under (a) normal conditions, as well as in (b) parkinsonism and (c) Huntington's disease. Normal neuronal activity is depicted as medium gray (a); increased activity is shaded dark gray and decreased activity is shaded light gray (b, c). Inhibitory connections are depicted as black arrows, and excitatory connections as white arrows. Both disease states lead to differential changes in the two striato-pallidal projections, which are indicated by the thickness of the connecting arrows. In parkinsonism, basal ganglia output to the thalamus (i.e. GPi/SNr to VL) is increased, whereas it is decreased in Huntington's disease. D, direct pathway (putamen to GPi/SNr); D1 and D2, dopamine receptors; I, indirect pathway (putamen to GPeSTNGPi/SNr).

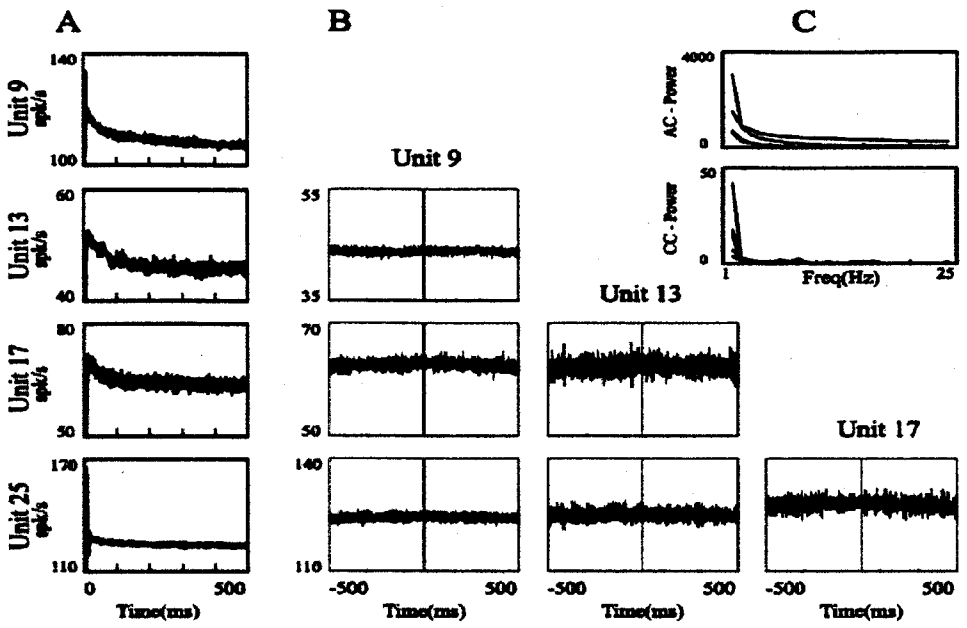


Figure 12. Auto- and cross-correlograms with power spectra of GP cells in a normal monkey. A, Autocorrelograms. B, Cross-correlation matrix. Identifcation of the trigger unit appears at the top, and identifcation of the reference unit appears at the left. Bin size was 1 msec, and no smoothing was performed. The y-axis displays conditional firing rate. C, Power spectra of all the autocorrelograms (top) and cross-correlograms (bottom). Cells 9 (Unit 9) and 17 (Unit 17) were from the GPe, and cells 13 (Unit 13) and 25 (Unit 25) were from the GPi. AC, Autocorrelograms; CC, cross-correlograms.

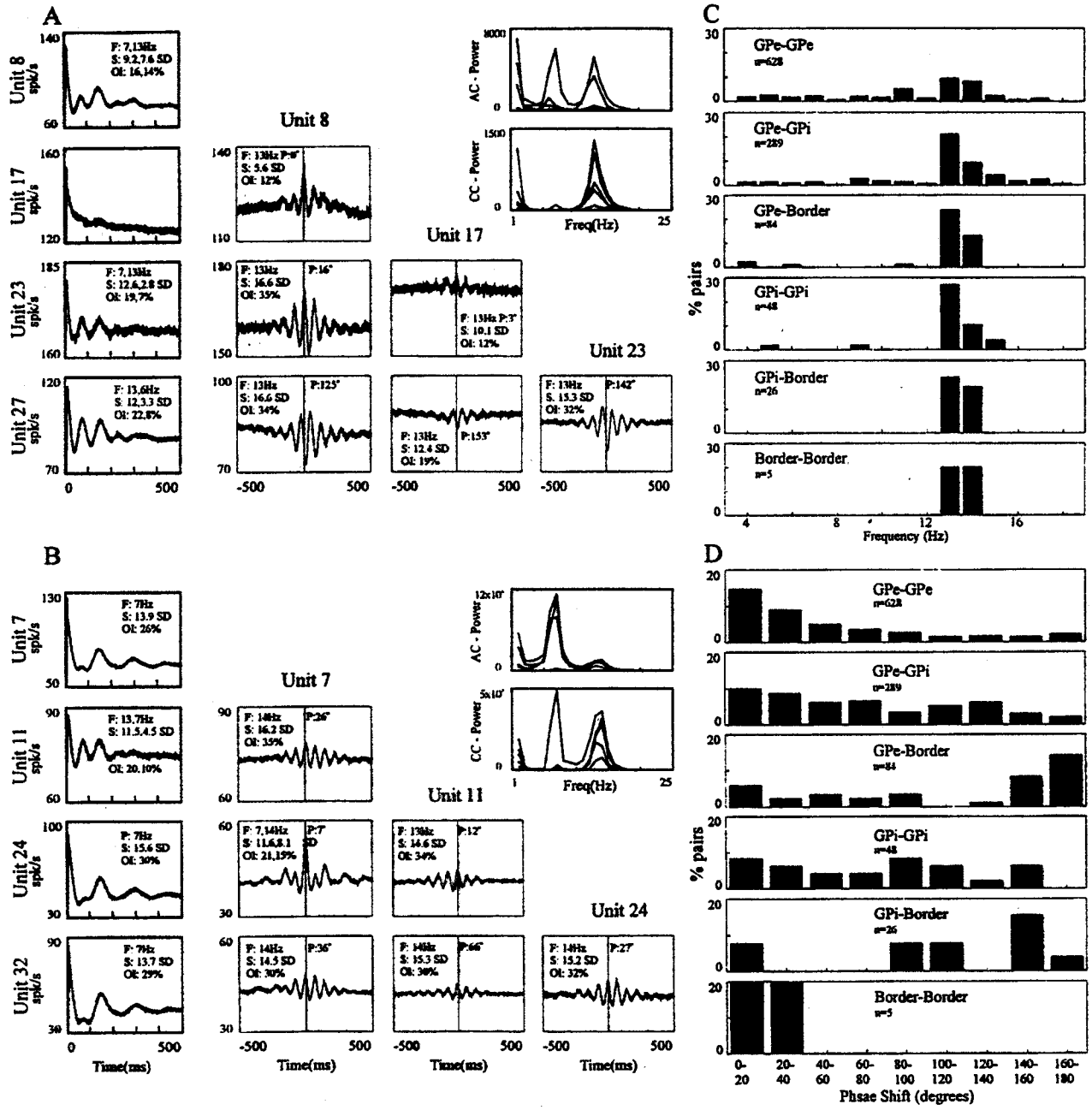
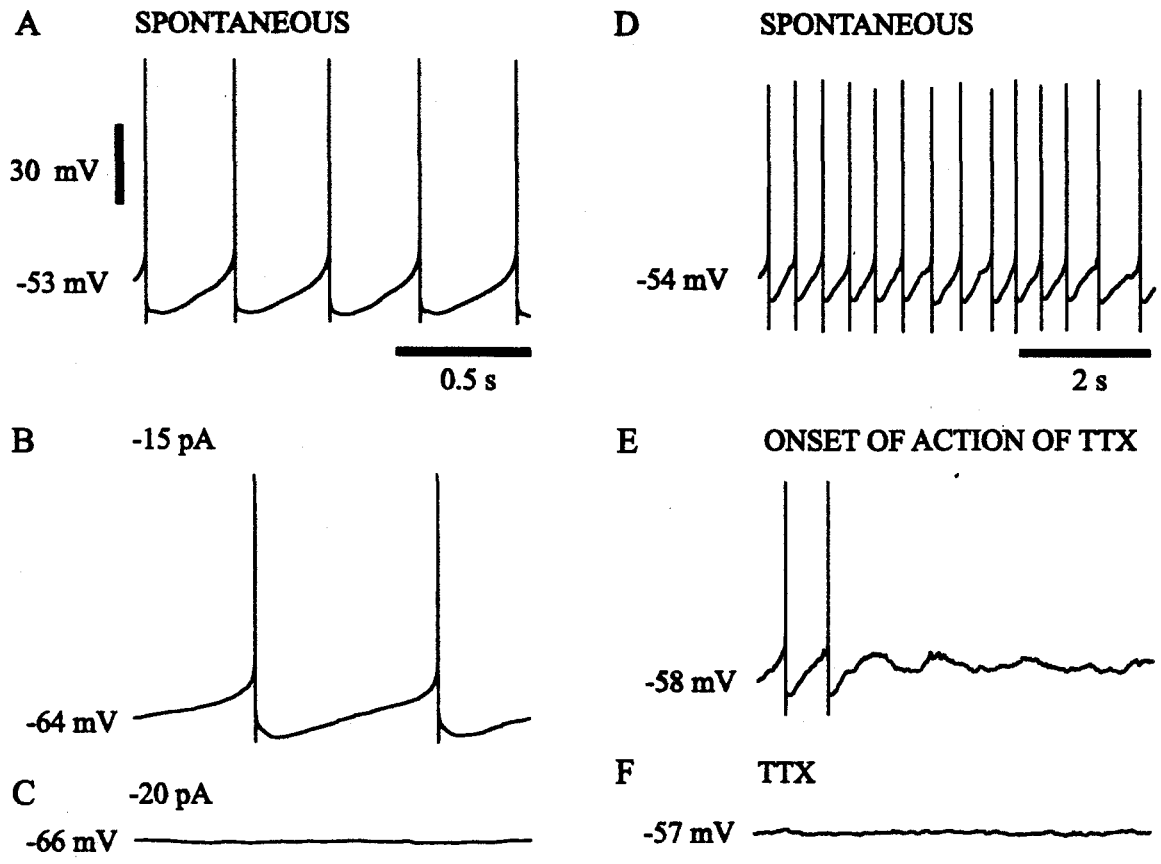
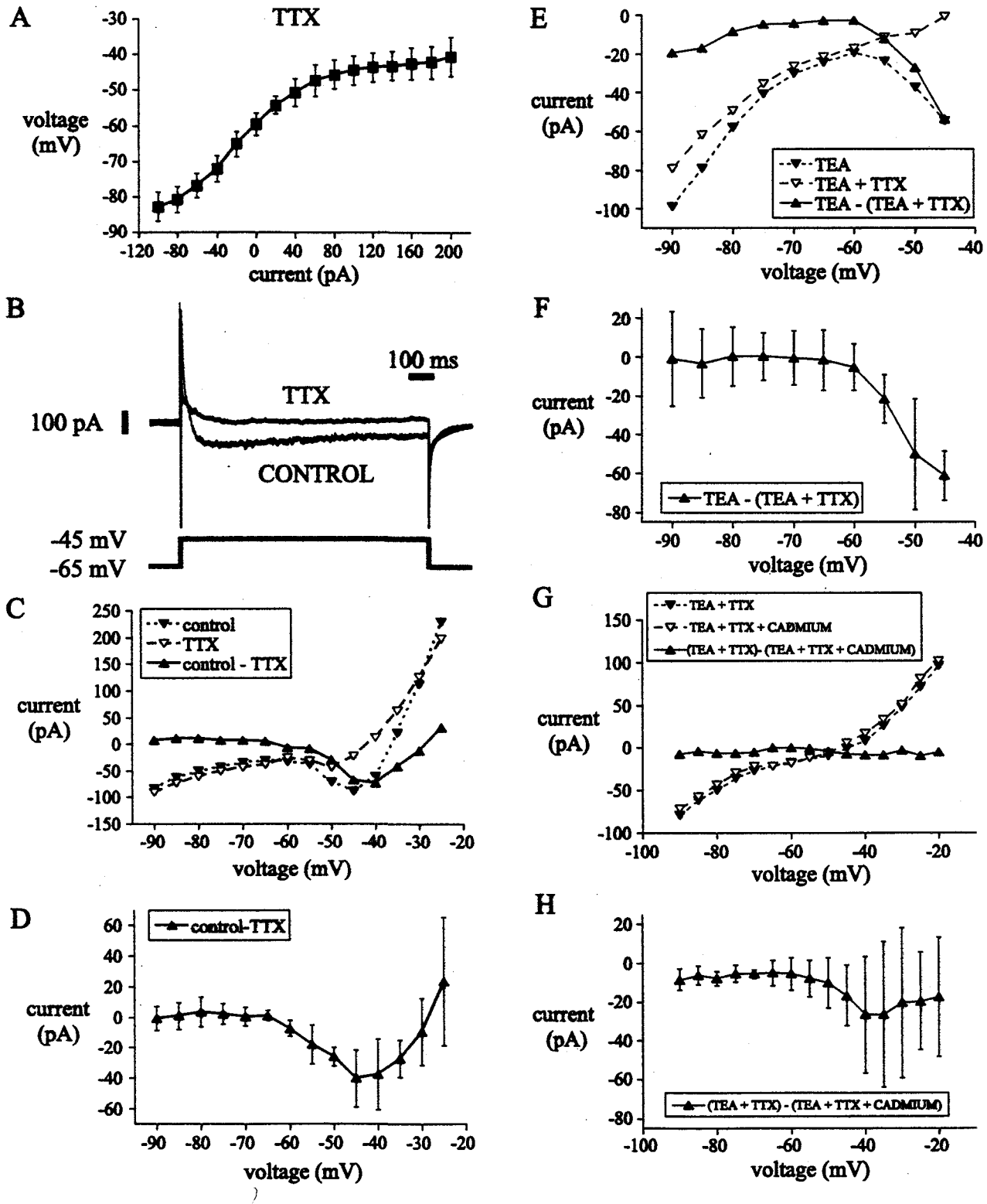
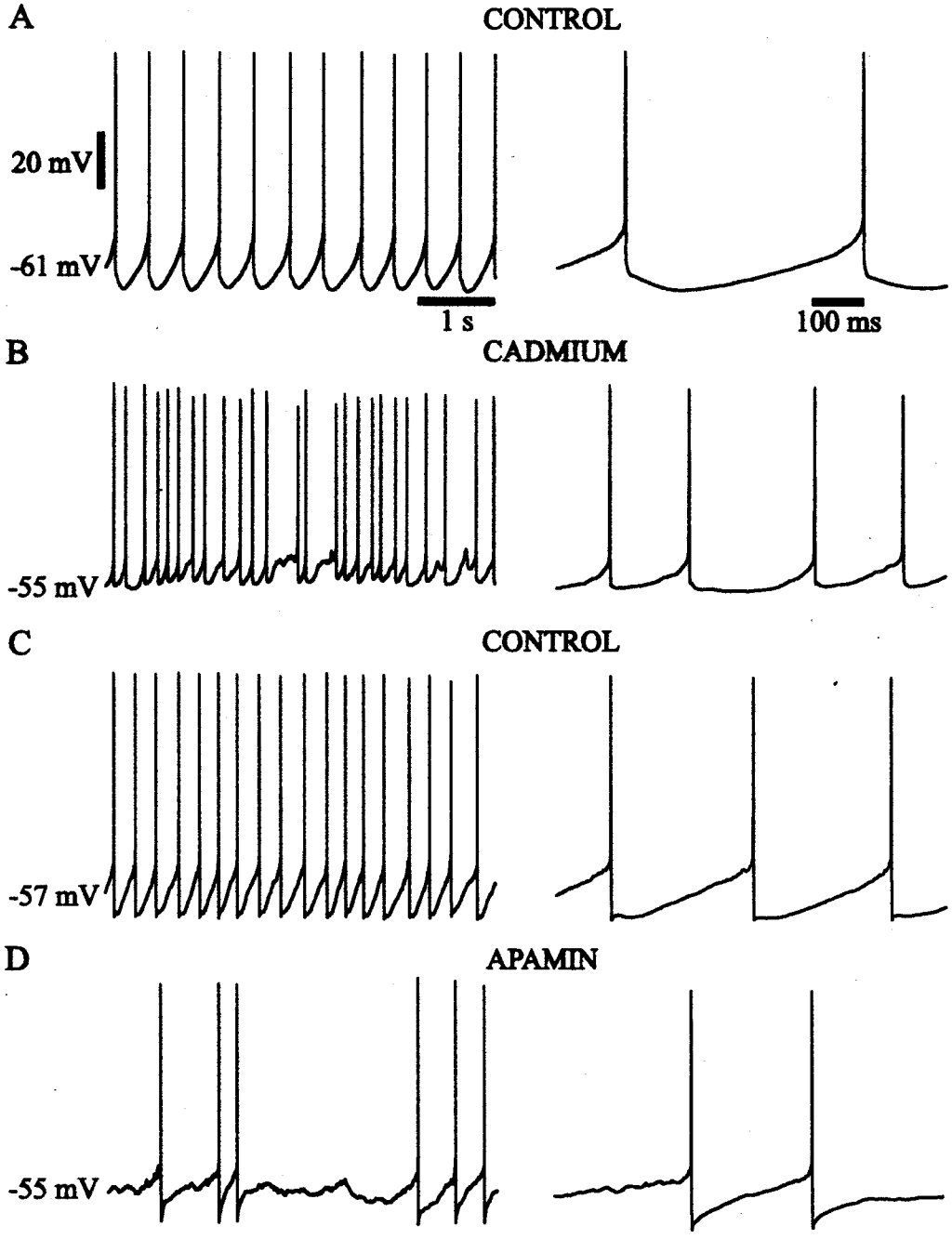
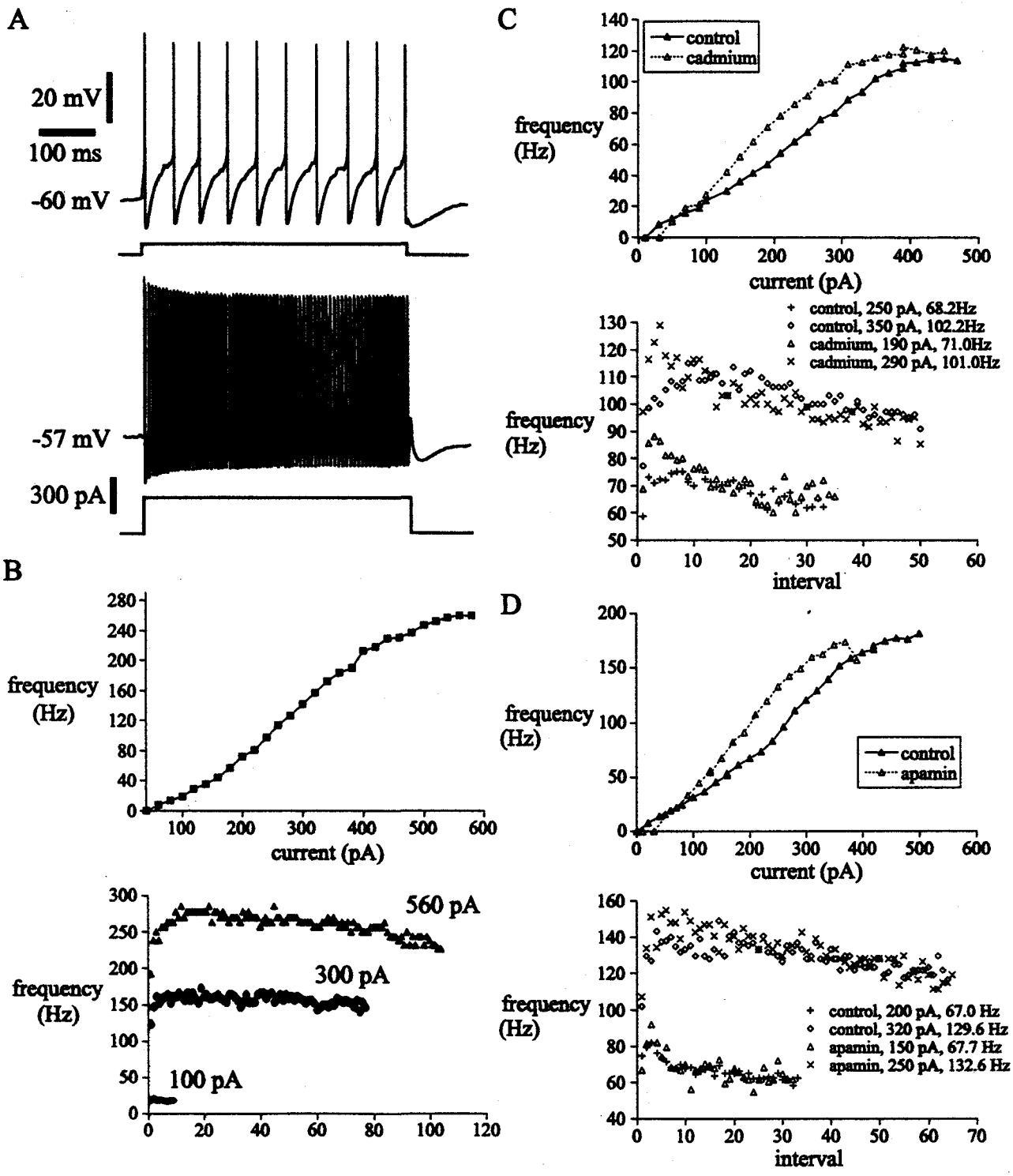


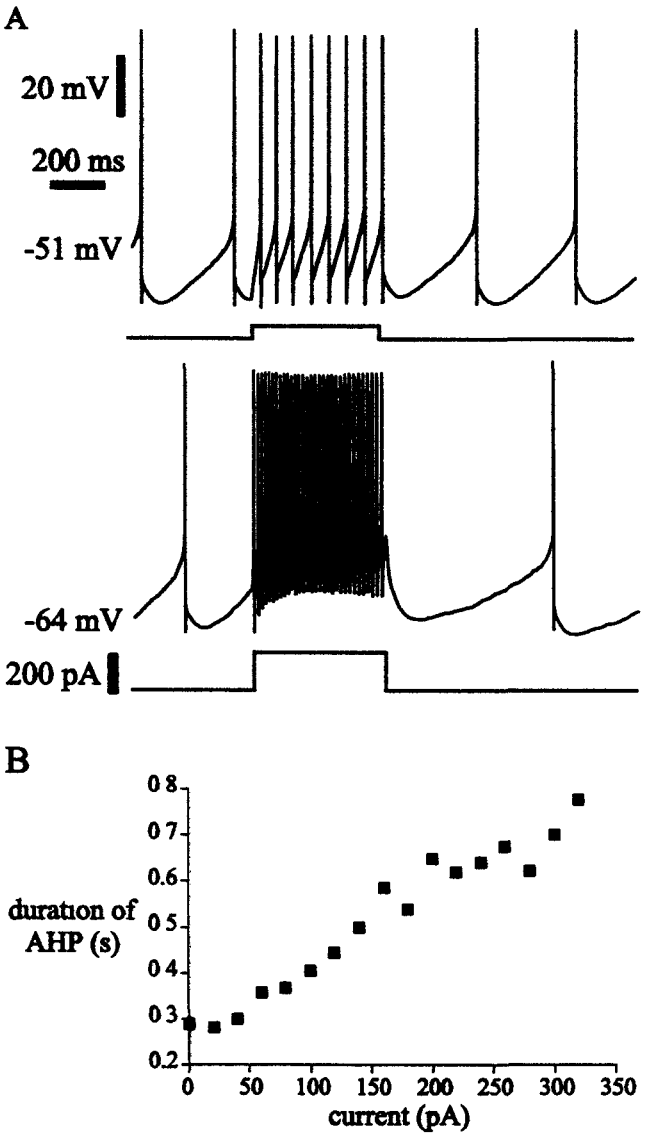
Figure 15. Cross-correlograms and their spectra in the MPTP-treated state. *A*, *B*, Auto- and cross-correlograms with power spectra of GP cells in MPTP-treated monkeys. All of the cross-correlograms have multiple significant peaks or troughs, and all of them have significant oscillations. Notice in *A* that cell 27 (*Unit 27*) is not in phase with all other cells, whereas in *B* all cells are phase-locked. In *A*, cells 8 (*Unit 8*) and 23 (*Unit 23*) were from GPe and cells 17 (*Unit 17*) and 27 (*Unit 27*) were from GPi. In *B*, all of the cells were from the GPe. Layout of *A* and *B* is as in Fig. 12. Details characterizing the oscillations are given on the graph: *F*, frequency of oscillatory correlograms; *p*, phase shift in degrees; *S*, signal-to-noise ratio; *OI*, oscillation index. In cases with more than one significant peak, the details of the peaks appear in order of their strength; *AC* = autocorrelograms; *CC* = cross-correlograms. *C*, Distribution of the frequencies of oscillatory cross-correlograms in the MPTP-treated state. *D*, Distribution of the phase shifts of oscillatory cross-correlograms in the MPTP-treated state. In *C* and *D* the *y*-axis shows percentage of oscillatory correlograms of all the correlograms recorded from each combination of nuclei. The total number of pairs recorded from each nuclei pair is listed in the *graphs*.

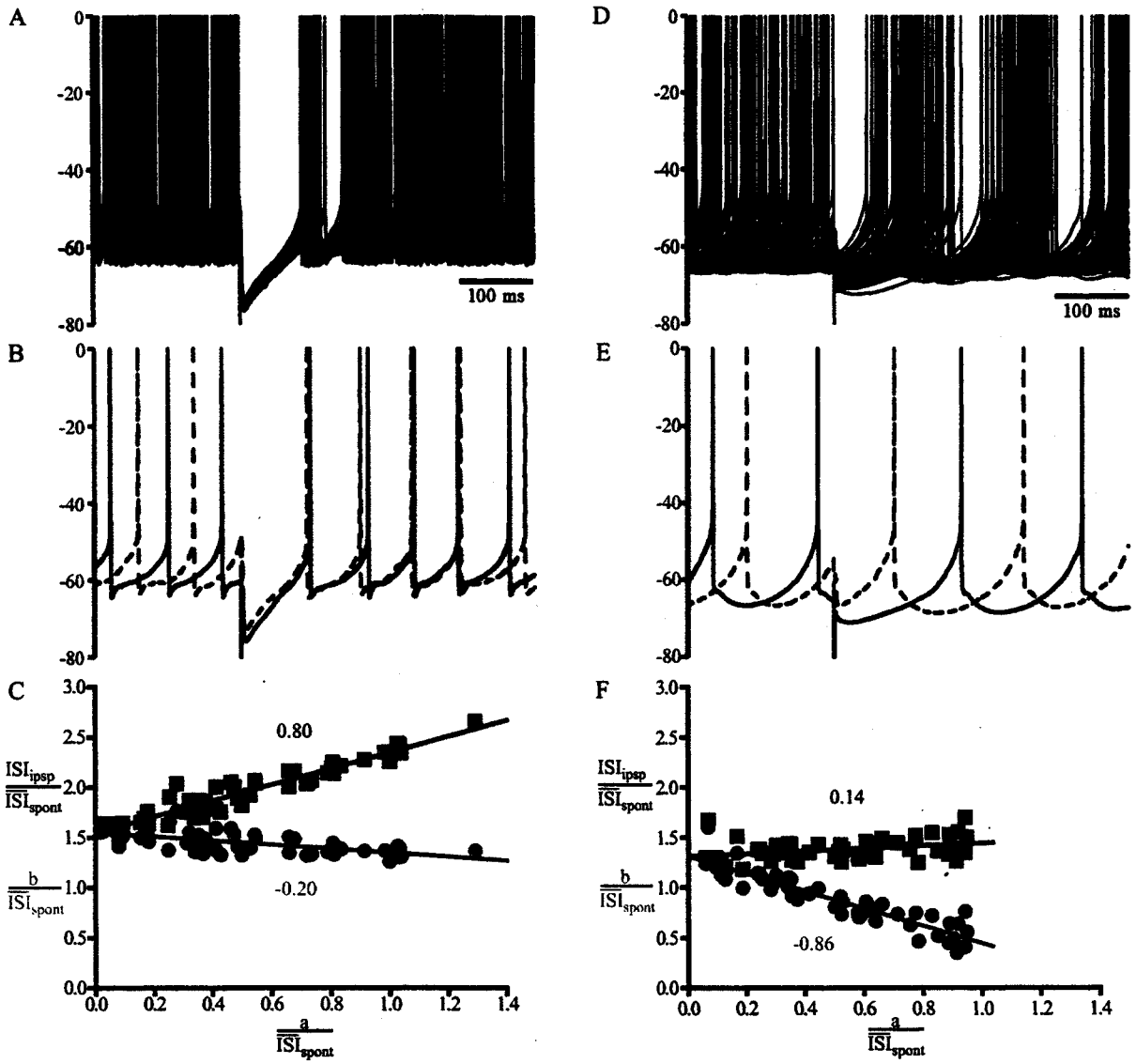

A
SPONTANEOUS
30 mV
-53 mV
0.5 s
B
-15 pA
-64 mV
C
-20 pA
-66 mV
D
SPONTANEOUS
-54 mV
2 s
E
ONSET OF ACTION OF TTX
-58 mV
F
TTX
-57 mV

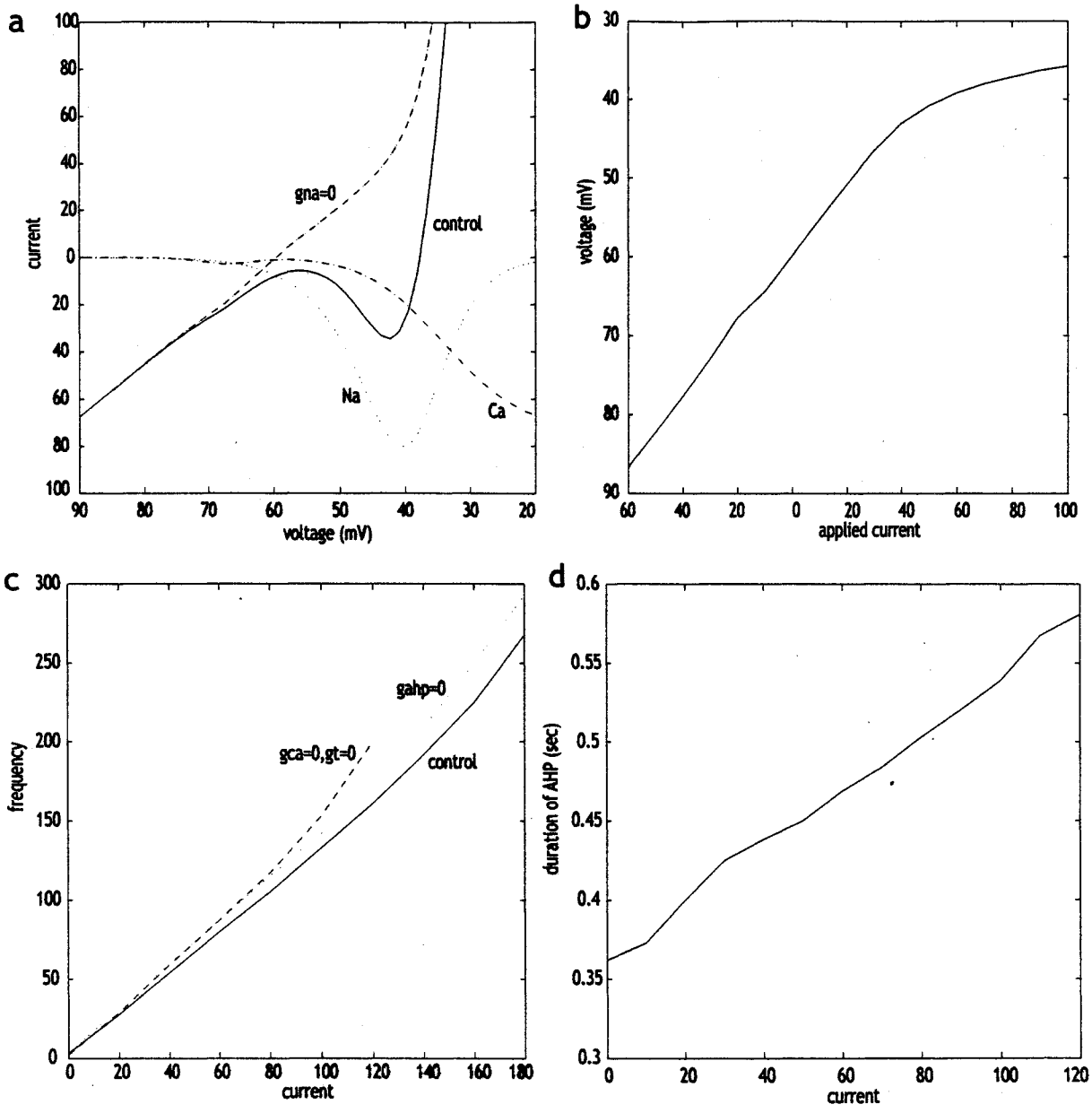

A
TTX
voltage (mV)
current (pA)
B
100 ms
TTX
100 pA
CONTROL
-45 mV
-65 mV
C
control
TTX
control - TTX
current (pA)
voltage (mV)
D
control-TTX
current (pA)
voltage (mV)
E
TEA
TEA + TTX
TEA - (TEA + TTX)
current (pA)
voltage (mV)
F
TEA - (TEA + TTX)
current (pA)
voltage (mV)
G
TEA + TTX
TEA + TTX + CADMIUM
(TEA + TTX)- (TEA + TTX + CADMIUM)
current (pA)
voltage (mV)
H
(TEA + TTX) - (TEA + TTX + CADMIUM)
current (pA)
voltage (mV)

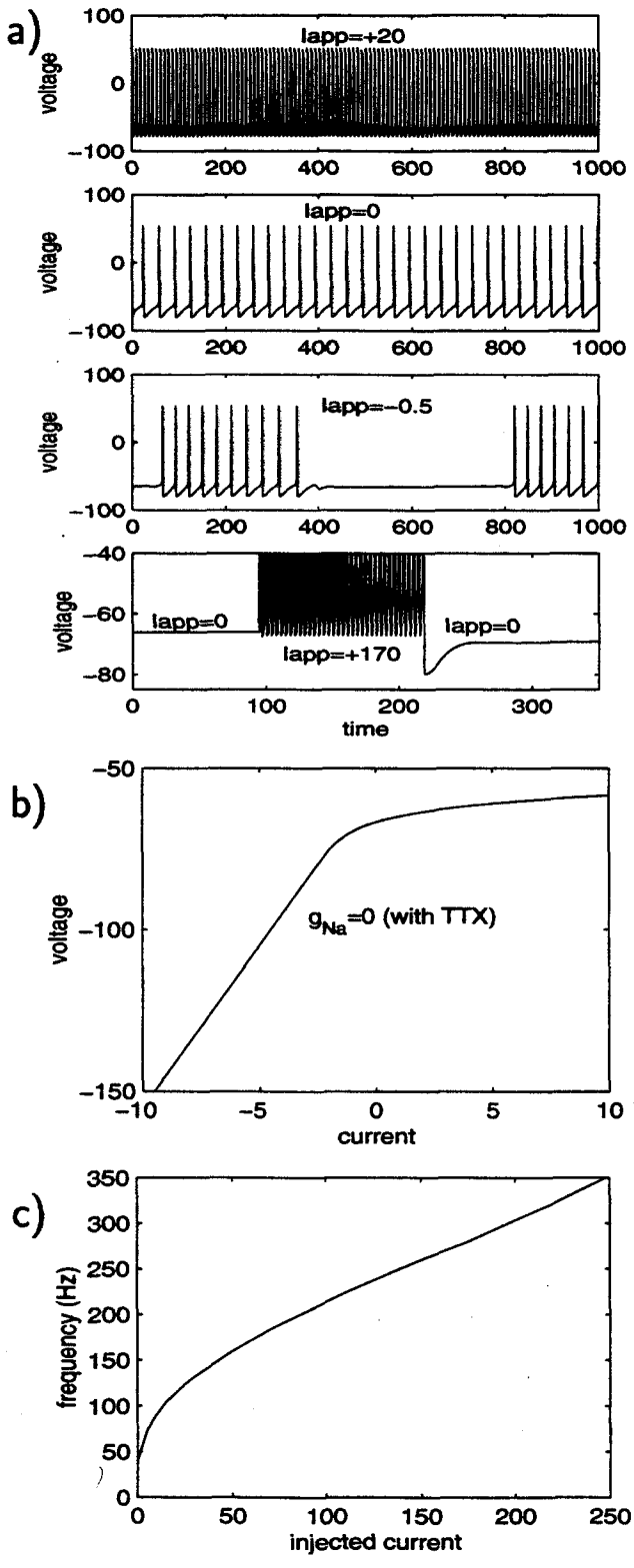

A
CONTROL
20 mV
-61 mV
1 s
100 ms
B
CADMIUM
-55 mV
C
CONTROL
-57 mV
D
APAMIN
-55 mV

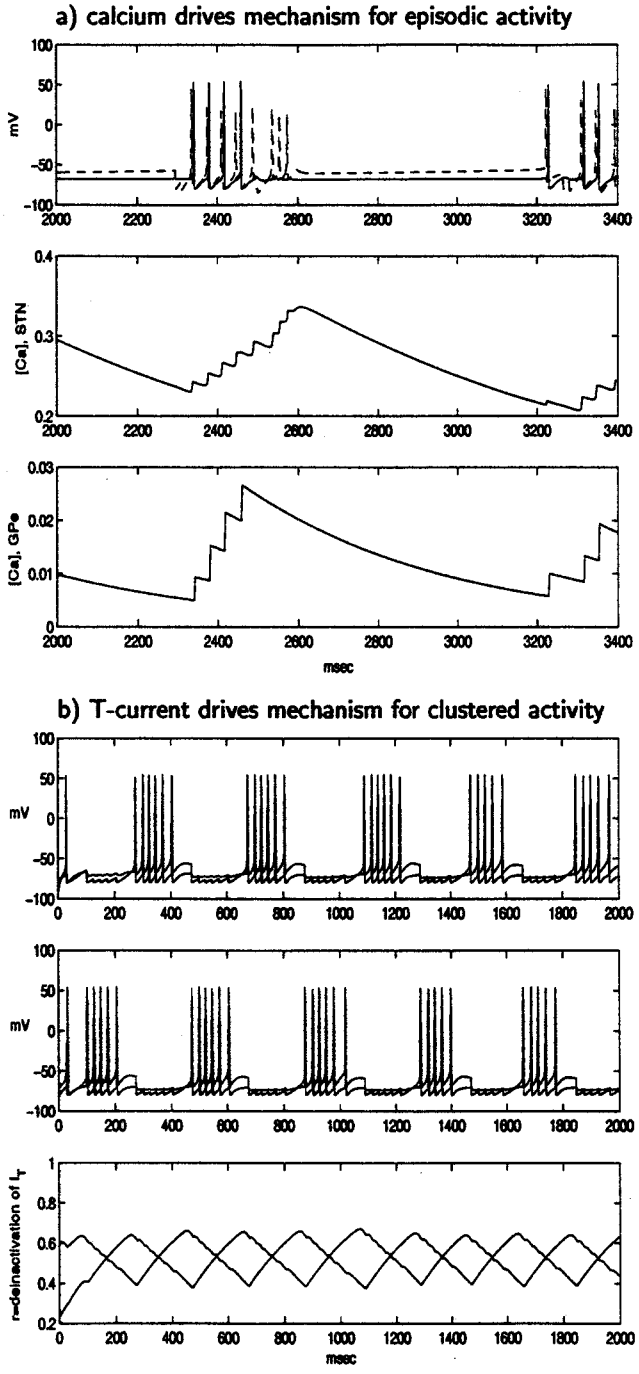

A
20 mV
100 ms
-60 mV
-57 mV
300 pA
B
frequency (Hz)
current (pA)
560 pA
300 pA
100 pA
C
control
cadmium
frequency (Hz)
current (pA)
control, 250 pA, 68.2Hz
control, 350 pA, 102.2Hz
cadmium, 190 pA, 71.0Hz
cadmium, 290 pA, 101.0Hz
interval
D
control
apamin
control, 200 pA, 67.0 Hz
control, 320 pA, 129.6 Hz
apamin, 150 pA, 67.7 Hz
apamin, 250 pA, 132.6 Hz

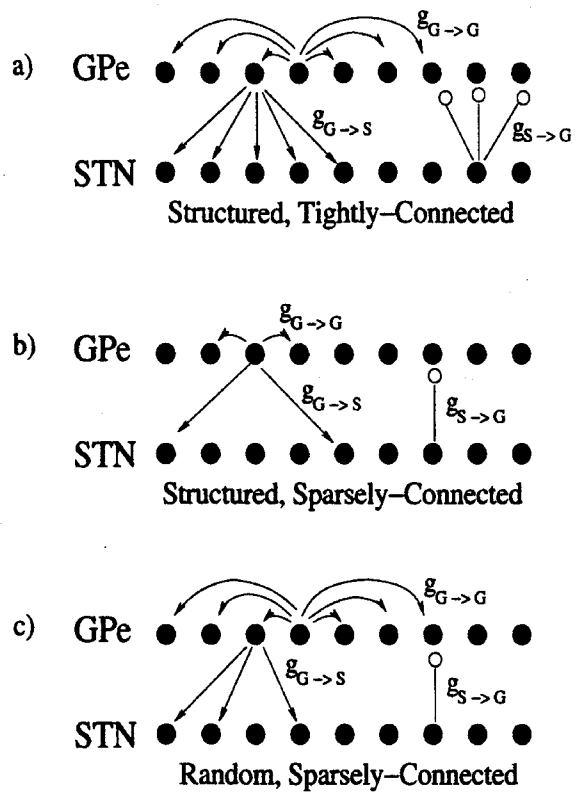

A
20 mV
200 ms
-51 mV
-64 mV
200 pA
B
duration of AHP (s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
50
100
150
200
250
300
350
current (pA)

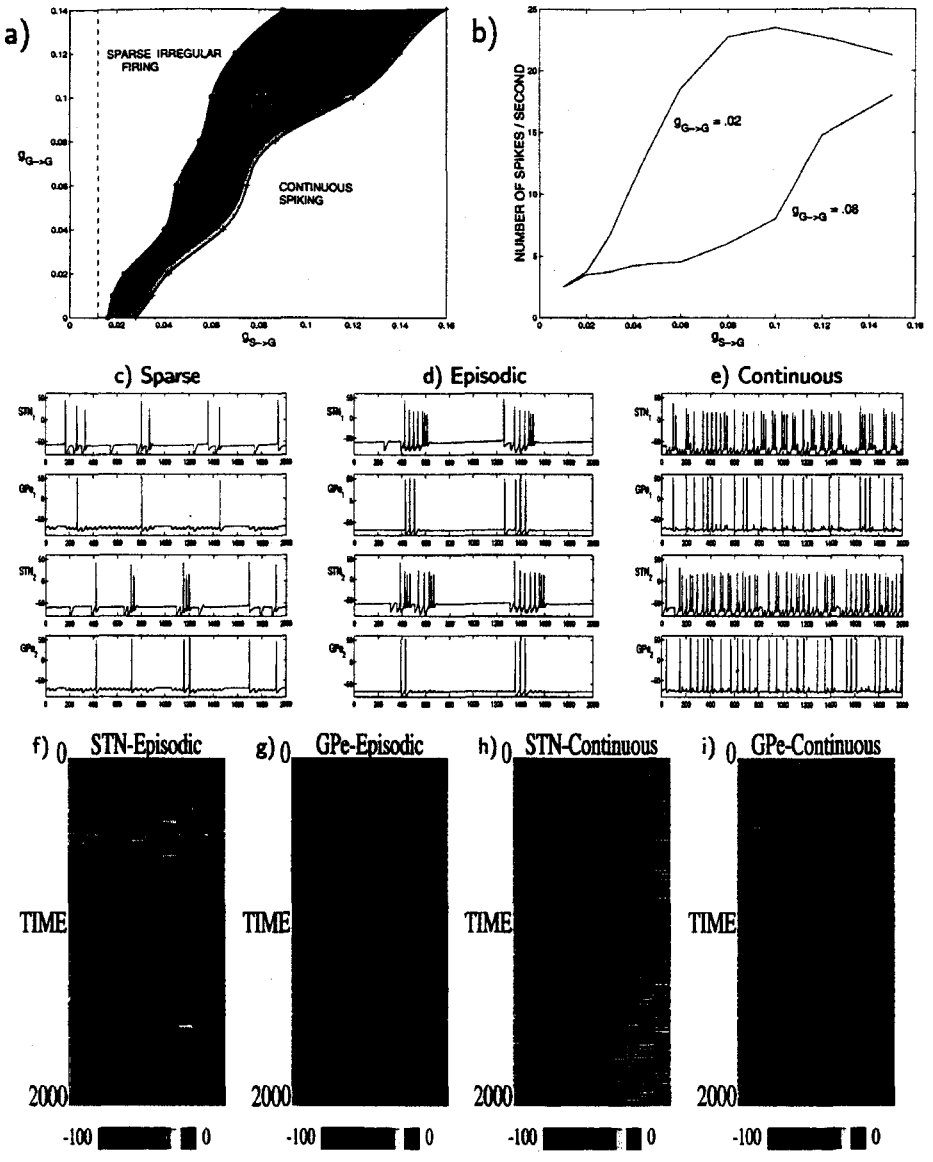

A
0
-20
-40
-60
-80
100 ms
D
0
-20
-40
-60
-80
100 ms
B
0
-20
-40
-60
-80
E
0
-20
-40
-60
-80
C
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.80
-0.20
ISIipsp / ISIspont
b / ISIspont
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
a / ISIspont
F
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.14
-0.86
ISIipsp / ISIspont
b / ISIspont
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
a / ISIspont

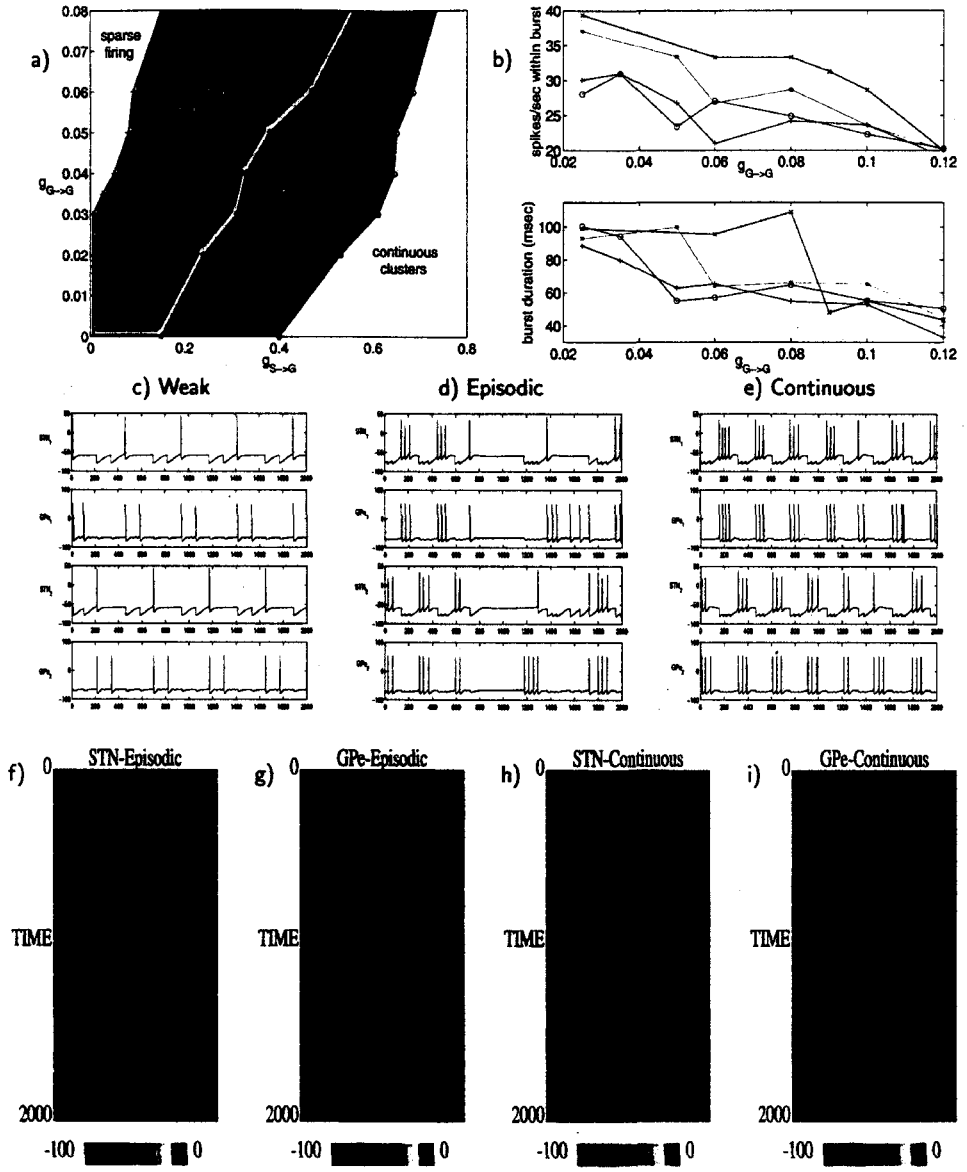

a
current
voltage (mV)
gna=0
control
Na
Ca
b
voltage (mV)
applied current
c
frequency
current
gahp=0
gca=0,gt=0
control
d
duration of AHP (sec)
current

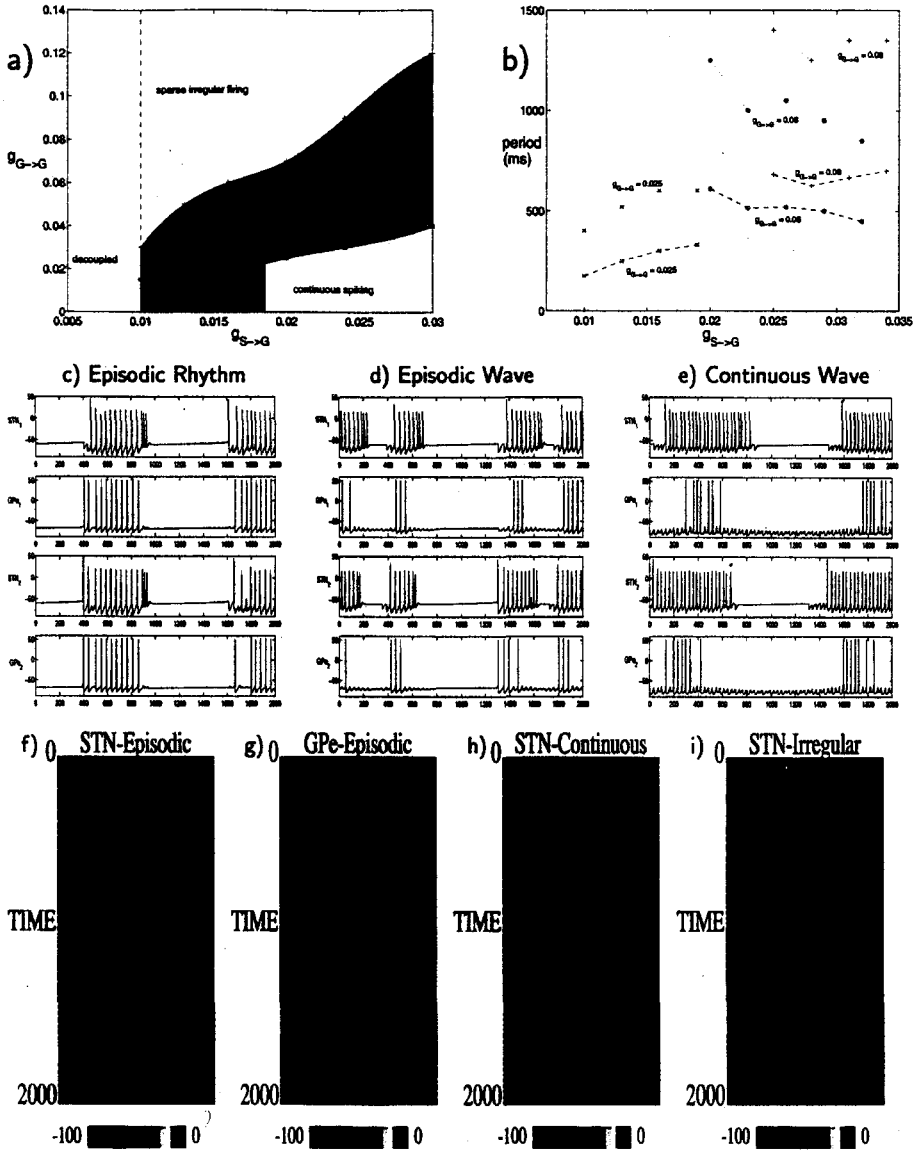

a)
Iapp=+20
Iapp=0
Iapp=−0.5
Iapp=0
Iapp=+170
Iapp=0
voltage
time
b)
g_{Na}=0 (with TTX)
voltage
current
c)
frequency (Hz)
injected current

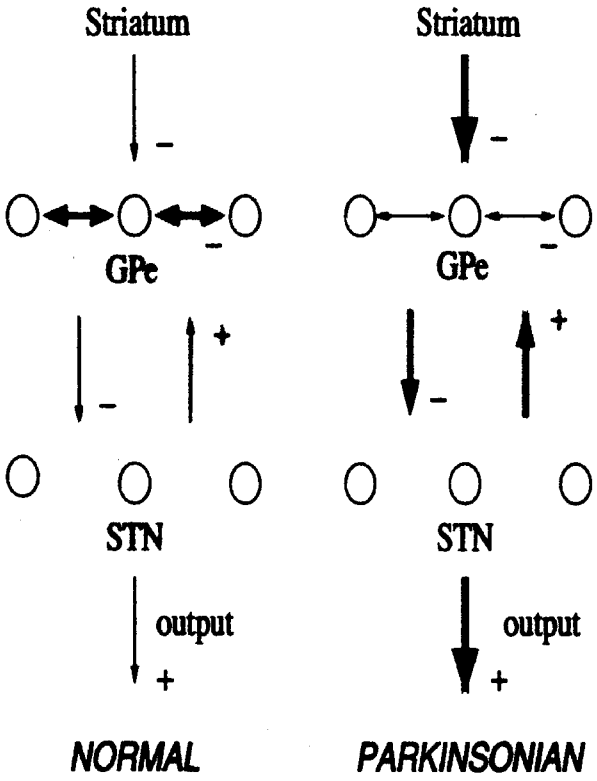

a) calcium drives mechanism for episodic activity
mV
[Ca]i STN
[Ca]i GPe
msec
b) T-current drives mechanism for clustered activity
mV
mV
n-deinactivation of I_T
msec


a)
GPe
STN
$g_{G->G}$
$g_{G->S}$
$g_{S->G}$
Structured, Tightly–Connected
b)
GPe
STN
$g_{G->G}$
$g_{G->S}$
$g_{S->G}$
Structured, Sparsely–Connected
c)
GPe
STN
$g_{G->G}$
$g_{G->S}$
$g_{S->G}$
Random, Sparsely–Connected


a)
SPARSE IRREGULAR FIRING
CONTINUOUS SPIKING
b)
NUMBER OF SPIKES / SECOND
c) Sparse
d) Episodic
e) Continuous
f) STN-Episodic
g) GPe-Episodic
h) STN-Continuous
i) GPe-Continuous
TIME
2000
-100
0


a)
sparse firing
continuous clusters
$g_{G->G}$
$g_{S->G}$
b)
spikes/sec within burst
burst duration (msec)
$g_{G->G}$
c) Weak
d) Episodic
e) Continuous
f) STN-Episodic
g) GPe-Episodic
h) STN-Continuous
i) GPe-Continuous
TIME
2000
-100
0


a)
sparse irregular firing
decoupled
continuous spiking
$g_{G->G}$
$g_{S->G}$
b)
period (ms)
$g_{S->G}$
c) Episodic Rhythm
d) Episodic Wave
e) Continuous Wave
f) STN-Episodic
g) GPe-Episodic
h) STN-Continuous
i) STN-Irregular
TIME
2000
-100
0


Striatum
Striatum
GPe
GPe
STN
STN
output
output
NORMAL
PARKINSONIAN