

Curriculum Vitae
Ann Martin Graybiel

Education and Positions:

Harvard University, A.B. <i>Magna cum Laude</i> , Phi Beta Kappa	1964
Tufts University, Department of Biology Woodrow Wilson Fellow	1965-1966
Massachusetts Institute of Technology, Ph.D. Department of Psychology and Brain Science	1971
Research Associate, M.I.T.	1971-1973
Assistant Professor in Psychology, M.I.T.	1973-1976
Associate Professor in Psychology, M.I.T.	1976-1980
Professor of Neuroanatomy, Dept. of Psychology, M.I.T.	1980-1983
Head, Course in Neuroscience and Professor, HST Division, Harvard Medical School	1986-1988
Professor of Neuroscience, Department of Brain and Cognitive Sciences, M.I.T.	1983-
Walter A. Rosenblith Professor of Neuroscience, M.I.T.	1994-2008
Investigator, McGovern Institute for Brain Research, M.I.T.	2001-
Affiliate, Picower Center for Learning and Memory, M.I.T.	2001-2012
Institute Professor, M.I.T.	2008-

Awards and Honors:

Porter Fellowship Award, American Physiological Society	1967
Williams and Wilkins Award, American Association of Anatomists	1970
Associate, Neuroscience Research Program (first woman)	1978
Charles Judson Herrick Award, American Association of Anatomists	1978
McKnight Senior Investigator Award	1985
Member, National Academy of Sciences, USA	1988
Javits Neuroscience Investigator Award, National Institutes of Health	1988, 1995
Honorary Member, Royal Academy of Medicine, Seville, Spain	1989
Member, American Academy of Arts and Sciences	1991
Member, National Academy of Medicine, USA (formerly the Institute of Medicine)	1994
Fellow, American Academy of Neurology	1997
President, International Basal Ganglia Society	1997-1998
Teaching Prize for Excellence in Graduate Education, School of Science, MIT	2000
Outstanding Women in Neuroscience Award, Brown University, Providence, Rhode Island	2001
National Medal of Science, USA	2001
James Rhyne Killian Jr. Faculty Achievement Award, M.I.T.	2002
Robert S. Dow Neuroscience Award	2002
Honorary Doctor of Science, Mount Sinai School of Medicine, New York, New York	2003
2004 Woman Leader of Parkinson's Science, Parkinson's Disease Foundation, New York, New York	2004
MERIT Award of the National Institutes of Health	2004
Radcliffe Alumnae Recognition Award	2004
Prix Plasticité Neuronale from the IPSEN Foundation	2005
Honorary Doctor of Science, Tufts University, Medford, Massachusetts	2005
Harold S. Diamond Honorary Professorship, National Parkinson Foundation	2005
NARSAD Distinguished Investigator Award	2007
Honorary Doctor of Philosophy, The Hebrew University, Jerusalem	2007
Honorary Doctor of Medical Science, Queens University, Belfast	2007
C. David Marsden Lectureship Award, Movement Disorder Society	2008
Vanderbilt Prize in Biomedical Science	2008
M.I.T. Institute Professor	2008

Honorary Member Award – 14 th Int’l Congress of Parkinson’s Disease and Movement Disorders	2010
The Kavli Prize	2012
Diana Helis Henry And Adrienne Helis Malvin Medical Research Foundations	2015
Joint Lecture Series in Parkinson’s Disease Research	
Member, American Philosophical Society	2016

Honorary Memberships:

Royal Academy of Medicine, Spain	1989
International Basal Ganglia Society	2007
The Movement Disorder Society	2010
Foreign Member of The Norwegian Academy of Science and Letters	2012

Selected Named Lectures:

First Special Lecture, Society for Neuroscience, Dallas, Texas	1985
Gordon H. Scott Memorial Lectureship, Detroit, Michigan	1986
John D. French Lectureship, UCLA, Los Angeles, California	1994
Olszewski Lectureship, Montreal Neurological Institute, Montreal, Canada	1994
Rushton Lecture, Florida State University, Tallahassee, Florida	1995
Servier Lecture, University of Montreal, Montreal, Canada	1995
Ragnar Granit Lecture, Karolinska Institute, Stockholm, Sweden	1995
Special Lecture, Society for Neuroscience, Washington, D.C.	1996
Grass Lecture, University of Indiana, Bloomington, Indiana	1999
George B. Murray Lecture, Massachusetts General Hospital, Boston, Massachusetts	1999
Melvin D. Yahr Lecture, Mt. Sinai School of Medicine, CUNY, New York, New York	1999
Distinguished Visiting Scientist Lecture, Albany Medical College, Albany, New York	2000
Plenary Lecture, French Movement Disorder and Basal Ganglia Societies, Paris, France	2000
NIH Tri-Institute Seminar, Bethesda, Maryland	2001
Robert S. Dow Neuroscience Award Lecture, Portland, Oregon	2002
NIH Director’s Lecture, Bethesda, Maryland	2002
Plenary Lecture, 6th IBRO World Congress of Neuroscience, Prague, Czech Republic	2003
John Flynn Memorial Lecture, Yale University, New Haven, Connecticut	2004
Norman Geschwind Memorial Lecture, Beth Israel-Deaconess Hospital, Boston, Massachusetts	2004
Distinguished Lecture and Rodolfo Rivas Memorial Lecture, University of Maryland, College Park, Maryland	2005
Plenary Lecture, Gordon Conference on Catecholamines, Andover, New Hampshire	2005
Plenary Lecture, Spanish Society on Neuroscience, Madrid, Spain	2005
Heller Lecture in Computational Neuroscience, Hebrew University, Jerusalem, Israel	2006
Millward Memorial Lecture, Brown University, Providence, Rhode Island	2006
Special Lecture, Society for Neuroscience, Atlanta, Georgia	2006
American Academy of Neurology Annual Meeting, Plenary Lecture, Chicago, Illinois	2008
C. David Marsden Lecture, Movement Disorder Society’s 12 th International Congress, Chicago, Illinois	2008
M.I.N.D. Institute Distinguished Lecture, Davis, California	2008
Lord Adrian Lecture, Cambridge, England	2008
Mildred Trotter Lecture, Washington University, St. Louis, Missouri	2009
David Smith Lecture, Oxford University, Oxford, England	2010
The Mellon Award Lecture, University of Pittsburgh, Pittsburgh, Pennsylvania	2010
Narabayashi Lecture, International Congress of Clinical Neurophysiology, Kobe, Japan	2010
Plenary Lecture, Turkish Neuroscience Meeting, Istanbul, Turkey	2011
Presidential Lecture, Society for Neuroscience, Washington, D.C.	2011
Segerfalk Lecture, Lund University, Lund, Sweden	2012
National Taiwan University Lecture, Taipei, Taiwan	2012
The Kavli Laureate Lecture, Oslo, Norway	2012
The Kavli Public Lecture, Bergen, Norway	2012
Carnegie Foundation Kavli Laureate Lecture, Washington, DC	2012

Druker Memorial Lecture, Beth Israel Deaconess Medical Center, Boston, Massachusetts	2013
Dean for Science Lecture in Neuroeconomics, New York University, New York, New York	2014
Jan and Dan Duncan Neurological Research Institute Distinguished Lecture, Houston, Texas	2014
Diana Helis Henry And Adrienne Helis Malvin Medical Research Foundations Joint Lecture Series in Parkinson's Disease Research	2015

Advisory Boards and Committees (National and International):

National Science Foundation	
Panel for Neurobiology	1976-1979
Neuroscience Oversight Review Board	1986
Society for Neuroscience	
Council	1976-1980
Program Committee	1976-1978
Gerard Prize Selection Committee	1989,1991
Board of Scientific Counselors of the NINCDS (National Institutes of Health)	1980-1984
American Association of Anatomists	
Cajal Club, Program Committee	1977
President, Cajal Club	1983-1984
C. Judson Herrick Award Committee	1985
Max Planck Institute for Psychiatry, Munich, Germany	1985-1989
Institute of Basic Research Scientific Advisory Board	1989-1998
The McKnight Endowment Fund for Neuroscience	1986-1996
Vice President	1986-1996
Board of Directors	1986-1996
Research Project Awards Committee	1986-1996
Development Awards Committee	1986-1996
Member, Senior Review Committee	1987-1996
Tourette Syndrome Association	1986-1992
Scientific Advisory Board	
Dystonia Medical Research Foundation	
Scientific Advisory Board	1989-1994
United Parkinson's Disease Foundation	
Scientific Advisory Board	1989-
International Brain Research Organization	
Executive Committee	1991-1997
Encyclopedia of Neuroscience	
Scientific Advisory Board	1993-
National Academy of Sciences	
Neuroscience Award Selection Committee, Chair	1993
Class II Membership Committee	1995-1998
Chair, Section of Neurobiology	1995-1998
Class II Secretary	2001-
Beckman Institute	
External Advisory Committee	1993-2007
Institute of Medicine	
Board on Neuroscience and Behavioral Health	1997-2001
Chair, Board on Neuroscience and Behavioral Health	2000-2001
National Parkinson Foundation	
Scientific Advisory Board	1997-2008
National Institute of Mental Health	
National Advisory Mental Health Council	1997-1999
Hereditary Disease Foundation	
Scientific Advisory Board	2000-2006
Alzheimer Research Forum	

Scientific Advisory Board	2000-
Max Planck Institute for Cybernetic Biology, Tübingen, Germany	
Scientific Advisory Board	2000-2006
American Association for the Advancement of Science	
Member-at-Large, Section Committee, Section on Neuroscience	2001-2005
Movement Disorder Society	
International Executive Committee	2001
Member, American College of Neuropsychopharmacology	2003
Society for Neuroscience International Affairs Committee – US National Committee (IAC-USNC) to the International Brain Research Organization (IBRO)	2007-
Stockholm Brain Institute, Stockholm, Sweden	
Scientific Advisory Board	2007-
Institut du Cerveau et de la moelle épinière (ICM)	
Scientific Advisory Board	2008-2013
Ernst Strüngmann Forum, Frankfurt, Germany	
Scientific Advisory Board	2008-
Biomedical Science Advisory Board at Vanderbilt University	2010-
Eidgenössische Technische Hochschule Zurich Scientific Advisory Board	2010-
Dopamine International Advisory Board	2011
MIT Presidential Search Committee	2012
Foundation IPSEN	2012-
Neuronal Plasticity Prize Jury	
Max Planck Florida Institute	
Scientific Advisory Board	2013-
Beckman Institute, University of Illinois at Urbana-Champaign	
External Advisory Committee	2013-
Bachmann-Strauss Dystonia & Parkinson Foundation, Inc.	
Scientific Advisory Board	2013-
Troland Research Award Selection Committee	2013
The Lurie Center for Autism	2013-
Scientific Advisory Board	
Pradel Research Award Committee (NAS)	2014

Editorial Boards:

<i>Neuroscience Letters</i>	1975-1984
<i>Neuroscience</i>	1976-1999
<i>Journal of Comparative Neurology</i>	1980-1984
<i>Neuroscience Research Communications</i>	1986-
<i>Movement Disorders</i>	1989-1993
<i>Neurodegeneration</i>	1991-1997
<i>Journal of Neurophysiology</i>	1992-
<i>Journal of Neuroscience</i>	1980-1983
	1988-2004
<i>Synapse</i>	1992-2004
<i>Biological Psychiatry</i>	1993-
<i>Anales de Anatomía</i>	1993-
<i>Parkinsonism and Related Disorders</i>	1994-1999
<i>Neuroscience Research</i>	2000
<i>Neuropsychopharmacology</i>	2000-
<i>Frontiers in Neuroscience</i>	2008-
<i>Journal of Comparative Neurology</i>	2008-2012
<i>Journal of Parkinson's Disease</i>	2010-

Research: Ann Graybiel discovered that the striatum, the largest subcortical structure of the mammalian forebrain, has a modular organization that is now recognized as shaping molecular signaling in the striatum and plasticity related to habit learning, repetitive behavior, motivational control, and human neurologic and neuropsychiatric disorders.

When Graybiel began her work, the striatum was known by physicians as important for motor disorders such as Huntington's disease and Parkinson's disease but was largely ignored by basic scientists, as it was thought to be a primitive, homogeneous structure. Graybiel nevertheless focused on the striatum, and in 1978, with student Ragsdale, discovered the neurochemical compartments of the human striatum: the striosomes and the surrounding matrix. It has now been found that this architecture is altered in some human neurological and neuropsychiatric disorders and in animal models of these conditions, and that this architecture is critical to the cholinergic-dopaminergic balance required for normal motor and motivational function.

Graybiel and her students discovered that nearly every neurotransmitter system known is differentially expressed according to this striosome-matrix architecture, and that this molecular modularity is linked to the input-output circuits of the striatum, the lineage programs giving rise to striatal neurons, and the development of their dopaminergic innervation in species ranging from rodents to humans. She showed that striosomes correspond to the sites at which the dopamine-containing nigrostriatal tract first terminates during development, and she and her students demonstrated, along with others, that striosomes in turn project to the dopamine-containing substantia nigra. Striosomes thus are critical components of striato-nigro-striatal loops affected in Parkinson's disease and other neurologic and neuropsychiatric disorders. With gene-induction methods, Graybiel and group then found that striosomes have differential sensitivity to many dopaminergic drugs, further pointing to dopamine-related functions. In successive studies, they found selective striosome-matrix neuronal vulnerability patterns in non-human primate and rodent models of Parkinson's disease, in models of dopa-responsive dystonia and L-dopa induced dyskinesias, and they with colleagues discovered that striosomes are selectively vulnerable in Huntington's patients exhibiting pronounced mood problems. Reinforcing these findings, Graybiel and group discovered novel CalDAG-GEF genes that link Ca^{2+} and DAG signaling to Ras superfamily (Ras, Rap) signaling, found that these have complementary expression in striosome and matrix compartments, and showed that they are dysregulated in human Parkinson's and Huntington's brains and in corresponding mouse models.

In parallel, Graybiel with her students discovered that input-output modules in the large matrix compartment organize information flow. Likening this physical architecture to learning architectures in computational models, Graybiel suggested that this organization could underlie habit learning. She put this hypothesis to the test by turning to multi-electrode techniques, allowing her group to make the first chronic recording from ensembles of neurons in the striatum and neocortex of awake, behaving rodents as they learned new tasks and developed habits. They discovered that highly patterned changes in ensemble activity occur in the striatum and neocortex as habits are formed, with activity bracketing the habitual behavior, which they related to learning of valued behavioral habits and repertoires. The task-bracketing patterns that they found in rodents, and then in non-human primates, suggest a potential biomarker of habitual behavior.

Capitalizing on newly available optogenetic methods, Graybiel and her group then manipulated the corticostriatal circuits that they had identified electrophysiologically. They found that they could block the formation of habits and block the expression of already formed habits, and that they could toggle habits on and off. Extending this work to a therapeutic model, they discovered that they could selectively block compulsive behavior in a mouse model of compulsive behavior. This work, still on-going, suggests a stunning level of on-line control of even apparently semi-automatic behaviors. Graybiel and her group have gone on to show links between these neural patterns and oscillatory activity patterns important in human disease. In long-term, chronic fast-scan cyclic voltammetric recordings in behaving animals, they discovered that striatal dopamine release can ramp up in relation to proximity to reward. This unexpected dopamine signal suggests a need for revising models of dopamine signaling as primarily occurring phasically in relation to reinforcement.

Critically, in early work, Graybiel, with Eblen, discovered that striosomes in non-human primates receive preferential input from cortical regions implicated, in humans, in anxiety, depression and emotional tone. With the chronic multi-electrode methods that her group developed for non-human primates, Graybiel and Amemori have found that they can modulate emotion-related decision-making by electrical microstimulation of these striosome-projecting cortical regions, inducing pessimistic or optimistic choices, and that these effects are reversible by anxiolytic treatment. Now, with optogenetics and recording in rodents, Graybiel with her fellows have provided causal evidence that cortico-striosomal circuits are critical for decision-making under cost-benefit conflict conditions in which positive and negative options must be weighed. This work has uncovered a pivotal role for striosomal circuits in the modulation of motivational signaling, now known to be affected in Huntington's and Parkinson's disease and a wide range of other disorders. Graybiel and her group are now generating and using engineered mice to explore the differential functions of striosomes and matrix in health and disease. Graybiel's work has ever-increasing importance for understanding circuits disrupted in neurological and neuropsychiatric disorders, their cellular and genetic basis, and the therapeutic strategies needed to relieve them.

Synopsis of Scientific Contributions of Graybiel and coworkers (please see list of publications for manuscripts):**Visuomotor Systems**

- Identified multiple-channel cortical connectivity of the pulvinar system of the thalamus. 1970-1983
- Delineated brainstem connections of oculomotor and visuomotor systems and discovered nearly every extrageniculate visual and visuo-oculomotor pathway in the brainstem. 1974-1980
- Identified mosaic organization of systems afferent to the superior colliculus. 1975-1978
- Delineated chemical compartments and mosaic organization of the superior colliculus. 1978-1984
- Identified sensory maps in the claustrum. 1980
- Identified chemical compartments of the visual thalamus and related these to the afferent-efferent subdivisions of these thalamic regions. 1980-1983

Basal Ganglia*Striosomes and Matrisomes*

- Identified histochemical compartments of the human striatum (striosomes and matrix). 1978
- Demonstrated that striatal inputs and outputs are organized in relation to striosomes. 1979-present
- Identified chemical compartments of embryonic and neonatal striatum and showed that these correspond to dopamine islands. 1980-1984
- Demonstrated that neuropeptides in striatum follow striosomal architecture and, subsequently, that most other neurotransmitter-related substances do so as well. 1981
- Demonstrated that striosomes are ontogenetic units of the striatum with defined developmental birthdates of striatal neurons. 1982
- Identified mosaic organization of the striatal matrix (matrisomes) using combined electrophysiology and anatomy. 1986
- Demonstrated that psychomotor stimulants induce immediate-early genes in striosome/matrix-specific patterns in the striatum. 1990-1993
- Identified convergent-divergent architecture of functionally-defined corticostriatal and striatopallidal circuits and likened this architecture to expert-systems learning architectures. 1991-1995
- Demonstrated that chronic psychomotor stimulant exposure induces network-level changes in gene expression in the striatum leading to striosome-enhanced induction patterns in rodents. 1996
- Demonstrated high correlation between striosome-predominant striatal gene expression patterns and stereotypic behavior induced by chronic exposure to psychomotor stimulants. 1999-2000
- Demonstrated that natural movement and sensorimotor inputs activate striatal matrix. 2002
- Demonstrated that after chronic psychomotor exposure, the stimulant induces striosome-predominant early-gene expression in the primate striatum. 2004
- Demonstrated that mood dysfunction in Huntington's disease patients is correlated with differential degeneration in striosomes of the striatum. 2006
- Demonstrated that differential degeneration of striosomes occurs in a mouse model of DOPA-responsive dystonia. 2008
- Demonstrated that DYT-3 dystonia-related protein N-TAF1 is enriched in the striosomal compartment of the striatum. 2011
- Demonstrated that microstimulation in striosome-projecting region of macaque anterior cingulate cortex induces negative value-based decision-making in non-human primates. 2012
- Identified a specific striosome-targeting corticostriatal circuit that selectively mediates decision-making under cost-benefit conflict conditions. 2015
- Demonstrated highly patterned prenatal development patterns of birth-dated striosomal and matrix neurons. 2015
- Demonstrated striosome-matrix developmental patterning of an autism spectrum disorder gene and its regulation (in review and on-going). 2016
- Demonstrated that the major components of striatal architecture are set up by sharply contrasting neural progenitor programs at the inception of striatal development (in submission). 2016

Physiology of Habit Learning and Cortico-Striatal Circuits, Neuroplasticity

- Demonstrated learning-related plasticity in spike activity of striatal tonically active neurons (TANs) during behavioral conditioning in primates, and showed that dopamine modulates expression of this neuroplasticity. 1994-1995
- Demonstrated that the activity of neurons in the striatum undergoes major reorganization as rats learn procedural tasks and form habits. 1999
- Demonstrated that thalamic inputs regulate expression of learning-related plasticity of striatal TANs. 2001
- Demonstrated that striatal TAN activity in macaque monkeys predicts behavioral response probability. 2002
- Identified neural activity in macaque monkeys prefrontal cortex representing boundaries of action sequences. 2003
- Demonstrated that striatal projection neurons exhibit multiple spiking changes during acquisition, extinction and reacquisition of a procedural “habit” task. 2005
- Demonstrated existence of highly contrasting learning-related neural dynamics in associative and sensorimotor striatum. 2010
- Demonstrated that optimal habits emerge without training in non-human primates. 2010
- Demonstrated that already acquired habits can be broken and reinstated in rats by on-line optogenetic inhibition of medial prefrontal cortex. 2012
- Demonstrated that dopamine depletion and L-DOPA treatment have selective effects on plasticity of learning-related ensemble spike activity in the sensorimotor striatum. 2013
- Demonstrated that dorsolateral striatum and medial prefrontal cortical habit-related regions exhibit strikingly different dynamics of neuroplasticity during habit learning, habit loss, and habit reinstatement. 2013
- Demonstrated that habit formation can be blocked by on-line optogenetic inhibition of medial prefrontal cortex. 2013
- Demonstrated that acquired compulsive behavior can be selectively blocked by on-line optogenetic excitation of orbitofrontal cortex and by excitation of orbitofrontal terminals within the striatum. 2013
- Discovered a novel, extended form of dopamine release signaling that occurs during approach to valued goals by use of fast-scan cyclic voltammetry in rats. 2013
- Demonstrated bivalent reinforcement signaling by cholinergic interneurons in ventral striatum during habit learning. 2014
- Demonstrated heightened stereotypy in mice genetically engineered to express exaggerated acetylcholine release. 2014
- Demonstrated that motivation and affective judgments elicit differential responses in cohorts of neurons in prefrontal cortex and cingulate cortex of macaque monkeys. 2015
- Demonstrated that natural habit learning in non-human primates leads to development of a caudate signal representing the integrated cost and benefit of the acquired behavior. 2015

Theoretical

- Proposed that the basal ganglia can act to affect cortical cognitive pattern generators, in addition to brainstem/spinal motor pattern generators. 1997
- Proposed that the basal ganglia act to enable chunking of action repertoires. 1998
- Proposed attractor state model of striatal processing. 2001
- Proposed the concept of ‘neural exploration’ and ‘neural exploitation’ to parallel behavioral exploration and exploitation in procedural learning. 2005
- Proposed hierarchical learning model suggesting that striosome-matrix architecture of the striatum provides template for context-specific learning. 2011

Striatal Oscillations

- Demonstrated that beta-band (10-25 Hz) oscillations are a prominent feature of striatal activity in normal, awake behaving macaques. 2003
- Demonstrated temporally coordinated LFP activity in simultaneous recordings from neocortex and striatum of awake, behaving macaques. 2005

- Demonstrated that theta rhythms in the striatum and hippocampus become coordinated during procedural learning. 2007-2008
- Demonstrated network-level shifts in frequencies of oscillatory rhythms and synchronized spike firing in ventromedial striatum during habit learning. 2011
- Discovered that multiple oscillatory frequency bands in local field potentials are selectively altered by dopamine depletion and L-DOPA treatment. 2012
- Demonstrated different co-occurring learning-related theta sub-band oscillation activity in sensorimotor and associative striatal regions during habit learning. 2014
- Demonstrated that brief bursts of beta oscillation mark the end of successfully completed task performance in non-human primates. 2015

Other work on basal ganglia

- Demonstrated that mouse weaver mutation depletes dopamine in patterns resembling those of Parkinson's disease. 1984
- Identified chemical compartments in substantia nigra pars compacta. 1989
- Demonstrated that intrastriatal grafts of fetal striatal cells develop striatal phenotype. 1989-1994
- Documented brain and behavioral consequences of dopamine D1 and D3 dopamine receptor deletion in transgenic mice. 1994-1996
- Introduced striatal organotypic slice cultures for studying regulation of gene expression in developing striatum. 1994
- Demonstrated that spatially selective phosphatase gates control cAMP-and Ca²⁺-mediated CREB phosphorylation in developing striatum using organotypic slice cultures. 1996
- Identified chemospecific compartments (“nigrosomes”) in human substantia nigra pars compacta and demonstrated that they are markers for neurodegeneration patterns in Parkinson’s disease. 1999
- Demonstrated existence of time-stamp encodings of time in cortico-basal ganglia circuits. 2009
- Demonstrated sharp increases in thyrotropin releasing hormone in striatum correlate with L-DOPA-induced dyskinesias. 2010
- Developed a chronic recording system for non-human primates with >100 independently movable electrodes. 2011
- Discovered that humanized Foxp2, engineered into mice, enhances learning to shift from place to habit strategies of performance. 2014

Methodological Development

- Developed microiontophoretic method for *in vivo* tracer experimentation. 1974
- Developed a silver intensification method for immunohistochemistry. 1996
- Developed a multi-electrode recording technique and devise with independently movable electrodes for long-term, chronic neural recording in non-human primate. 2012
- Developed a non-invasive head-holding devise for chronic non-human primate neural recording to avoid use of invasive head immobilization. 2015
- Developed novel multi-stage algorithm for automated spike-sorting of high-dimensional neuronal data with high background noise. 2015
- Developed a non-linear multi-dimensional hidden state (NMHS) approach to complex neural circuit analysis. 2016

Novel Gene Families

- Cloned and characterized the cAMP-GEF family of brain-enriched genes. 1998
- Cloned and characterized the CalDAG-GEF family of brain-enriched genes and demonstrated that they are striatum-enriched and have differential striosome-enriched (CalDAG-GEFII) and matrix-enriched (CalDAG-GEFI) distributions in the striatum. 1998
- Demonstrated that CalDAG-GEFI is essential for platelet aggregation and thrombus formation. 2004
- Demonstrated that CalDAG-GEFI is essential to neutrophil adhesion and trafficking. 2006
- Demonstrated that CalDAG-GEFI is essential for specific forms of neuroplasticity in the striatum including the development of drug-induced sensitization of stereotypic behavior and long-term potentiation (abstract only, in progress). 2005-present

- Demonstrated, with collaborators, that that the human LAD-III syndrome is associated with defective expression of CalDAG-GEFI in the hematopoietic system. 2007
- Demonstrated that the striatum-enriched genes CalDAG-GEFI and CalDAG-GEFII are strongly and inversely dysregulated in relation to severity of L-DOPA-induced dyskinesias (AIMs) in rat model of Parkinson's disease. 2009
- Demonstrated that CalDAG-GEFI down-regulation is protective in a model of Huntington's disease neurodegeneration and related to lowered expression of Htt nuclear aggregates. 2010
- Demonstrated that CalDAG-GEFI constitutive and conditional deletion in mice promotes behavioral repetitiveness and affects selectively a muscarinic cholinergic receptor-driven signaling pathway in the striatum (in preparation and on-going). 2014-present

Publications of Ann Martin Graybiel:**Books:**

1. Kimura, M. and Graybiel, A. M., eds. (1995) *Functions of the Cortico-Basal Ganglia Loop*. Springer-Verlag: New York.
2. Graybiel, A.M., DeLong, M.R., and Kitai, S.T., Eds. (2003) *The Basal Ganglia VI*. New York: Kluwer Academic/Plenum.
3. Grillner, S. and Graybiel, A.M., Eds. (2006) *Microcircuits: The Interface between Neurons and Global Brain Function*. Cambridge, MA: MIT Press.

Papers:

1. Graybiel, A.M. and Held, R. (1970) Prismatic adaptation under scotopic and photopic conditions. *J. Exp. Psychol.*, 85:16-22.
2. Graybiel, A.M. (1970) Some thalamocortical projections of the pulvinar-posterior system of the thalamus in the cat. *Brain Res.*, 22:131-136.
3. Graybiel, A.M. (1971) Some fiber connections of the posterior thalamus in the cat. Doctoral dissertation, Massachusetts Institute of Technology.
4. Graybiel, A.M. (1972) Some extrageniculate visual pathways in the cat. *Invest. Ophthalmol.*, 11:322-332.
5. Graybiel, A.M. (1972) Some fiber pathways related to the posterior thalamic region in the cat. *Brain Behav. Evol.*, 6:363-393.
6. Graybiel, A.M. (1972) Some ascending connections of the pulvinar and nucleus lateralis posterior of the thalamus of the cat. *Brain Res.*, 44:99-125.
7. Graybiel, A.M. (1973) The thalamo-cortical projection of the so-called posterior nuclear group: a study with anterograde degeneration methods in the cat. *Brain Res.*, 49:229-244.
8. Graybiel, A.M., Nauta, H.J.W., Lasek, R.J., and Nauta, W.J.H. (1973) A cerebello-olivary pathway in the cat: an experimental study using autoradiographic tracing techniques. *Brain Res.*, 58:205-211.
9. Graybiel, A.M. (1974) Studies on the anatomical organization of posterior association cortex. In: *The Neurosciences: Third Study Program*, F.O. Schmitt and F.G. Worden, Eds. Cambridge: MIT, pp. 205-214.
10. Graybiel, A.M. and Devor, M. (1974) A microelectrophoretic delivery technique for use with horseradish peroxidase. *Brain Res.*, 68:167-173.
11. Graybiel, A.M. (1974) Visuo-cerebellar and cerebello-visual connections involving the ventral lateral geniculate nucleus. *Exp. Brain Res.*, 20:303-306.
12. Graybiel, A.M. and Hartweg, E.A. (1974) Some afferent connections of the oculomotor complex in the cat: an experimental study with tracer techniques. *Brain Res.*, 81:543-551.
13. Graybiel, A.M. (1975) Wallerian degeneration and anterograde tracer methods. In: *The Use of Axonal Transport for Studies of Neuronal Connectivity*, W.M. Cowan and M. Cuénod, Eds. Amsterdam: Elsevier, pp. 174-216.
14. Graybiel, A.M. (1975) Anatomical pathways in the brain stem oculomotor system. In: *Eye Movements and Movement Perception*, J. Lott Brown, Ed. Rochester, NY: Center for Visual Science, pp. 37-38.
15. Graybiel, A.M. (1975) Anatomical organization of retinotectal afferents in the cat: an autoradiographic study. *Brain Res.*, 96:1-23.
16. Gould, B.B. and Graybiel, A.M. (1976) Afferents to the cerebellar cortex in the cat: evidence for an intrinsic pathway leading from the deep nuclei to the cortex. *Brain Res.*, 110:601-611.
17. Graybiel, A.M. (1976) Evidence for banding of the cat's ipsilateral retinotectal connection. *Brain Res.*, 114:318-327.
18. Graybiel, A.M. (1977) Direct and indirect preoculomotor pathways of the brainstem: an autoradiographic study of the pontine reticular formation in the cat. *J. Comp. Neurol.*, 175:37-78.
19. Graybiel, A.M. (1977) Organization of oculomotor pathways in the cat and rhesus monkey. In: *Control of Gaze by Brain Stem Neurons*, R.G. Baker and A. Berthoz, Eds. Amsterdam: Elsevier, pp. 79-88.

20. Graybiel, A.M. (1977) Basal ganglia in health and disease. In: *Society for Neuroscience, 6th Annual Meeting, Summaries of Symposia* (BIS Conference Report No. 45). Los Angeles: Brain Information Service, pp. 41-45.
21. Graybiel, A.M. (1978) Organization of the nigrotectal connection: an experimental tracer study in the cat. *Brain Res.*, 143:339-348.
22. Graybiel, A.M. (1978) A stereometric pattern of distribution of acetylthiocholinesterase in the deep layers of the superior colliculus. *Nature*, 272:539-541.
23. Graybiel, A.M. (1978) A satellite system of the superior colliculus: the parabigeminal nucleus and its projections to the superficial collicular layers. *Brain Res.*, 145:365-374.
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