BIOGRAPHICAL SKETCH

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NAME: STRICK, PETER

eRA COMMONS USER NAME (agency login): strickp

POSITION TITLE: Professor

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable.)*

INSTITUTION AND LOCATION	DEGREE (if applicable)	Completion Date MM/YYYY	FIELD OF STUDY
University of Pennsylvania, Philadelphia, PA	BA	05/1968	Biology
University of Pennsylvania, Philadelphia, PA	PHD	08/1972	Neuroscience/Neuroanatomy
Lab of Neurophysiology, NIMH/NIH, MD	POSTDOC	07/1976	Neuroscience/Neurophysiology

A. Personal Statement. My research focuses on 4 major topics: (i) the motor areas of the cerebral cortex- their involvement in movement generation and control, as well as in motor skill acquisition and retention; (ii) the motor, cognitive and affective functions of the basal ganglia and cerebellum; (iii) the neural basis for the mind-body connection; and (iv) unraveling the complex neural networks that comprise the central nervous system.

Research training: As a graduate student at the University of Pennsylvania, I learned light and electron microscopic techniques for tracing pathways in the nervous system of experimental animals. Then, as a postdoctoral fellow in Evarts lab at NIMH, I learned the techniques for recording single neuron activity in brains of awake, trained monkeys. In 1986, a Javits Award gave me an extra two years of funding. I used this as the opportunity to take a 6-month sabbatical with Hans Kuypers at Cambridge University and learn the techniques for research with neurotropic viruses. This enabled me to develop the use of herpes simplex virus type 1 and then, rabies virus as transneuronal tracers in the nervous system of nonhuman primates. Five years later, I commuted biweekly to collaborate with Kamil Ugurbil at the University of Minnesota and learn the methods for functional imaging with the BOLD technique. Around the same time, I spent a month at the Uniformed Health Services University working in Dr. Sharon Juliano's laboratory to learn the 2 deoxy-glucose technique for examining functional activity in the brains of nonhuman primates. In 2002, I spent a month in Dr. Amiram Grinvald's Lab at the Weizmann Institute to learn the techniques for optical imaging of signals from the cortex of awake monkeys. Last year, I attended the "Molecular Biology Summer Workshop" sponsored by New England BioLabs at Smith College.

Publication record: I have >100 publications listed in PubMed. These publications include 15 papers in high profile/high impact journals such as *Science*, *Nature*, and *PNAS*. A number of my papers are highly cited. Among review chapters, Alexander, DeLong and Strick ('86, ~6450 citations) is one of the most cited papers in systems neuroscience, and Picard and Strick ('96; ~1330 citations) is one of the most cited papers in *Cerebral Cortex*. Among scientific manuscripts, Dum and Strick ('91) and Middleton and Strick ('94) have each been cited nearly 1000 times.

Professional service: I was Associate Editor ('86-'95) and then Editor-in-Chief of the *Journal of Neurophysiology* ('95-'02). I currently serve as Senior Editor of *Cerebral Cortex* (2003-). I have served on 2 NIH Study Sections ('82-'86; '07-'11). I co-founded and served as Program Chair - Conference Co-Chair ('91-'07) and then, President - Conference Chair ('07-'11) of *Neural Control of Movement*.

Mentoring: I have >40 years of experience mentoring students, including numerous undergraduates and medical students, 12 graduate students, 15 residents in different medical specialties, 23 postdoctoral fellows and numerous junior faculty. My trainees have gone on to successful academic careers as Assistant, Associate, Full Professors and Department Chairmen at various universities, as well as science careers in industry and journalism. This list of trainees includes 4 individuals from under-represented populations.

The following list of papers identifies our recent work on the networks involved in the "Mind-Body Problem" .

1. Rathelot JA, Strick PL. Muscle representation in the macaque motor cortex: an anatomical perspective. Proc Natl Acad Sci U S A. 2006 May 23;103(21):8257-62. PubMed PMID: 16702556; PubMed Central PMCID: PMC1461407.
2. Rathelot JA, Strick PL. Subdivisions of primary motor cortex based on cortico-motoneuronal cells. Proc Natl Acad Sci U S A. 2009 Jan 20;106(3):918-23. PubMed PMID: 19139417; PubMed Central PMCID: PMC2621250.
3. Levinthal DJ, Strick PL. The motor cortex communicates with the kidney. J Neurosci. 2012 May 9;32(19):6726-31. PubMed PMID: 22573695; PubMed Central PMCID: PMC3363289.
4. Dum RP, Strick PL. Transneuronal tracing with neurotropic viruses reveals network macroarchitecture. Curr Opin Neurobiol. 2013 Apr;23(2):245-9. PubMed PMID: 23287632; PubMed Central PMCID: PMC3920982.
5. Dum, R.P., Levinthal, D.J. and Strick, P.L.: Motor, Cognitive and Affective Areas of the Cerebral Cortex Control the Adrenal Medulla. Proc Natl Acad Sci U S A., *accepted 07-11-16*.

B. Positions and Honors

Positions and Employment

1976 - 1999	Assistant -> Associate -> Full Professor, Neurosurgery & Physiology, SUNY-Upstate Medical Center, Syracuse, NY
1976 - 1999	Staff Neurophysiologist -> Research Career Scientist, Syracuse VA Medical Center
1988 - 1999	George W. Perkins III Memorial Professorship in Neurosurgery, SUNY-Upstate Medical Center
2000 - 2015	Co-Director, Center for the Neural Basis of Cognition, University of Pittsburgh, Pittsburgh, PA
2000 -	Professor, Department of Neurobiology, University of Pittsburgh School of Medicine
2000 - 2015	Senior Research Career Scientist, Pittsburgh VA Medical Center, Pittsburgh, PA
2006 -	Director, Systems Neuroscience Institute, University of Pittsburgh School of Medicine
2006 -	Adjunct Professor (with Advising Privileges), Dept. of Biological Sci., Carnegie Mellon Univ.
2009 - 2012	Endowed Chair in Systems Neuroscience, University of Pittsburgh
2012 -	Co-Director, Center for Neuroscience at the University of Pittsburgh
2012 -	Thomas Detre Professor & Chair of Neurobiology, University of Pittsburgh School of Medicine
2014 -	Scientific Director, University of Pittsburgh Brain Institute

Other Experience and Professional Memberships

-	Member, Society for Neuroscience
-	Member, American Association of Anatomists
-	Member, American Physiological Society
-	Member, American Association for the Advancement of Science

Honors

1979	C.J. Herrick Award, American Association of Anatomists
1981	Superior Performance Award, Veterans Administration
1982	Associate Research Career Scientist Award, Veterans Administration
1986	Javits Neuroscience Investigator Award, National Institute of Neurological Disease and Stroke
1987	Research Career Scientist Award, Veterans Administration
1995	Established Investigator Award, NARSAD
1996	President's Award for Excellence and Leadership in Research, SUNY-Upstate Medical Center
1999	Elected, Fellow, American Association for the Advancement of Science
2003	Elected, Associate, Neuroscience Research Program, La Jolla
2004	Elected, Fellow, American Academy of Arts and Sciences
2007	Elected, Member, International Neuropsychology Symposium
2011	Awarded, Distinguished Professor of Neurobiology, University of Pittsburgh School of Medicine, Pittsburgh, PA
2012	Elected, Member, National Academy of Sciences
2013	Chancellor's Distinguished Research Award, Senior Scholar, University of Pittsburgh

C. Contribution to Science

1. **Identification of the Cortical Motor Areas**. My work in this area began with the first demonstration that the primary motor cortex (M1) receives input from multiple "premotor areas" in the frontal lobe (Muakkassa and Strick, '79). These and other findings led us to begin a series of studies to examine the organization of output pathways from the premotor areas. We demonstrated that all of the premotor areas project directly to the spinal cord (Dum and Strick, '91). In fact, we showed that the number and density of corticospinal neurons in the premotor areas is comparable to the number and density in M1. Using rabies virus as a tracer, we showed that corticomotoneuronal (CM) cells, the output neurons with monosynaptic input to motoneurons, are located largely in a special caudal region of M1 (Rathelot and Strick, '09). We used a similar approach to show that the rat's cortical motor areas play a major role in the top-down control of the kidney (Levinthal and Strick, '12).

a. Dum RP, Strick PL. The origin of corticospinal projections from the premotor areas in the frontal lobe. J Neurosci. 1991 Mar;11(3):667-89. PubMed PMID: 1705965.
b. Rathelot JA, Strick PL. Muscle representation in the macaque motor cortex: an anatomical perspective. Proc Natl Acad Sci U S A. 2006 May 23;103(21):8257-62. PubMed PMID: 16702556; PubMed Central PMCID: PMC1461407.
c. Rathelot JA, Strick PL. Subdivisions of primary motor cortex based on cortico-motoneuronal cells. Proc Natl Acad Sci U S A. 2009 Jan 20;106(3):918-23. PubMed PMID: 19139417; PubMed Central PMCID: PMC2621250.
d. Levinthal DJ, Strick PL. The motor cortex communicates with the kidney. J Neurosci. 2012 May 9;32(19):6726-31. PubMed PMID: 22573695; PubMed Central PMCID: PMC3363289.

2. **Muscle and movement representation in M1**. Our anatomical results provide a framework for us to examine the function of M1 and the premotor areas. Using a unique behavioral task we showed that "muscles" and "movements" are represented by the activity of M1 neurons (Kakei et al., '99). In contrast, only movements are represented by the activity of neurons in an adjacent premotor area, the PMv (Kakei et al., 01). Recently, we used the same behavioral task and spike-triggered averaging to demonstrate that CM cells in M1 generate patterns of muscle activity that are tuned to the specific functions of a muscle (Griffin et al., in press). Some CM cells generate agonist activity whereas others generate synergist, fixator or antagonist activity.

a. Kakei S, Hoffman DS, Strick PL. Muscle and movement representations in the primary motor cortex. Science. 1999 Sep 24;285(5436):2136-9. PubMed PMID: 10497133.
b. Kakei S, Hoffman DS, Strick PL. Direction of action is represented in the ventral premotor cortex. Nat Neurosci. 2001 Oct;4(10):1020-5. PubMed PMID: 11547338.
c. Griffin DM, Hoffman DS, Strick PL. Corticomotoneuronal cells are "functionally tuned." Science. 2015 Nov 6;350(6261):667-70. PubMed PMID: 26542568.

3. **Motor skill acquisition and retention**. Guided by our anatomical studies, we performed a meta-analysis of the functional activations seen on the medial wall of the hemisphere of humans during motor tasks (Picard and Strick, '96). We demonstrated that humans contained multiple premotor areas comparable to those of the monkey. These observations provided a framework for identifying the SMA and distinguishing it from the PreSMA. We also identified cingulate zones for the human that are homologous to the cingulate motor areas of the monkey. Our analysis suggested that the SMA is active during the performance of simple movements, as well as during the preparation for complex movements. We confirmed this suggestion about the SMA in functional imaging studies in monkeys (Picard and Strick, '97, '03).

   In the course of these imaging studies we discovered that the acquisition of a motor skill led to profound changes in the functional organization of M1. Using single neuron recording we found evidence that practice sculpts the response properties of M1 neurons (Matsuzaka et al., '07). These results led us to propose that M1 is a site of storage for the internal representation of skilled sequential movements. Using a combination of neuron recording and functional imaging in trained monkeys, we demonstrated that the development of skill through extended practice results in a reduction in the synaptic activity required to produce internally generated movement sequences (Picard et al., ’13). These results have led us to propose that extended practice leading to skilled performance results in more efficient generation of neuronal activity in M1. We plan to test this proposal in future studies.

a. Picard N, Strick PL. Motor areas of the medial wall: a review of their location and functional activation. Cereb Cortex. 1996 May-Jun;6(3):342-53. PubMed PMID: 8670662.
b. Picard N, Strick PL. Activation of the supplementary motor area (SMA) during performance of visually guided movements. Cereb Cortex. 2003 Sep;13(9):977-86. PubMed PMID: 12902397.
c. Matsuzaka Y, Picard N, Strick PL. Skill representation in the primary motor cortex after long-term practice. J Neurophysiol. 2007 Feb;97(2):1819-32. PubMed PMID: 17182912.
d. Picard N, Matsuzaka Y, Strick PL. Extended practice of a motor skill is associated with reduced metabolic activity in M1. Nat Neurosci. 2013 Sep;16(9):1340-7. PubMed PMID: 23912947; PubMed Central PMCID: PMC3757119.

4. **Basal ganglia and cerebellar connections with the cerebral cortex and with each other**. Based on a review of the literature, we proposed that the basal ganglia participate in five major loops with motor and non-motor areas of the cerebral cortex (Alexander et al., ’86). This led us to conclude that the basal ganglia have a major influence not only on the control of movement, but also on cognitive and affective functions. In a series of studies with viruses as tracers we showed that the cortical targets of both the basal ganglia and the cerebellum include multiple motor, prefrontal, and posterior parietal areas of the cerebral cortex. These connections provide the neural substrate for the involvement of the basal ganglia and the cerebellum in a wide range of cognitive processes such as working memory, rule-based learning, switching attention, and visuo-spatial perception.

   Most concepts about basal ganglia and cerebellar function have emphasized their separate interconnections with the cerebral cortex. The use of virus tracing enabled us to demonstrate that these two major subcortical structures are linked together to form a densely interconnected functional network (Hoshi et al., ’05; Bostan et al., ‘10).

a. Alexander GE, DeLong MR, Strick PL. Parallel organization of functionally segregated circuits linking basal ganglia and cortex. Annu Rev Neurosci. 1986;9:357-81. PubMed PMID: 3085570.
b. Kelly RM, Strick PL. Cerebellar loops with motor cortex and prefrontal cortex of a nonhuman primate. J Neurosci. 2003 Sep 10;23(23):8432-44. PubMed PMID: 12968006.
c. Hoshi E, Tremblay L, Féger J, Carras PL, Strick PL. The cerebellum communicates with the basal ganglia. Nat Neurosci. 2005 Nov;8(11):1491-3. PubMed PMID: 16205719.
d. Bostan AC, Dum RP, Strick PL. The basal ganglia communicate with the cerebellum. Proc Natl Acad Sci U S A. 2010 May 4;107(18):8452-6. PubMed PMID: 20404184; PubMed Central PMCID: PMC2889518.

5. **Development of transneuronal tracing with neurotropic viruses**. My lab has worked with neurotropic viruses as transneuronal tracers since the late ‘80s (Ugolini et al., ’89). We were the first to use neurotropic viruses as transneuronal tracers in nonhuman primates, the first to show that the direction of transneuronal transport of HSV1 is strain dependent (Zemanick et al., PNAS, ’91), and the first to use transneuronal transport to examine basal ganglia and cerebellar circuits with motor and non-motor areas of the cerebral cortex (Hoover and Strick, ‘93; Middleton and Strick, ’94). My lab developed the use of rabies virus as a transneuronal tracer in nonhuman primates (Kelly and Strick, ’00) and we were the first to use this approach to explore circuits of 3 or more synaptically connected neurons (Kelly and Strick, ’ 03; Levinthal and Strick, ’12; Dum and Strick ’13). We continue to explore the characteristics of rabies transport in the nervous system and recently demonstrated that the virus is transported by neurons in the autonomic nervous system (Levinthal and Strick, ‘12). Since 2004, I have been the PI of “*Center for Neuroanatomy with Neurotropic Viruses*” (OD P40 OD010996). One of the goals of the center is to conduct research that results in the development of new and improved tools for transneuronal tracing.

a. Zemanick MC, Strick PL, Dix RD. Direction of transneuronal transport of herpes simplex virus 1 in the primate motor system is strain-dependent. Proc Natl Acad Sci U S A. 1991 Sep 15;88(18):8048-51. PubMed PMID: 1654557; PubMed Central PMCID: PMC52443.
b. Kelly RM, Strick PL. Rabies as a transneuronal tracer of circuits in the central nervous system. J Neurosci Methods. 2000 Nov 15;103(1):63-71. PubMed PMID: 11074096.
c. Dum RP, Strick PL. Transneuronal tracing with neurotropic viruses reveals network macroarchitecture. Curr Opin Neurobiol. 2013 Apr;23(2):245-9. PubMed PMID: 23287632; PubMed Central PMCID: PMC3920982.

Complete List of Published Work in My Bibliography:
http://www.ncbi.nlm.nih.gov/myncbi/18QBhybc5vo5z/bibliography/45906377/public/?sort=date&direction=ascending

D. Research Support

Ongoing Research Support

R01 NS024328-27; Strick, Peter (PI), Role: PI 12/01/86-03/31/16
Premotor Areas in the Frontal Lobe
The goals of this grant are to determine: 1) which premotor areas are major sources of descending commands to motoneurons; 2) whether the premotor areas provide a cortical interface between the oculomotor and skelemotor systems; and 3) whether premotor areas provide a cortical interface between the visceromotor and skeletomotor systems.

P40 OD010996-11; Strick, Peter (PI), Role: PI 07/01/03-06/30/20
Center for Neuroanatomy with Neurotropic Viruses
This grant funds a state-of-the-art National Resource Center for scientists interested in using neurotropic viruses as transneuronal tracers. The center has two goals: 1) to provide the neuroscience community with access to the highly specialized reagents, training and facilities that are necessary for the use of neurotropic viruses as transneuronal tracers; and 2) to conduct research that results in the development of new and improved tools for transneuronal tracing.

P30 NS076405-04; Strick, Peter (PI), Role: PI 09/30/12-06/30/17
Center for Neuroscience Research In Non-Human Primates
This grant supports a Center that is designed to provide critical resources for neuroscience research using nonhuman primates.

Completed Research Support

P01 NS044393; Grafton, Scott (PI), Role: PI of project 1 09/01/09-08/31/14
Integration of motor programs across time
Project 1: The Cortical Motor Areas and Motor Skills. The primary goal of this project was to determine whether long-term practice on a sequence of movements leads to changes in the response properties of neurons in M1 and in the premotor areas that project to M1.

R01 MH056661-15; Strick, Peter (PI), Role: PI 12/01/96-04/30/14
Basal Ganglia and Higher Cortical Function
The goal of this project was to define the organization of the neural circuits that link the basal ganglia with non-motor areas of the cerebral cortex.

I01 BX000510-04; Strick, Peter (PI), Role: PI 10/01/09-09/30/13
Central Control of Movement
The goal of this project was to investigate the “coordinate frames” represented in the Primary Motor Cortex and in the immediately adjacent Premotor Areas (PMd and PMv).