Sensory & Motor Systems Neuroscience, BMSC-GA 4462 and G80/89.2202, Spring 2018

Lectures
Tuesdays & Thursdays, 10:00 am - 11:50
Downtown: Meyer Hall (6 Washington Place), Room 760
Uptown: New Science Building (NSB) 12th Floor Conference Room

Labs
Fridays, 9:30-12:30 (Group A) or 1:30-4:30 (Group B)
NS2 labs run in parallel to the course (similar to the Cellular Neuroscience course). Neuroscience PhD students should co-register for NEURL-GA 2204 (Lab in Neural Science II). Labs will be held most Fridays when there isn't a scheduled conference (see below).

Conferences
There are 5 conferences throughout the semester. The conferences are interleaved with the labs. The conference schedule is:

	Group A (Date, Time, Location)			Group B (Date, Time, Location)		
Conference 1	2/09	10 am – 12 noon	Meyer 760	2/09	1:30 – 3:30 pm	Meyer 760
Conference 2	3/09	10 am – 12 noon	Meyer 760	3/09	1:30 – 3:30 pm	Meyer 760
Conference 3	3/30	10 am – 12 noon	NSB 1220	3/30	1:30 – 3:30 pm	NSB 1209
Conference 4	4/20	10 am – 12 noon	Meyer 760	4/20	1:30 – 3:30 pm	NSB 1209
Conference 5	5/3	10 am – 12 noon	NSB 1220	5/3	10 am – 12 noon	NSB 1209

Exams and Grading
There will be 2 take-home exams, each counting for one-half of the final grade. The format of the exam questions will be short essays.

- Exam 1 will be distributed on March 9 and answers will be due March 16.
- Exam 2 will be distributed May 4 and answers will be due May 11.

Participation in the conferences is also required to receive credit for the course (see below for more detail on the Conferences). Each unexcused conference absence will result in a letter grade reduction (A to A-, B+ to B, etc.).

Textbook
Squire LR, Berg D, Bloom FE, du Lac S, Ghosh A, Spitzer NC (2012). *Fundamental Neuroscience (4th edition)*. San Diego: Academic Press.

Readings
A list of assigned readings from the textbook and from the primary literature can be found on the Syllabus page of the course website by lecture. PDFs of journal articles (and lecture slides) are available in the Resources tab.

Some readings are labeled as "secondary readings". We strongly encourage you to read all the papers, but for some topics there are quite a few papers assigned, as there often isn't a single review paper that covers all relevant material. At the same time, we do not expect you to read every word. Because of the overwhelming amount of scientific literature in every sub-area of neuroscience, you need to develop a skill for rapidly scanning the literature to glean the basics, and then be able to go back as needed for the

details. For topics with a long reading list, you should look through each of the "secondary readings" to see what's there, read the abstract and introduction, look at the figures and figure captions. This is the same as what you should do when exploring the literature in your area of research. Then, based on your interests and what you feel you need to know, you can pick and choose which of these "secondary readings" to read in more detail.

Conferences

Conferences are like journal club discussion sessions. Two (or more) papers will be assigned for each conference. Each student will be responsible for leading the discussion of one paper for one conference; we will distribute these assignments at the beginning of the semester. Students are not expected to prepare a lecture, but must be prepared to lead a discussion of the paper by providing an introduction to the topic, details of the hypotheses tested, methods used, and results found. Presenting students will need to place the paper in the broader context of its field, and this will likely require presenters to read additional papers. **Presenters should contact the faculty in charge of their conference well in advance to discuss their presentation and get suggestions for additional papers to aid their preparation for leading the conference.** The faculty members leading each conference are listed in the syllabus. Note that students should take the initiative in contacting the faculty member in charge of their conference, but if a problem arises contact Estefany.Benedith@nyumc.org or Rachel.Weintraub@nyumc.org.

All students are required to read all the papers and contribute to the discussion. To aid preparation, you will be given specific questions to answer for each paper. Print your answers and hand them in at the end of each conference. Attendance is required. **Each unexcused conference absence will result in a letter grade reduction (A to A-, B+ to B, etc.).** More than one absence may result in no credit for the course.

Because the class is so large this year, we will split you into two sections/groups for each conference: group A and group B.

Grading

There will be 2 take-home exams, each counting for one-half of the final grade. The format of the exam questions will be short essays. Participation in the conferences is also required (as noted above) to receive credit for the course. Each unexcused conference absence will result in a letter grade reduction (A to A-, B+ to B, etc.).

NS2 Schedule of Lectures, Conferences and Exams Spring 2018

Date	Lec/Conf	Location	Topic (faculty leaders)
Jan 23	Lec	Meyer 760	Retina (Shapley)
Jan 25	Lec	Meyer 851	Functional architecture of the LGN & V1 cortex (Hawken)
Jan 30	Lec	Meyer 760	Cortical circuits, cell types and connections (Hawken)
Feb 1	Lec	Meyer 760	V1 functional characteristics, theory & computation (Movshon)
Feb 6	Lec (Simoncelli)	Meyer 760	Theories of encoding of sensory information
Feb 8	Lec	Meyer 760	Extrastriate visual cortex: organization (Movshon)
Feb 9	*Conf (10-Noon)*	*Meyer 760*	*(Movshon)*
	Conf (1:30-3:30)	*Meyer 760*	*(Hawken)*
Feb 13	Lec	Meyer 760	Extrastriate visual cortex: dorsal pathway (Movshon)
Feb 15	Lec	Meyer 851	Extrastriate visual cortex: ventral pathway (Movshon)
Feb 15	Lec (3:00-5:00)	Alexandria 901	Audition: periphery (Froemke)
Feb 20	Lec	Alexandria 901	Audition: central (Froemke)
Feb 22	Lec	Meyer 760	Perceptual decision-making (Kiani)
Feb 27	Lec	Meyer 760	Theories of decoding of sensory information (Simoncelli)
Mar 1	Lec	Meyer 760	Development of visual cortex (Movshon)
Mar 9	*Conf (10-Noon)*	*Meyer 760*	*(Simoncelli) Group A*
	Conf (1:30-3:30)	*Meyer 760*	*(Shapley) Group B*
Mar 9	**Midterm exam given**		
Mar 12 – 16	Spring Recess		
Mar 16	**Midterm exam due**		
Mar 20	Lec	NSB 1220CR	Chemical senses: periphery (Rinberg)
Mar 22	Lec	NSB 1220CR	Chemical senses: central (Rinberg)
Mar 27	Lec	NSB 1220CR	Somatosensation: periphery (Gardner)
Mar 29	Lec	NSB 1220CR	Somatosensation: central (Gardner)
Mar 30	*Conf (10-Noon)*	*NSB 1220*	*(Rinberg) Group A*
	Conf (1:30-3:30)	*NSB 1209*	*(Ringstad) Group B*
Apr 3	Lec	NSB 1220	Pain and temperature sense (Gardner)
Apr 5	Lec	NSB 1220	Muscles, motor neurons & motor pools (Lang)
Apr 10	Lec	NSB 1220	Reflexes I: Sherrington reflexes & CPGs (Lang)
Apr 12	Lec	NSB 1220	Reflexes II: posture & locomotion (Lang)
Apr 19	Lec	NSB 1220	Descending motor control, motor cortex (Schneider)
Apr 20	*Conf (10-Noon)*	*Meyer 760*	*(Schneiider)*
	Conf (1:30-3:30)	*NSB 1209*	*(Tritsch)*
Apr 24	Lec	Meyer 760	Sensorimotor integration, posterior parietal cortex (Schneider)
Apr 26	Lec	NSB 1220	Cerebellum (Llinas)
Apr 27	Lec	Meyer 760	Basal ganglia (Glimcher)
May 1	Lec	Meyer 760	Eye movements I: VOR & OKN (Glimcher)
May 3	*Conf (10-noon)*	*NSB 1209*	*Group A (Lang)*
	Conf (10-noon)	*NSB 1220*	*Group B (Long)*

May 4	Lec	Meyer 760	Eye movements II: saccades, pursuit, vergence (Glimcher)

May 4 **Final exam given**
May 11 **Final exam due**

Students:

Group A:
Bredenberg, Colin
Brissette, Ben
Diaz, Veronica
Ehrlich, Alison
Goldblatt, Dena
Hamling, Kyla
Hu, Peiyao
Kim, Rachel
Li, Liujunli
Parthasarathy, Nikhil
Peng, Yalun

Group B:
Dai, Bing
Feinman, Reuben
Herrero-Vidal, Pedro
Holey, Brooke
Huszar, Roman
Manoocheri, Kasra
Miranda, Paige
Rashid, Shannon
Schuster, Luisa
Voelcker, Tina
Zhou, WenXi

Spring 2018 Sensory and Motor Systems Neuroscience Syllabus

Assigned Readings by Lecture

A mixture of textbook chapters and primary articles are assigned for each lecture. All journal articles can also be found under the Resources tab, organized by lecture. (Conference reading assignments are TBD and will be posted in ALEX as soon as they are available.)

Jan 23 Retina (Shapley)
Textbook: Ch 22 & 26
Primary readings:

- Arshavsky VY1, Lamb TD, Pugh EN Jr. (2002) G proteins and phototransduction. Annu Rev Physiol. 64:153-87.
- Westheimer G (2007). The ON-OFF dichotomy in visual processing: from receptors to perception. Progress in Retinal and Eye Research 26:636-648.
- Wu SM (2010). Synaptic organization of the vertebrate retina: general principles and species-specific variations: the Friedenwald lecture. Investigative ophthalmology & visual science 51:1263-1274.

Secondary readings:

- Shapley R (2009) Linear and nonlinear systems analysis of the visual system: Why does it seem so linear? A review dedicated to the memory of Henk Spekreijse. Vision Res. 2009 49:907-21

Jan 25 Functional architecture of the LGN & V1 cortex (Hawken)
Jan 30 Cortical Circuits, cell types and connections (Hawken)
Textbook: Ch 26
Primary readings:

- Nassi JJ, Callaway EM (2009). Parallel processing strategies of the primate visual system. Nature Reviews Neuroscience 10:360-372.
- Sincich LC, Horton JC (2005). The circuitry of V1 and V2: integration of color, form, and motion. Ann Rev Neurosci 28:303-326.
- Lund JS, Angelucci A, Bressloff PC (2003). Anatomical substrates for functional columns in macaque monkey primary visual cortex. Cereb Cortex 13:15-24.
- Angelucci A, Bijanzadeh M, Nurminen L, Federer F, Merlin S, Bresslof P (2017) Circuits and mechanisms for surround modulation in visual cortex. Ann Rev Neurosci 40:425-451.

Secondary readings:

- Nauhaus I, Nielsen, KJ (2014) Building maps from maps in primary visual cortex. Current Opinion in Neurobiology 24: 1-6
- Glickfeld LL, Reid RC, Andermann ML (2014) A mouse model of higher cortical visual function. Current Opinion in Neurobiology 24: 28-33.
- Chatterjee S, Callaway EM (2003) Parallel colour-opponent pathways to primary visual cortex. Nature 426:
- Economides JR, Sincich LC, Adams DL, Horton JC (2011). Orientation tuning of cytochrome oxidase patches in macaque primary visual cortex. Nature Neuroscience 14:1574-1580.
- Bonin et al (2011) Local diversity and fine-scale organization of receptive fields in mouse visual cortex. J Neurosci 31:18506-18521.
- Ringach et al (2016) Spatial clustering of tuning in mouse primary visual cortex. Nat Commun. 7:12270.

Feb 1 V1 functional characteristics, theory & computation (Movshon)

Textbook: Ch 26
Primary readings:

- Adelson EH, Bergen JR (1991). The plenoptic function and the elements of early vision. From From M. Landy and J. A. Movshon (eds), Computational Models of Visual Processing (pp. 3-20). Cambridge, MA: MIT Press.
- Carandini M, Heeger DJ (2011). Normalization as a canonical neural computation. Nature Reviews Neuroscience 13:51-62.
- Hubel D, Wiesel T (1998). Early exploration of the visual cortex. Neuron 20:401-412.
- Hubel D, Wiesel T (2012). David Hubel and Torsten Wiesel. Neuron 75:182-184
- Lennie P, Movshon JA (2005). Coding of color and form in the geniculostriate visual pathway (invited review). J Opt Soc Am A 22(10), 2013-2033.
- Priebe NJ, Fester D (2012). Mechanisms of neuronal computation in mammalian visual cortex. Neuron 75:194-208.

Feb 27 Theories of encoding of sensory information (Simoncelli)
Primary readings:

- Barlow (1961). Possible principles underlying the transformation of sensory messages. In Sensory Communication (WA, Rossenblith, ed), MIT Press.
- Olshausen BA, Field DJ (1996). Emergence of simple-cell receptive field properties by learning a sparse code for natural images. Nature 381:607-609.
- Schwartz O, Simoncelli EP (2001). Natural signal statistics and sensory gain control. Nat Neurosci 4: 819-825.

Feb 8 Extrastriate visual cortex: organization (Movshon)

Primary Readings:

- Douglas RJ, Martin KA. Behavioral architecture of the cortical sheet. Current Biology. 2012 Dec 18;22(24):R1033-8.
- Glasser MF, Coalson TS, Robinson EC, Hacker CD, Harwell J, Yacoub E, Ugurbil K, Andersson J, Beckmann CF, Jenkinson M, Smith SM. A multi-modal parcellation of human cerebral cortex. Nature. 2016 Jul 20.
- Mante V, Frazor RA, Bonin V, Geisler WS, Carandini M. Independence of luminance and contrast in natural scenes and in the early visual system. Nature neuroscience. 2005 Dec 1;8(12):1690-7.
- Markov NT, Ercsey-Ravasz MM, Gomes AR, Lamy C, Magrou L, Vezoli J, Misery P, Falchier A, Quilodran R, Gariel MA, Sallet J. A weighted and directed interareal connectivity matrix for macaque cerebral cortex. Cerebral cortex. 2012 Sep 25:bhs270.

Feb 9 Conference 1 A:10-Noon, B:1:30 -3:30 (Movshon, Hawken)

Feb 13 Extrastriate visual cortex: dorsal pathway (Movshon)

Textbook: Chs 26, 44 & 46
Primary reading:

- Orban GA (2008). Higher order visual processing in macaque extrastriate cortex. Phyisiol Rev 88:59-89.
- Movshon JA, Simoncelli EP. Representation of naturalistic image structure in the primate visual cortex. InCold Spring Harbor symposia on quantitative biology 2014 Jan 1 (Vol. 79, pp. 115-122). Cold Spring Harbor Laboratory Press.
- von der Heydt R. Figure–ground organization and the emergence of proto-objects in the visual cortex. Frontiers in psychology. 2015 Nov 3;6:1695.
- Yamins DL, Hong H, Cadieu CF, Solomon EA, Seibert D, DiCarlo JJ. Performance-optimized hierarchical models predict neural responses in higher visual cortex. Proceedings of the National Academy of Sciences. 2014 Jun 10;111(23):8619-24.

Secondary reading:
- Goodale, MA (2010). Transforming vision into action. Vis Res, in press
- Parker AJ. Binocular depth perception and the cerebral cortex. Nature Reviews Neuroscience. 2007 May 1;8(5):379-91.v
- Westheimer G. The third dimension in the primary visual cortex. The Journal of physiology. 2009 Jun 15;587(12):2807-16.

Feb 15 Extrastriate visual cortex: ventral pathway (Movshon)

Textbook: Ch 26, 44 & 46
Primary reading:

- Orban GA (2008). Higher order visual processing in macaque extrastriate cortex. Phyisiol Rev 88:59-89.

- Markov N, et. al. (2013). Cortical High-Density Counterstream Architectures. Science 342: 1238406.

Secondary readings:

- DiCarlo JJ, Cox DD (2007). Untangling invariant object recognition. Trends Cogn Sci 11:333-341.
- DiCarlo JJ, Zoccolan D, Rust NC. How does the brain solve visual object recognition?. Neuron. 2012 Feb 9;73(3):415-34. Rust NC, DiCarlo JJ (2010). Selectivity and tolerance ("invariance") both increase as visual information propagates from cortical area V4 to IT. J Neurosci 30:12978-12995.
- Connor CE, Brincat SL, Pasupathy A (2007). Transformation of shape information in the ventral pathway. Curr Opin Neurobiol 17:140-147.
- Freiwald WA, Tsao DY. Functional compartmentalization and viewpoint generalization within the macaque face-processing system. Science. 2010 Nov 5;330(6005):845-51.
- Lafer-Sousa R, Conway BR. Parallel, multi-stage processing of colors, faces and shapes in macaque inferior temporal cortex. Nature neuroscience. 2013 Dec 1;16(12):1870-8.
- Tsao DY, Moeller S, Freiwald WA. Comparing face patch systems in macaques and humans. Proceedings of the National Academy of Sciences. 2008 Dec 9;105(49):19514-9.

Feb 15 (3-5pm) Audition: periphery (Froemke)
Textbook: Ch 22 & 25
Primary readings:

- Brownell WE, et al. (1985) . Evoked mechanical responses of isolated cochlear outer hair cells. Science 227:194-196
- Hofman PM, et al.(1998). Relearning sound localization with new ears. Nat Neurosci 1:417-421.
- Rose JE, et al. (1971). SOme effects of stimulus intensity on response of auditory nerve fibers in the squirrel monkey. J Neurophysiol 34:685-699.

Secondary readings:

- Hudspeth AJ (2008). Making an effort to listen: mechanical amplification in the ear. Neuron 59: 530-545.
- Narayan SS, et al. (1998). Frequency tuning of basilar membrane and auditory nerve fibers in the same cochleae. Science 282: 1882-1884.
- Van Wanrooij MM, Van Opstal AJ (2005). Relearning sound localization with a new ear. J Neurosci 25:5413-5424.

Feb 20 Audition: central (Froemke)
Textbook: Ch 25
Primary readings:

- Brand A, et al (2002). Precise inhibition is essential for microsecond interaural time difference coding. Nature, 417:543-547.
- Carr CE, Konishi M (1990). A circuit for detection of interaural time differences in the brain stem of the barn owl. J Neurosci 10:3227-3246.
- Knudsen EI, Konishi M (1978). A neural map of auditory space in the owl. Science 200:795-997.
- Bakin JS and Weinberger NM (1996). Induction of a physiological memory in the cerebral cortex by stimulation of the nucleus basalis. PNAS 93:11219-11224.
- De Villers-Sidani E, et. al. (2007). Critical window for spectral turning defined in the primary auditory cortex (A1) in rat. J Neurosci 27:180-189.
- Wehr M and Zador AM (2003). Balanced inhibition underlies tuning and sharpens spike timing in auditory cortex. Nature 426: 442-446.

Secondary readings:

- Miller LM, et al.(2001). Functional convergence of response properties in the auditory thalamocortical system. Neuron 32:151-160.
- Tzounopoulos T, et al. (2004). Cell-specific, spike timing-dependent plasticities in the dorsal cochlear nucleus. Nat Neurosci 7:719-725.
- Zhou M., et al. (2012). Generation of intensity selectivity by differential synaptic tuning: fast-saturating excitation but slow-saturating inhibition. J Neurosci 32:18068-18078.
- Buonomano DV and Merzenich MM (1998). Cortical plasticity: from synapses to maps. Annu Rev Neurosci 21:149-186.

Feb 22 Perceptual decision making (Kiani)
Primary reading:

- Gold JI, Shadlen MN (2007). The neural basis of decision making, Ann Rev Neurosci 30:535-574.

Secondary readings:

- Shadlen et al. (1996). A computational analysis of the relationship between neuronal and behavioral responses to visual motion. J Neurosci 16:1486-1510.
- Nienborg H, Cumming B (2010). Correlations between the activity of sensory neurons and behavior: how much do they tell us about a neuron's causality? Curr Opin Neurobiol 20:376-381.
- Chowdhury SA, DeAngelis GC (2008). Fine discrimination training alters the causal contribution of macaque area MT to depth perception. Neuron 60:367-377.
- Hedges J, et. al. (2011). Dissociation of neuronal and psychophysical responses to local and global motion. Current Biology 21, 2023-2028.
- Guo W, et al. (2012). Robustness of cortical topography across fields, laminae, anesthetic states, and neurophysiological signal types. J Neurosci 32:9159-9172.

- Nelken I, et al. (2003). Primary auditory cortex of cats: feature detection or something else? Biol Cybern 89:397-406.

Feb 27 **Theories of decoding of sensory information (Simoncelli)**
Primary readings:

- Georgopoulos, A.P., Kalaska, J.F., Caminiti, R., and Massey, J.T. (1982). On the relations between the direction of two-dimensional arm movements and cell discharge in primate motor cortex. J. Neurosci. 2:1527-1537.
- Wei Ji Ma, Jeffrey M Beck, Peter E Latham & Alexandre Pouget (2006). Bayesian inference with probabilistic population codes. Nature Neuroscience - 9, 1432 - 1438.

Secondary reading:

- A A Stocker and E P Simoncelli (2006). Noise characteristics and prior expectations in human visual speed perception. Nature Neuroscience 9(4): 578--585

Mar 1 Development of visual cortex (Movshon)
Textbook: Ch 21
Primary readings:

- Kiorpes L, Movshon JA (2013). Neural limitations on visual development in primates: Beyond striate cortex. In The Visual Neurosciences, Werner & Chalupa (eds.), MIT Press (Cambridge MA), Ch 99, pages 1423-1431.
- Espinosa JS, Stryker MP. Development and plasticity of the primary visual cortex. Neuron. 2012 Jul 26;75(2):230-49.
- Hubel DH, Wiesel TN, LeVay S. Plasticity of ocular dominance columns in monkey striate cortex. Philosophical Transactions of the Royal Society of London B: Biological Sciences. 1977 Apr 26;278(961):377-409.

March 9 Conference 2, A: 10-Noon (Simoncelli) B: 1:30-3:30 (Shapley)

Mar 20 Chemical senses: periphery (Rinberg)
Textbook: Ch 22 & 23
Primary readings:

- Axel R (2004). Scents and sensibility: A molecular logic of olfactory perception. Nobel Lecture.
- Yarmolinsky DA, Zuker CS, Ryba NJ (2009). Common sense about taste: from mammals to insects. Cell 139(2):234-44.

Secondary readings:

- Buck L, Axel R (1991). A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. Cell 65(1):175-87.
- Hoon MA, Adler E, Lindemeier J, Battey JF, Ryba NJ, Zuker CS (1999). Putative mammalian taste receptors: a class of taste-specific GPCRs with distinct topographic selectivity. Cell 96(4):541-51.
- Clyne PJ, Warr CG, Freeman MR, Lessing D, Kim J, Carlson JR (1999). A novel family of divergent seven-transmembrane proteins: candidate odorant receptors in Drosophila. Neuron 22(2):327-38.
- Wang JW, Wong AM, Flores J, Vosshall LB, Axel R (2003). Two-photon calcium imaging reveals an odor-evoked map of activity in the fly brain. Cell 112(2):271-82.
- Lee T, Luo L (2001). Mosaic analysis with a repressible cell marker (MARCM) for Drosophila neural development. Trends Neurosci 24:251-254.

Mar 22 (3-5pm) Chemical senses: central (Rinberg)
Primary readings:

- Masse, N. Y., Turner, G. C., & Jefferis, G. S. (2009). Olfactory information processing in Drosophila. Current Biology, 19(16), R700-R713.
- Shusterman, R., Smear, M. C., Koulakov, A. A. & Rinberg, D.(2011) Precise olfactory responses tile the sniff cycle. *Nat Neurosci* **14,** 1039–1044.
- Sosulski, D. L., Lissitsyna Bloom, M., Cutforth, T., Axel, R. & Datta, S. R.(2011) Distinct representations of olfactory information in different cortical centres. Nature 472, 213–216.

Secondary readings:

- Soucy, E. R., Albeanu, D. F., Fantana, A. L., Murthy, V. N. & Meister, M.(2009). Precision and diversity in an odor map on the olfactory bulb. *Nat Neurosci* **12,** 210–220 .
- Kato, H. K., Chu, M. W., Isaacson, J. S. & Komiyama, T. (2012) Dynamic sensory representations in the olfactory bulb: modulation by wakefulness and experience. Neuron 76, 962–97.
- Stettler, D. D. & Axel, R. Representations of odor in the piriform cortex. (2009). Neuron 63, 854–864.
- Boyd, A. M., Sturgill, J. F., Poo, C. & Isaacson, J. S. (2012). Cortical Feedback Control of Olfactory Bulb Circuits. Neuron 76, 1161–1174.

Mar 27 Somatosensation: Periphery (Gardner)
Primary readings:

- Gardner EP, Johnson KO (2012). 23. Touch. In: Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ (eds.) Principles of Neural Science. 5th Edition. New York: McGraw-Hill, pp. 498-510.

- Johansson RS, Flanagan JR. (2009) Coding and use of tactile signals from the fingertips in object manipulation tasks. Nature Reviews: Neuroscience 14: 345-359.
- Lumpkin EA, Caterina MJ. (2007) Mechanisms of sensory transduction in the skin. Nature 445: 858-865.

Secondary readings:

- Johnson KO (2001). The roles and functions of cutaneous mechanoreceptors. Curr Opin Neurobiol 11:455-461.
- Rice FL, Mance A, Munger BL. (1986) A comparative light microscopic analysis of the senory innervation of the mystacial pad. I. Innervation of vibrissal follicle-sinus complexes. J Comp Neurol 252: 154-174.
- Brecht M, Preilowski B, Merzenich MM. (1997) Functional architecture of the mystacial vibrissae. Behav Brain Res 84: 81-97.

Mar 29 Somatosensation: Central (Gardner)
Primary readings:

- Gardner EP, Johnson KO (2012). 23. Touch. In: Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ (eds.) Principles of Neural Science. 5th Edition. New York: McGraw-Hill, pp. 498-510.
- Recanzone GH, Merzenich MM, Schreiner CE. (1992) Changes in the distributed temporal response properties of cortical neurons reflect improvements in performance in a temporally based tactile discrimination task. J Neurophysiol 67: 1071-1091.
- Romo R, Salinas E (2003). Flutter Discrimination: Neural codes, perception, memory and decision making. Nature Reviews Neuroscience 4:293-218.

Secondary readings:

- Mountcastle VB (1997). The columnar organization of the neocortex. Brain 120:701-722.
- Merzenich MM, Kaas JH, Wall J, Nelson RJ, Sur M, Felleman D. 1983. Topographic reorganization of somatosensory cortical areas 3b and 1 in adult monkeys following restricted deafferentation. Neuroscience 8: 33-55.
- Romo R, Hernandez A, Zainos A, Lemus l, Brody CD. (2002) Neural correlates of decision-making in secondary somatosensory cortex. Nature Neuroscience 5: 1217-1225.
- Diamond ME, von Heimendahl M, Knutseh PM, Kleinfeld D, Ahissar E. (2008) 'Where' and 'what' in the whisker sensorimotor system. Nature Reviews: Neuroscience 9: 601-612.

Mar 30 Conference 3 Group A: 10-noon (Rinberg) Group B: 1:30-3:30 (Ringstad)

Apr 3 Pain and temperature sense (Gardner)
Primary reading:

- Basbaum AI, Jessel TM (2012). 24. Pain. In: Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ (eds.) Principles of Neural Science. 5th Edition. New York: McGraw-Hill.

Secondary reading:

- Dhaka A, Viswanath V, Patapoutian A. Trp ion channels and temperature sensation. Annu. Rev. Neurosci.. 2006 Jul 21;29:135-61.
- Dubin AE, Patapoutian A. Nociceptors: the sensors of the pain pathway. The Journal of clinical investigation. 2010 Nov 1;120(11):3760-72.
- Julius D, Basbaum AI. Molecular mechanisms of nociception. Nature. 2001 Sep 13;413(6852):203-10.
- Tracey I. Getting the pain you expect: mechanisms of placebo, nocebo and reappraisal effects in humans. Nature medicine. 2010 Nov 1;16(11):1277-83.
- Tracey I, Mantyh PW. The cerebral signature for pain perception and its modulation. Neuron. 2007 Aug 2;55(3):377-91.
- Woolf CJ, Ma Q. Nociceptors—noxious stimulus detectors. Neuron. 2007 Aug 2;55

Apr 5 Muscles, motor neurons & motor pools (Lang)
Textbook: Ch 27 & 28
Primary reading:

- Berne & Levy (2010). Skeletal Muscle Physiology, Ch. 12 in Principles of Physiology 6th edition (Koeppen BM and Stanton BA, eds), Mosby/Elsevier.

Apr 10 Reflexes I: Sherrington reflexes & CPGs (Lang)
Textbook: Ch 27 & 28
Primary reading:

- Burke RE. Spinal Cord: Ventral Horn. From *Synaptic Organization of the Brain*.

Secondary reading:

- Sherrington CS. Introductory-Coordination of the Simple Reflex. In *The integrative action of the nervous system* pp 17-50.
- Bernstein N (1935). The problem of the interrelation of co-ordination and localization. Arch Biol Sci 38. Reprinted in Whiting HTA (ed) (1984) Human Motor Actions.

Apr 12 Reflexes II: Posture & locomotion (Lang)
Textbook: Ch 27 & 28

Apr 19 Descending motor control, motor cortex (Schneider)

Primary readings:

- Kalaska JF, Cohen DA, Hyde ML, Prud'homme M. A comparison of movement direction-related versus load direction-related activity in primate motor cortex, using a two-dimensional reaching task. The Journal of neuroscience. 1989 Jun 1;9(6):2080-102.
- Scott SH. Optimal feedback control and the neural basis of volitional motor control. Nature Reviews Neuroscience. 2004 Jul 1;5(7):532-46.
- Tanji J, Evarts EV. Anticipatory activity of motor cortex neurons in relation to direction of an intended movement. Journal of Neurophysiology. 1976 Sep 1;39(5):1062-8.

Apr 20 Conference 4 A:10-Noon, B:1:30 -3:30 (Schneider, Long)

Apr 24 Sensorimotor integration, posterior parietal cortex (Schneider)
Textbook: Ch 29
Primary reading:

- Andersen RA, Buneo CA (2002). Intentional maps in posterior parietal cortex. Annu Rev Neurosci. 25:189-220.

Apr 26 Cerebellum (Llinas)
Textbook: Ch 31
Primary readings:

- Rodolfo R & Negrello MN (2015), Scholarpedia, l0(1):4606

Apr 27 Basal ganglia (Glimcher)
Textbook: Ch 30
Primary readings:

- Haber SN (2003). The primate basal ganglia: parallel and integrative networks. J Chem Neuroanat, 26:317-330.
- Glimcher PW (2011). Understanding dopamine and reinforcement learning: The dopamine reward prediction error hypothesis. Proc Natl Acad Sci, 108 Suppl 3:15647-15654.

May 1 Eye movements I: VOR & OKN (Glimcher)
Textbook: Ch 32
Primary reading:

- The vestibular-optokinetic system, Ch 2 in Leigh RJ and Zee, DS, The Neurology of Eye Movements, London: Oxford (2006).

Apr 27 Conference 5 A (Lang) 10-noon B (Long) 4-6 pm

May 4 Eye movements II: Saccades, pursuit, vergence (Glimcher)
Textbook: Ch 32
Primary readings:

- The saccadic system, Ch 3 in Leigh RJ and Zee, DS, The Neurology of Eye Movements, London: Oxford (2006).
- Smooth pursuit and visual fixation, Ch 4 in Leigh RJ and Zee, DS, The Neurology of Eye Movements, London: Oxford (2006).