Neuroscience of Reward

Psyc80 – Winter 2014
Dartmouth College
Professor Kyle Smith

Class: 10-11:50 Tu & Thurs
Office hours: by appointment
Contact: 603-646-1486; kyle.s.smith@dartmouth.edu; 266 Moore Hall

This course will focus on brain mechanisms of reward. We will cover old and new ideas about pleaure in the brain, but mainly will dicuss advances in neuroscience research on various aspects of pleasure. We might even learn about general principles of brain function in the process. Course material will be posted on Canvas, and is subject to modification hroughout the semester. Our goal is not only to learn about the curent status of the field, but also to gain strength in core elements of science inquiry: reading primary literature, digesting it, thinking about it critically (even if you don't understand it all), and presenting about it cogently.

Tentative Schedule (updates posted on Canvas):

January 7 & 9	Introduction to concepts, strategies, and technologies
January 14 & 16:	New limbic system; reward hotspots; liking vs. wanting
January 21 & 23	Neural coding of pleasure
January 28 & 30	Pleasure electrodes; the role of dopamine
February 4 & 6	Heirarchies of control; cortex involvement
February 11 & 13	Unconscious reward; drug reward
February 18 & 20	Hunger; sex and affiliation
Februrary 25 & 27	Optogenetic control; Pleasure functions
March 4	DEPTH PAPERS DUE
March 4 & 6	Overflow material; wild new experiments

X-hours: As of now they are unschedued, but they may be used as we progress through the course (Wed 3-3:50).

Course Structure and Assignments:

Participation: The class is run as sort of a "journal club" with a big emphasis on discussion. So, attendance and participation is critical (and a part of your grade). You will be called on to give your opinions and thoughts online as well as in class. There are no bad comments or questions, even basic ones about the brain.

Reading. We will be reading published peer-reviewed articles or book chapters. Reading *before* class is essential to a successful course experience. Every student is expected to read (1) the assigned regular articles, and (2) one extra reading of your choice from the list of reviews or experiment articles prior to that class. Additional readings apply for the *presentation-paper* and *depth paper*. The reading list and electronic PDFs or links will be posted on Canvas.

Online journal entries. Everyone will contribute online comments (half-page) to the Canvas discussion board *before* each class, including classes in which students present material (due by midnight the night before; double-length if deadline missed). For these, you are asked to write your observations, opinions, and thoughts about a class topic and reading. These should be formally written and should relate directly to the reading material. But the content can vary greatly depending on what piques your interest and can flow in a stream-of-consciousness way (sort of like a blog entry). Each commentary should include *two questions* pertaining to the material for potential discussion in the class. The first one is due before January 9 (topic: the limbic system material).

Presentation-paper. Everyone will be assigned one class day/topic to present to the class. For this, you will read the required articles and *two* additional readings. You will select one of the listed experiment readings (or another, with my permission) and present it to the class. Presentations will be about 20 min, and will include background (from required readings and the selected article), methods, results, and implications. We will then open the class up for discussion. I will present an article on the limbic system topic to provide an example. Powerpoint is not necessary, but advisable (for graphs, pictures, videos, etc). It is recommended you practice with a friend to help develop your presentation. In addition, a paper on this topic will be due within 1 week of the presentation (5-7 typed pages, 1.5-2 spacing, 11pt Ariel or Times font). For this, you will write a summary of the material and insert some independnet thoughts/comments/ideas (see writing tips below).

Depth paper. Everyone will complete a depth paper (8-12 pages) on the topic below using at least 5 readings from the course; finding additional readings is encouraged. Depth papers are *due March 4 at noon*. An outline, either in writing or in conversation, will be due to me during the week of Feb 3 (at the latest) so I can make sure you are on the right track for developing and organizing your ideas. I am happy to provide advice and additional material. It is encouraged that each person keeps a bibliography of the readings they've done (the citation plus a short summary); these will be useful to you when writing later.

> *Depth question*: You are a neuroscientist and have any tool you want at your fingertips: fMRI, stimulation and recording electrodes, lesions, optogenetics, viruses & CLARITY anatomical tools, and drugs. It is possible for you to stimulate/inhibit/record any type of neuron or brain pathway, in any species, for any type of reward. Design one ore more studies to evaluate brain mechanisms of reward based on what we've learned in the course. Make sure experiments contain proper controls. Consder procedures to help you interpret effects as related to pleasure versus motivation, learning, expectation, etc. Paper organization: background, research question(s), methods, potential results, interpretations and implications. Only a rough sketch of methods is needed, but it should be clear that you understand the basics of the techniques, what you propose to do with them, what you will measure, and how you will interpret possible results. Potential research questions could include deciphering how brain reward centers work, figuring out brain reward anatomy (i.e. defining the limbic system), understanding or treating addiction or anhedonia, resolving how different kinds of rewards are represented in the brain, understanding how an experience can made to be rewarding or not depending on your state (e.g., satiety vs. hunger), understanding sexual preference, investigating reward centers across species, or any unresolved question on the topics covered in class or raised in the readings.

Grading:

Class participation	10%
Online entries	20%
In-class presentation	20%
Presentation paper	20%
Depth topic paper	30%

*****Late journal entry: accepted for 24 more hours, but double length required.
**Late papers: accepted, but one letter grade lower for each 24 hr period it is late.
***Late presentations: not possible.

Notes on writing and plagiarism:

Quick plagiarism note*:* Don't do it! The brain is pretty good at pattern detection, so it is usually evident when material is copied or when sections of a paper diverge from the student's style.

Longer plagiarism note: It is not easy not to do it! Writing about scientific publications without just rephrasing is difficult, particularly when not everything is fully understood. Doing this properly takes time and practice, and one goal of the course is to move us in that direction. I don't expect to see a perfect scientific treatment at this stage. But I do want to see evidence of independent thought, of considering the material and implications (rather than just regurgitating it), and of some creativity in putting this together. When quoting, be sure appropriate citations are made.

Writing tips: (1) get a big picture or idea in your mind from the reading, and then write with paragraphs tackling sub-themes, as we all learned to do (topic sentence, etc.). (2) It can work well to interleave your own thoughts and experiences, or to reference to material not on the reading list even from other disciplines, or to take question the validity of the results and interpretations (e.g., if experiments were well-controlled, or if gaps are missing in arguments; don't worry whether I would agree). I don't care if you use the first person. (3) Consider incorporating thoughts on future experiments, whether directly feeding off of the work or applied to other species or conditions; likewise, general ideas to test in some way in the future. (4) Quoting the material can work if done in moderation, but the majority of it must be your own writing. (5) Always feel free to get feedback prior to deadlines.

Some thought questions for writing if you are stuck: What might be some additional useful experiments or comparisons? Does this give you insight into your own experiences? What kind of reward might you experience on occasions, and how could you test that? In the case of a patient or experimental preparation, what are some other tests or questions that you would like to address? What are the limitations to the experimental approach or concept, and how might they be improved? Are there other types of experience that might be rewarding? How might they be studied? If there were dysfunction (hyper or hopoactivity) in these systems, what might happen to a person? What are your ethical limitations for experiments and treatments of disorders as our knowledge of reward evolves? Although we are focusing on biological mechanism here, there are other factors that might be considered for reward as well (evoluationary, developmental, societal, cross-species comparisons, etc.).

Course Topics and Readings

Emotion and The Limbic System

- James, W. (1884). What is an emotion, Mind, 9:188-205. [http://psychclassics.yorku.ca/James/emotion.htm]
- LeDoux, J. (1996). Limbic system chapter in The Emotional Brain. New York: Simon & Schuster

Extra readings:

- Cannon, W. B. (1987). The James-Lange theory of emotions: a critical examination and an alternative theory. By Walter B. Cannon, 1927. Am J Psychol, 100(3-4), 567-586.
- Papez, J. W. (1995 [original 1937]). A proposed mechanism of emotion. 1937.
- Journal of Neuropsychiatry & Clinical Neurosciences, 7(1), 103-112.
- Maclean, P. (1955). The limbic system ('visceral brain') and emotional behavior. Archives of Neurology & Psychiatry, 73, 120-133.
- Damasio, A. (2003). Feelings of emotion and the self. Ann N Y Acad Sci, 1001, 253-261.

The New Limbic System

- Morgane, P. J., & Mokler, D. J. (2006). The limbic brain: Continuing resolution. Neuroscience & Biobehavioral Reviews, 30(2), 119-125.

[think: is the "limbic system"a useful concept? What would we have without it?]

Extra readings – reviews:

- Zahm, D. S. (2006). The evolving theory of basal forebrain functional--anatomical 'macrosystems'. Neuroscience & Biobehavioral Reviews, 30(2), 148-172.
- Swanson, L. W. (2005). Anatomy of the soul as reflected in the cerebral hemispheres: neural circuits underlying voluntary control of basic motivated behaviors. J Comp Neurol, 493(1), 122-131.
- Heimer, L., & Van Hoesen, G. W. (2006). The limbic lobe and its output channels: Implications for emotional functions and adaptive behavior. Neuroscience & Biobehavioral Reviews, 30(2), 126-147.
- LeDoux J (2012). Rethinking the emotional brain. Neuron, 73(4):653-76.

Extra readings – experiments:

- Watabe-Uchida M, Zhu L, Ogawa SK, Vamanrao A, Uchida N (2012) Whole-brain mapping of direct inputs to midbrain dopamine neurons. Neuron, 74(5):858-73. *[nice use of new techology (viruses) to map all inputs to the dopamine system]*
- Thompson RH, Swanson LW Hypothesis-driven structural connectivity analysis supports network over hierarchical model of brain architecture. PNAS, 107(34):15235-9.
- Haber SN, Fudge JL, McFarland NR Striatonigrostriatal pathways in primates form an ascending spiral from the shell to the dorsolateral striatum. J Neurosci, 20(6):2369-82.
- CLARITY: http://www.youtube.com/watch?v=c-NMfp13Uug

Sources of (food) Reward in the Brain: Liking vs. Wanting

- Smith, K. S., Mahler, S. V., Pecina, S., & Berridge, K. C. (2009). Hedonic Hotspots: Generating Sensory Pleasure in the Brain. In M. Kringelbach & K. C. Berridge (Eds.), Pleasures of the Brain. Oxford, U.K.: Oxford University Press. *[this will be a useful reference for much of the course]*

Extra reading – reviews

- Berridge KC (1996). Food reward: brain substrates of wanting and liking. Neurosci Biobehav Rev, 20(1):1-25.
- Finlayson G, King N, Blundell JE (2007). Liking vs. wanting food: importance for human appetite control and weight regulation. Neurosci Biobehav Rev, 31(7):987-1002.
- Mela DJ (2006). Eating for pleasure or just wanting to eat? Reconsidering sensory hedonic responses as a driver of obesity. Appetite, 47(1):10-7.

Extra reading – experirments:

- Mahler SV, Smith KS, Berridge KC (2007). Endocannabinoids modulate taste 'liking' in the nucleus accumbens. Neuropsychopharmacology, 32*(11):2267-78*.
- Söderpalm AH, Berridge KC (2000). The hedonic impact and intake of food are increased by midazolam microinjection in the parabrachial nucleus. Brain Res, 877(2):288-97.
- Smith KS, Berridge KC (2007). Opioid limbic circuit for reward: interaction between hedonic hotspots of nucleus accumbens and ventral pallidum. J Neurosci, 27(7):1594-605.

Neural Coding of Reward – Physiology

- Tindell AJ, Smith KS, Peciña S, Berridge KC, Aldridge JW (2006). Ventral pallidum firing codes hedonic reward: when a bad taste turns good. J Neurophys, 96(5):2399-409.
    - Wheeler RA, Carelli RM (2006). The neuroscience of pleasure. Focus on "Ventral pallidum firing codes hedonic reward: when a bad taste turns good". J Neurophys, 96(5):2175-6. *[this is an overview of the above article; good to read together]*
- Schultz, W. (2006). Behavioral Theories and the Neurophysiology of Reward. Annu Rev Psychol, 57:87-115.

[Think: what are the various ways reward can be encoded in activity? What does activity reveal about when/how things are rewarding?]

Extra reading – reviews:

- Schoenbaum G, Takahashi Y, Liu TL, McDannald MA (2011). Does the orbitofrontal cortex signal value? Ann N Y Acad Sci, 1239:87-99.
- Dar JJ, Carelli RM (2007). The nucleus accumbens and Pavlovian reward learning. Neuroscientist, 13(2):148-59.

Extra reading – experiments:

- Smith KS**,** Berridge KC, Aldridge JW (2011). Disentangling pleasure from incentive salience and learning signals in brain reward circuitry. Proceedings of the National Academy of Sciences, 108(27):E255-64.
- Jezzini A, Mazzucato L, La Camera G, Fontanini A. Processing of hedonic and chemosensory features of taste in medial prefrontal and insular networks. J Neurosci, 33(48):18966-78.

- Roitman MF, Wheeler RA, Carelli RM (2005). Nucleus accumbens neurons are innately tuned for rewarding and aversive taste stimuli, encode their predictors, and are linked to motor output. Neuron, 45(4):587-97.
- Shuler MG, Bear MF (2006). Reward timing in the primary visual cortex. Science, 311(5767):1606-9.

Neural Coding of Reward – Human Imaging

- Kringelbach, M. L. (2009). The hedonic brain: A functional neuroanatomy of human pleasure. In M. L. Kringelbach & K. C. Berridge (Eds.), Pleasures of the brain. Oxford, U.K.: Oxford University Press. *[think: what are common brain substrates for different rewards, different species? What are we getting from imaging that we can't from physiology, and vice versa?]*

Extra reading – review:

- Haber SN, Knutson B (2010). The reward circuit: linking primate anatomy and human imaging. Neuropsychopharmacology, 35(1):4-26.

Extra reading – experiments:

- Small, D. M., Zatorre, R. J., Dagher, A., Evans, A. C., & Jones-Gotman, M. (2001). Changes in brain activity related to eating chocolate - From pleasure to aversion. Brain, 124, 1720-1733.
- Blood, A. J., & Zatorre, R. J. (2001). Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. Proc Natl Acad Sci U S A, *98*(20), 11818-11823.
- Simmons WK, Rapuano KM, Ingeholm JE, Avery J, Kallman S, Hall KD, Martin A (in press). The ventral pallidum and orbitofrontal cortex support food pleasantness inferences. Brain Struct Funct.
- Beaver JD, Lawrence AD, van Ditzhuijzen J, Davis MH, Woods A, Calder AJ (2006). Individual differences in reward drive predict neural responses to images of food. J Neurosci, 26(19):5160-6.
- M.R. Delgado, L.E. Nystrom, C. Fissell, D.C. Noll, J.A. Fiez (2000). Tracking the hemodynamic responses to reward and punishment in the striatum. J Neurophysiol, 84:3072–3077

Electrical Brain Stimulation & Pleasure

- Heath, R. G. (1972). Pleasure and brain activity in man. Deep and surface electroencephalograms during orgasm. Journal of Nervous and Mental Disease, 154(1), 3-18. *[Warning: there are some very unethicle things in here, but it is probably the first "pleasure electrode" demonstration in humans].*
- Okun, M. S., Bowers, D., Springer, U., Shapira, N. A., Malone, D., Rezai, A. R., et al. (2004). What's in a "smile?" Intra-operative observations of contralateral smiles induced by deep brain stimulation. Neurocase: Case Studies In Neuropsychology, Neuropsychiatry, And Behavioural Neurology, 10(4), 271-279.

Extra reading – review:

- Green, A. L., Pereira, E. A., & Aziz, T. Z. (2009). Deep brain stimulation and pleasure. In M. L. Kringelbach & K. C. Berridge (Eds.), Pleasures of the brain. Oxford, U.K.: Oxford University Press.

Extra reading – experiments:

- Krack, P., Kumar, R., Ardouin, C., Dowsey, P. L., McVicker, J. M., Benabid, A. L., et al. (2001). Mirthful laughter induced by subthalamic nucleus stimulation. Movement Disorders: Official Journal Of The Movement Disorder Society, 16(5), 867-875.
- Morgan, J. C., diDonato, C. J., Iyer, S. S., Jenkins, P. D., Smith, J. R., & Sethi, K. D. (2006). Self-stimulatory behavior associated with deep brain stimulation in Parkinson's disease. Mov Disord, 21(2), 283-285.
- Halbig, T. D., Gruber, D., Kopp, U. A., Schneider, G. H., Trottenberg, T., & Kupsch, A. (2005). Pallidal stimulation in dystonia: effects on cognition, mood, and quality of life. J Neurol Neurosurg Psychiatry, 76(12), 1713-1716.
- Olds J Milner P (1954). Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. J Comp Physiol Psychol, 47(6):419-27. *[old "pleasure electrodes" paper in rats].*

What is the Role of Dopamine in Reward?

- Montague, P. R., Hyman, S. E., & Cohen, J. D. (2004). Computational roles for dopamine in behavioural control. Nature, 431(7010):760-767.
- Berridge, K. C. (2007). The debate over dopamine's role in reward: the case for incentive salience. Psychopharmacology (Berl).

Extra reading – reviews:
- Salamone JD, Correa M (2012). The mysterious motivational functions of mesolimbic dopamine. Neuron, 76(3):470-85.
- Leyton, M (2009). The neurobiology of desire humans. In: Kringelbach, ML, Berridge, KC, editors. Pleasures of the brain. Oxford, U.K.: Oxford University Press.
- Wise, R. A. (2006). Role of brain dopamine in food reward and reinforcement. Philos Trans R Soc Lond B Biol Sci, 361(1471):1149-1158.

Extra reading – experiments:
- Cagniard, B., Beeler, J. A., Britt, J. P., McGehee, D. S., Marinelli, M., & Zhuang, X. (2006). Dopamine scales performance in the absence of new learning. Neuron, 51(5), 541-547.
- Flagel SB et al. (2011). A selective role for dopamine in reward learning. Nature, 469(7328): 53–57.
- Pessiglione, M., B. Seymour, et al. (2006). Dopamine-dependent prediction errors underpin reward-seeking behaviour in humans. Nature, 442(7106):1042-5.

Hierarchical Control Centers

- John Hughlings Jackson biography. [*skip "biographical sketch" section*].
- Grill HJ, Norgren R (1978). The taste reactivity test. II. Mimetic responses to gustatory stimuli in chronic thalamic and chronic decerebrate rats. Brain Res, 143(2):281-97.
- Cromwell HC, Berridge KC (1993). Where does damage lead to enhanced food aversion: the ventral pallidum/substantia innominata or lateral hypothalamus? Brain Res, 624(1-2):1-10.

[think about Grill and Cromwell in relation to the Hughlings Jackson ideas]

Extra reading – experiments:
- Vijayaraghavan L, Vaidya JG, Humphreys CT, Beglinger LJ, Paradiso S (2008). Emotional and motivational changes after bilateral lesions of the globus pallidus. Neuropsychology, 22(3):412-8.
- Miller JM, Vorel SR, Tranguch AJ, Kenny ET, Mazzoni P, van Gorp WG, Kleber HD (2006. Anhedonia after a selective bilateral lesion of the globus pallidus. Am J Psychiatry, 163(5):786-8
- Miller FR, Sherrington CS (1915). Some observations on the bucco-pharyngeal stage of reflex diglutition in the cat. Q J Exp Physiol, 9:147-186.
- Steiner JE (1973). The gustofacial response: Observations of normal and anencephalic newborn infants. Symp Oral Sensation Perception, 4:254-278.
- Bard P (1934). On emotional expression after decortication with some remarks on certain theoretical views. Part II. Psychol Rev, 41:424-449.

Cortex and Higher Cognitive Roles

- Craig, A.D., How do you feel right now? Nature Neurosci Review, 2009
- Feldman Barrett, L., & Wager, T. D. (2006). The Structure of Emotion: Evidence From Neuroimaging Studies. Current Directions in Psychological Science 15(2), 79-83.

Extra readings – reviews:
- F. Grabenhorst, E.T. Rolls (2011). Value, pleasure and choice in the ventral prefrontal cortex. Trends Cogn Sci, 15:56–67.
- A. Bechara (2004). The role of emotion in decision-making: evidence from neurological patients with orbitofrontal damage. Brain Cogn, 55:30–40.
- Schooler, J. W., & Mauss, I. B. (2009). To be happy and to know it: The experience and meta-awareness of pleasure. In M. L. Kringelbach & K. C. Berridge (Eds.), Pleasures of the Brain. Oxford, U.K.: Oxford University Press.

Extra readings – experiments:

- Beer, J. S., Heerey, E. A., Keltner, D., Scabini, D., & Knight, R. T. (2003) The regulatory function of self-conscious emotion: insights from patients with orbitofrontal damage. Journal of Personality and Social Psychology, 85:594-604.
- Naqvi, N. H., Rudrauf, D., Damasio, H., & Bechara, A. (2007). Damage to the insula disrupts addiction to cigarette smoking. Science, 315(5811):531-534.
- O'Doherty J, Kringelbach ML, Rolls ET, Hornak J, Andrews C (2001. Abstract reward and punishment representations in the human orbitofrontal cortex. Nat Neurosci, 4(1):95-102.
- Critchley, H. D., Wiens, S., Rotshtein, P., Ohman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. Nat Neurosci, 7(2):189-195.

[See also expeirment articles from earlier Human Imaging topic]

Unconscious Reward (or is there such a thing?)

- Winkielman, P., & Berridge, K. C. (2004). Unconscious emotion. Current Directions in Psychological Science, 13(3), 120-123.

[think: what is unconscious vs. necessarily conscious. No real right answer here.]

Extra reading – experiments:

- Adolphs R, Tranel D, Koenigs M, Damasio AR (2005). Preferring one taste over another without recognizing either. Nat Neurosci, 8(7):860-1.
- Damasio A, Damasio H, Tranel D (2013). Persistence of feelings and sentience after bilateral damage of the insula. Cereb Cortex, 23(4):833-46.
- Pessiglione M, Schmidt L, Draganski B, Kalisch R, Lau H, Dolan RJ, Frith CD (2007). How the brain translates money into force: a neuroimaging study of subliminal motivation. Science, 316(5826):904-6.

Drug Reward and Addiction

[pick 2 of these readings]

- Koob, GF, Le Moal, M. (2008) Neurobiological mechanisms for opponent motivational processes in addiction. Philos Trans R Soc Lond B Biol Sci, 363:3113-3123.
- Robinson, T. E., & Berridge, K. C. (2003). Addiction. Annual Review of Psychology, 54(1), 25-53.
- Everitt, BJ, Belin, D, Economidou, D, Pelloux, Y, Dalley, JW, Robbins, TW. (2008). Neural mechanisms underlying the vulnerability to develop compulsive drug-seeking habits and addiction. Philos Trans R Soc Lond B Biol Sci, 363:3125-3135.

Extra reading – reviews:

- Kalivas, P. W., & Volkow, N. D. (2005). The neural basis of addiction: a pathology of motivation and choice. Am J Psychiatry, 162(8):1403-1413.
- Volkow, ND, Wang, G-J, Fowler, JS, Telang, F. Overlapping neuronal circuits in addiction and obesity: evidence of systems pathology. Philosophical Transactions of the Royal Society B: Biological Sciences, 363:3191-3200.
- Hyman, S. E., Malenka, R. C., & Nestler, E. J. (2006). Neural mechanisms of addiction: the role of reward-related learning and memory. Annu Rev Neurosci, 29:565-598.

Extra reading – experiments:

- Evans, A. H., Pavese, N., Lawrence, A. D., Tai, Y. F., Appel, S., Doder, M., et al. (2006). Compulsive drug use linked to sensitized ventral striatal dopamine transmission. Ann Neurol, 59(5), 852-858.
- Childress AR et al. (2008). Prelude to passion: limbic activation by "unseen" drug and sexual cues. PLoS One, 3(1):e1506.
- Drevets WC et al. (2001). Amphetamine-induced dopamine release in human ventral striatum correlates with euphoria. Biol Psychiatry, 49(2):81-96.
- Wheeler RA, Twining RC, Jones JL, Slater JM, Grigson PS, Carelli RM (2008). Behavioral and electrophysiological indices of negative affect predict cocaine self-administration. Neuron, 57(5):774-85.
- Di Chiara, G., and Imperato, A. (1988). Drugs abused by humans preferentially increase synaptic dopamine concentrations in the mesolimbic system of freely moving rats. PNAS, 85:5274–5278.

Hunger Modulation of Reward

- Winn, P., The lateral hypothalamus and motivated behavior: an old syndrome reassessed and a new perspective gained, Current Directions in Psychological Science, 4 (1995) 182-187.
- Gao, Q., & Horvath, T. L. (2007). Neurobiology of feeding and energy expenditure. Annu Rev Neurosci, 30, 367-398.

Extra reading – reviews:

- Berthoud, HR, Morrison, C. (2008) The brain, appetite, and obesity. Annu Rev Psychol;59:55-92.
- Morton, G. J., Cummings, D. E., Baskin, D. G., Barsh, G. S., & Schwartz, M. W. (2006). Central nervous system control of food intake and body weight. Nature, 443(7109), 289-295.
- Johnson, A. K. (2007). The sensory psychobiology of thirst and salt appetite. Med Sci Sports Exerc, 39(8), 1388-1400.
- Kelley, A. E., Baldo, B. A., & Pratt, W. E. (2005). A proposed hypothalamic-thalamic-striatal axis for the integration of energy balance, arousal, and food reward. J Comp Neurol, 493(1), 72-85.
- Cota, D., Tschop, M. H., Horvath, T. L., & Levine, A. S. (2006). Cannabinoids, opioids and eating behavior: the molecular face of hedonism? Brain Res Rev, 51(1), 85-107.

Extra reading – experiments

- Harris, G. C., Wimmer, M., & Aston-Jones, G. (2005). A role for lateral hypothalamic orexin neurons in reward seeking. Nature, 437(7058), 556-559.
- Fulton, S., Pissios, P., Manchon, R., Stiles, L., Frank, L., Pothos, E. N., et al. (2006). Leptin Regulation of the Mesoaccumbens Dopamine Pathway. Neuron, 51(6), 811-822.
- Ho CY, Berridge KC (2013). An orexin hotspot in ventral pallidum amplifies hedonic 'liking' for sweetness. Neuropsychopharmacology, 38(9):1655-6.

Sex, Affiliation, Society

- Georgiadis JR, Kortekas R (2009). The sweetest taboo: Functional neurobiology of human sexuality in relation to pleasure. In: Kringelbach, ML, Berridge, KC, editors. Pleasures of the Brain. Oxford, U.K.: Oxford University Press.
- Young LJ, Lim MM, Gingrich B, Insel TR (2001). Cellular mechanisms of social attachment. Horm Behav, 40(2):133-8.

Extra readings – reviews:

- Komisaruk BR, Whipple B (2005). Functional MRI of the brain during orgasm in women. Annu Rev Sex Res. 2005, 16:62-86.
- de Waal, F. B. M. (1995). Bonobo sex and society. Scientific American, March 1995.

Extra readings – experiments:

- Resendez SL, Dome M, Gormley G, Franco D, Nevárez N, Hamid AA, Aragona BJ (2013). μ-Opioid receptors within subregions of the striatum mediate pair bond formation through parallel yet distinct reward mechanisms.. J Neurosci, 33(21):9140-9.
- Lim MM, Wang Z, Olazábal DE, Ren X, Terwilliger EF, Young LJ (2004. Enhanced partner preference in a promiscuous species by manipulating the expression of a single gene. Nature, 429(6993):754-7.
- Aragona BJ, Liu Y, Yu YJ, Curtis JT, Detwiler JM, Insel TR, Wang Z (2006). Nucleus accumbens dopamine differentially mediates the formation and maintenance of monogamous pair bonds. Nat Neurosci, 9(1):133-9.
- Cooper JC, Kreps TA, Wiebe T, Pirkl T, Knutson B (2010). When giving is good: ventromedial prefrontal cortex activation for others' intentions. Neuron, 67(3):511-21.
- K. Izuma, D.N. Saito, N. Sadato (2008). Processing of social and monetary rewards in the human striatum. Neuron, 58:284–294
- A. Lin, R. Adolphs, A. Rangel (2012). Social and monetary reward learning engage overlapping neural substrates. Soc Cogn Affect Neurosci, 7(3):274-81.

Optogenetic Control of Reward Systems

- Deisseroth (2010). Controlling the brain with light. Scientific American. Nov;303(5):48-55
- Stuber GD, Britt JP, Bonci A (2012). Optogenetic modulation of neural circuits that underlie reward seeking. Biol Psychiatry 15;71(12):1061-7

[think: where are we going with this? Recapitulating the brain-stimulation work? Or finding real reward mechanisms? This technology opens up tons of new possible experiments – think of some]

Extra readings – reviews:

- Nieh EH, Kim SY, Namburi P, Tye KM (2013). Optogenetic dissection of neural circuits underlying emotional valence and motivated behaviors. Brain Res, 1511:73-92.
- Steinberg EE, Janak PH. Establishing causality for dopamine in neural function and behavior with optogenetics. Brain Res, 1511:46-64.

[see also: http://www.stanford.edu/group/dlab/optogenetics/index.html]

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