Experimental College, Tufts University, Spring 2014 Syllabus

The Mind's Eye: Neuroscience in the Movies

1. Course Description

Hollywood has infused some of the most influential scenes in cinema with neuroscientific backdrops: Neo uploading Kung Fu to his mind; Cobb incepting an idea within a dream; Tyler Durden's true alter-ego; Jason Bourne's high-octane amnesia. A common thread that ties these movies together is the idea that the brain is the mind's physical substrate through which ideas, memories, and personalities can be artificially enhanced or distorted. The aim of this course is to learn the broad principles of brain science and then to apply this knowledge to tease out what Hollywood often gets right or wrong. Using neuroscience as an arc, we will review and discuss the primary literature in the field that focuses on topics including memory erasure and reactivation, drug addiction, behavioral control and impaired cognition—all with the goal of analytically weaving in and out of relevant science fiction movies.

Remarkably, neuroscience is reaching a point where questions are rapidly being plucked from the tree of science fiction and grounded in experimental reality. During each class, we will cover the associated primary literature in the field related to a particular brain system and discuss how it relates to a relevant movie. For example, two recent landmark studies authored by myself and colleagues have demonstrated that it is possible to erase or reactivate specific memories in the brain, and now these findings can be used to put movies like *Eternal Sunshine of the Spotless Mind* and *Total Recall* into a larger, cultural and scientific perspective. Using this format of framing primary literature against memorable popular depictions of brain science, this class aims to provide students with a broad understanding of how the brain works and provide a critical lens through which cinematic sci-fi can be evaluated and dissected.

As a final objective, this class seeks to help students form a two-way bridge between fictional inspiration and scientific advancement—the former inspiring experiments in the latter; the latter informing the technological marvels conveyed in the former.

2. Biographical Statement

Steve Ramirez is a PhD candidate at MIT in the Department of Brain & Cognitive Sciences. His research—performed under the mentorship of Nobel laureate Susumu Tonegawa—is focused on finding, activating, erasing, and artificially modifying memories in the brain. Steve's pioneering work has been published in *Nature* and *Science,* and he recently gave a TED talk explaining his work on memory manipulation. His projects have received wide media coverage by the New York Times, BBC, Guardian, CNN, The Economist, and Time. In 2013, he received the MIT Technology Review's *World's Top 35 Innovators under the Age of 35* award for his work on memory reactivation and false memory generation. Steve has also received back-to-back teaching awards for his commitment to undergraduate education at MIT and has taught courses on neuroscience, memory, and physiology.

Emily Hueske received her PhD at MIT in the Department of Brain & Cognitive Sciences in 2011 where her research focused on the brain's dopaminergic reward system and its role in decision-making. Her current research, like Steve's, utilizes a recently developed revolutionary set of tools in neuroscience known as optogenetics, named Method of the Year across scientific disciplines in 2010 by the journal *Nature*. Her research currently focuses on manipulating and controlling the dopamine system in a manner that controls and predictably biases decision-making. Her past research has been published in the journals *Nature Neuroscience*, *Journal of Neuroscience* and *Genetics*. During her graduate work at MIT, Emily created and taught a course on brain anatomy. She has won multiple awards for her dedication to teaching at MIT. She has been profiled for her teaching-related activities in the *Howard Hughes Medical Institute Science Bulletin* and on public radio's *WGBH Science City.* Her continuing post-doctoral research in the laboratory of Susumu Tonegawa provides constant exposure to research at the leading edge of questions surrounding the brain's memory and reward systems. Indeed, many of the topics in class bordering on science fiction, such as artificially activating the brain's reward centers with just pulses of light, directly resonate with the class sections on neuromodulators and their relationship to movies such as *Requiem for a Dream.*

3. Statement of Goals for the Course

Goals of the Experimental College

This class aims to lead students on an engaging and memorable tour of the systems of the brain using popular and science fiction movies as a springboard for discussion and critique. Secondly, this class aims to introduce the most innovative and widespread tools of modern neuroscience, tools that are moving what was previously science fiction closer to the realm of reality. Thirdly, through this survey of brain systems and modern methods, this class aims to equip students to deconstruct and evaluate what is science and what is fiction among popular media portrayals of brain-related phenomena. Lastly, this class encourages students to seek and embrace creative scientific inspiration from the science fiction of cinema, literature and other arts. In a final project, students will find an inspiration, evaluate the status of relevant primary and secondary literature, and conceive of and propose a hypothesis and investigation or innovation that informs or impacts the human condition.

The primary goal of this course is to provide students with a memorable understanding of how the brain works. We will cover how neuroscience tools and methods work by using Hollywood as a repository of nearly unlimited science-inspired creativity and as a springboard for discussion and critique. Each class will focus heavily on discussing a carefully chosen movie and the associated primary literature so that, as a team, we can analyze and critique our cinematic art with the conceptual tools of neuroscience. For example, recent studies have provided tantalizing evidence that concepts such as memory erasure *a la Eternal Sunshine of the Spotless Mind* or false memory formation *a la Inception* are scientifically tractable problems that are now entering the realm of reality.

Each class will begin with a 30-minute explanation of the experiments covered in the assigned primary literature, and we will spend the remaining time in a Socratic seminar style discussion to apply this knowledge to evaluation of the topic and movie at hand. By the end of the semester, students will have substantially investigated and discussed: the brain's multiple memory systems, cutting-edge techniques such as optogenetics and electrophysiology used to tinker with brain cells and behavior, the brain's reward circuitry, human false memory formation, implications of these and other brain related topics on modern jurisprudence, and how all this circuitry goes awry during addiction, amnesia, or psychiatric illnesses. In parallel, aspects of these topics are vividly depicted in movies such as *Memento, Total Recall, Requiem for a Dream, Inception,* and *A Beautiful Mind,* respectively. With these goals in mind, at the end of each week students will emerge with an appreciation for the function of a relevant brain system, an understanding of the scope and limits of existing tools and methods used to study the brain, and the ability to evaluate popular media portrayals of a brain-related phenomenon.

Note: While this class is ideally taught after the students have viewed the weekly feature film in its entirety, we understand that this may not be feasible for every student for multiple reasons, including access to the movies directly. That said, every class nonetheless is meant to be self-contained: we will use the most relevant clips from each movie throughout the class so that we can view and analyze them together alongside the week's assigned readings; this will ensure that everyone has equal exposure to the most related scenes infused with neuroscience and we will also introduce each clip with the appropriate background.

Our Learning Objectives

4. **Syllabus Structured to Cover our Subject in a Thirteen Week Semester**

Week 1 – Introduction to the Course and a Boot Camp on Memory

When we close our eyes and think back to our childhood, to our first kiss, or to this morning's breakfast, our brains perform the remarkable task of mental time travel. For over a century, brain scientists and film directors have attempted to dissect the mind to reveal its inner-workings and how neuronal machinery gives rise to something as complex and seemingly ephemeral as memory. One structure of the brain, tucked in just behind our ears, called the hippocampus has continued to captivate brain researchers and film directors because of its central role in enabling the kinds of memories that thread our overall sense of being. When that thread is damaged, we get *Memento's* Leonard Shelby and *The Bourne Trilogy's* Jason Bourne (a topic which we will take to task in week 2). In the spirit of the experimental college, this lecture will introduce the experimental concept of bridging Hollywood and neuroscience, and end by using the hippocampus as a conceptual pivot point to tour the brain's multiple memory systems.

Review: Rachel Bernstein – *Science on Set*
Review: Brenda Milner – *Cognitive Neuroscience and the study of memory*

Supplementary Material: Steven Pinker - *How the Mind Works,* ch. 1.

Week 2 – The Brain's Multiple Memory Systems (Memento / The Bourne Identity)

Jason Bourne and Leonard Shelby cannot remember their personal autobiographies; they are persons suspended in time with no memory of their past. Despite their amnesia, they are still exceptional at handling weapons, driving seamlessly at 100mph, and hand-to-hand combat. How is it that these characters can remember how to shoot a gun flawlessly but cannot remember their own identities or yesterday's breakfast? The most famous patient in neuroscience—the mighty H.M., who also had a similar type of amnesia as a result of hippocampus damage—has helped us understand that the brain systems that mediate our personal narratives and those that mediate fluid motor movements are largely separate; damage to one often leaves the other intact, therefore leaving the behavioral outputs intact as well. In this class, we will discuss what H.M. taught neuroscience and how damage to the hippocampus gives rises to a very specific kind of amnesia—a kind of amnesia that Bourne and Shelby share. We will spend the majority of the time discussing the cognitive and behavioral impairments these two characters have in light of their brain damage, while simultaneously using two primary reviews as lenses through which to investigate what *Memento* and *The Bourne Trilogy* got right and wrong about amnesia.

Primary Source - Howard Eichenbaum: *What H.M. taught us*
Review – Benjamin Motz: Cognitive science in popular film

Supplementary Review - Larry Squire: *Memory Systems of the brain: a brief history and current perspective*

Week 3 – Erasing memories (Eternal Sunshine Of the Spotless Mind)

We can all understand the experience of a breakup so heart-squeezing that were the technology available to erase that gut-wrenching visceral sadness, we might temporarily consider removing the emotions to escape the incapacitation. After their breakup, Joel and Clementine have decided to do exactly this; they hired a company that specializes in memory erasure to get rid of their memories of each other so that they can get back to living normal lives. Remarkably, recent work in neuroscience has demonstrated that it may actually be possible to both identify and erase the traumatic components of a specific memory—starting in mice and recently applied to humans.

Here, we use these groundbreaking studies to point out what's possible *in principle* with memory erasure and to discuss the ethical ramifications of doing so. We will discuss techniques in genetic engineering and in human psychology that permit types of memory erasure. Moreover, *Eternal Sunshine* provides a unique opportunity to investigate the personal decision to erase information out of our minds, a possibility that current researchers have successfully demonstrated by erasing a fear memory in both cognitively intact humans and patients with post-traumatic stress disorder. We will use these experiments as compasses to navigate the cutting-edge of what's currently possible with memory erasure, and we will end by highlighting a handful of scientific hiccups that *Eternal Sunshine* contains, which together exemplify common misconceptions of how memories are stored in the brain.

Primary Source – Han et al.: *Selective erasure of a fear memory*
Primary Source – Schiller et al.: *Preventing the return of fear in humans*

Week 4 – Artificially activating memories (Total Recall)

This class will reveal revolutionary techniques in modern neuroscience that have made it possible to isolate and reactivate memories with flickers of light—a technique called optogenetics. Hollywood was the first to inspire the imaginations of brain researchers by proposing that memories could be artificially triggered and distorted. In *Total Recall,* Douglas Quaid found this out firsthand after visiting a company called *Rekall,* which provides its clients with new and richly detailed memories of a life they could only dream of one day

having. But when artificially triggered memories and real memories become conflated, the subjects no longer can tease apart what's real and what's mentally simulated. Recently, with the advent of a technique called optogenetics—a technique that can trick brain cells to respond to pulses of light—neuroscience has plucked these ideas from the tree of science fiction and grounded them in experimental reality. One study that we will discuss in particular managed to artificially reactivate a fear memory in a mouse simply by using pulses of light, opening the floodgates for experiments that seek to theatrically jumpstart the process of recollection. In this class, we will discuss both the concepts and experiments that highlight: 1) *Total Recall* was partially correct about how to reactivate memories, 2) How we can apply these technologies in rodents and humans, 3) The legal implications of manipulating memories. Specifically, we will use the assigned reading as a framework for interpreting *Total Recall* and end by speculating on the future of memory reactivation.

Primary Source – Liu et al.: *Optogenetic stimulation of a hippocampal engram activates fear memory recall*
Review – Wilder Penfield: *Stimulating memories in humans*

Week 5 – Incepting ideas into the brain (Inception)

Cobb has a very particular set of skills, which, strictly speaking, aren't legal; he can infiltrate minds and plant ideas to fool subjects into having false memories. With the combination of French horns and dreams within dreams, *Inception* infused new life into the cinematic genre of mind control. We will begin by rephrasing the main question of *Inception*—"How do we implant an idea into someone else's mind?"—as a more scientifically tractable problem—"how do we alter the contents of a memory?" From the psychotherapy sessions conjuring up memories of childhood abuse to the eyewitnesses who are certain of the attacker's identities, false memories often permeate our day-to-day lives and are deceivingly easy to induce in others. This cognitive quirk has immense consequences for both our daily routines and, often devastatingly, modern jurisprudence. Here we review primary literature demonstrating how false memories are formed in humans, how one group artificially created a false memory in mice using optogenetics, and how together, these two concepts can be used to deconstruct the neuroscience portrayed in *Inception.* We will end by discussing false memories from both a societal and experimental setting—by and large, the same hippocampus machinery that enables true memories also enables false memories. As a dialogue-driven class, we will answer the question, "Is Cobb's attempt at implanting an idea really scientifically feasible?"

Primary Source – Ramirez et al.: *Creating a false memory in the hippocampus*
Review - Lisa Saksida: *Shining a light on memory representations*

Supplementary reading: Daniel Schacter's *The Seven Sins of Memory*. (Two chapters on suggestibility and misattribution)

Week 6 – Enhancing cognition (Limitless)

It's 2am and we have a final exam tomorrow. We have a dozen chapters to read, twice as many terms to memorize, and only half the amount of coffee needed to carry us into the morning. What if we could take a pill that let us instantaneously memorize our readings in the first pass? What if this pill helped us immediately access 100% of our brain as opposed to the quiet 10% that we supposedly use at any given moment? Eddie Morra—a struggling writer who turns to this pill to help him escape his financial woes—finds out that accessing 100% of his brain turns him into a cerebral wizard who is capable of predicting the ebb and flow of the stock market, of writing novels filled with incredible genius, and of remembering everything he's ever learned and experienced. *Limitless* contains provocative scenes of accessing previously dormant, inaccessible thoughts, of using a miracle pill to unleash the staggering power of the brain's previously untapped potential. These concepts are complimentary to rodent research that indeed has shown that it is possible to genetically modify mice to be smarter, to give them a drug to enhance cognitive performance, or a combination of the two to engineer an aptly titled "supermouse". In this class we will use a primary review and paper to discuss what these drugs are, their effects and side effects on the brain, and how drugs such as Adderall, which conceptually mimic the pills used in *Limitless*, influence our thought processes.

Primary paper: Tang et al.: *Genetic enhancement of learning and memory in mice*
Review: Maxwell Mehlman: *Cognition-Enhancing Drugs*
Commentary: Kristin Leutwyler – *Making smart mice*

http://www.nature.com/news/2008/080409/full/452674a.html
http://www.nature.com/news/2009/091014/full/461862a.html

Week 7 – Drug addiction (American Gangster/Breaking Bad. Supplementary: Requiem for a Dream)

For the 2nd semester in a row, it's 2am and we have a final exam the next day. We find that we can't study anymore without the multiple helpings of coffee—a relatively benign addiction, we reason. However, taken to its extreme, cognitive enhancing drugs inflict neuronal havoc on our brain's "reward centers," often causing addiction, cognitive impairments, future relapses, and long-term changes to our behavior. *American Gangster, Requiem for a Dream* and *Breaking Bad* offer a chillingly realistic portrayal of drug addiction through the characters of Harry Goldfarb, Frank Lucas, and the iconic Walter White. Week 7 is a no holds barred vortex into the dark and derelict world of drug addiction—ranging

from ecstasy and cocaine to heroin and methamphetamine. We will use two reviews from the primary literature that analyze the spectrum of human behavior and how it changes, deteriorates, and sometimes triumphs over drug addiction. The characters of Goldfarb, Lucas, and White capture the essence of this drug-induced spiral in dramatically different ways; the former becomes a pawn to his heroin, while the latter two deteriorate into calculating sociopathic drug lords. Both are qualities sometimes seen in real addicts as their personal lives dissolve. A deep explanation of their change in behaviors requires an understanding of how and why the brain is easily hijacked while on drugs; we will begin and end by touring the dopamine and serotonin systems and their relation to the formation of addiction.

Primary paper: Robins et al.: *Drug use by U.S. Army enlisted men in Vietnam: a follow-up on their return home.*
Review: Barry Everitt: *Neural systems of reinforcement for drug addiction*
Review: Leshner: *Addiction is a brain disease, and it matters*

Week 8 – Multiple Personality Disorder and Schizophrenia (Fight Club / A Beautiful Mind)

Week 7 introduced drugs as a kind of vehicle to exogenously produce changes in brain activity. Sometimes, however, cognitive machinery can go awry without drugs and is a result of genetic predisposition interacting with our environment. *Fight Club's* Jack/Tyler Durden and *A Beautiful Mind's* John Nash impressively embody a fundamental principle of neuroscience, namely, that broken brain pieces give rise to broken thoughts, and sometimes the environment doesn't help. What is multiple personality disorder and how does it relate to schizophrenia, if at all? These two psychological disturbances have given rise to countless iterations in popular culture. They have often been conflated as the same thing as well, and few cinematic examples capture the raw reality of each disorder. We will discuss one review per disorder in an effort to analyze week 8's movies, with special attention paid to visual hallucinations and the phenomenon of *dissociating* from reality. The brain is a powerful organ and, when disturbed, can produce equally powerful alternate personalities, egos, and realities—however, to what extent do these films accurately capture these phantasmagoric experiences? This question has a definitive answer, and we will end the class with a modern perspective on and interpretation of psychiatric disorders and the brain systems underlying these cognitive impairments.

Review: Thomas Insel – *Rethinking schizophrenia*
Review: Joan Ellason - *Positive and Negative Symptoms in Dissociative Identity Disorder and Schizophrenia: A Comparative Analysis*
Primary Source: Eric Vermetten: *Hippocampal and Amygdalar Volumes in Dissociative Identity Disorder*

Supplementary material:
http://www.nytimes.com/2013/09/08/opinion/sunday/the-new-science-of-mind.html?pagewanted=all&_r=0

Week 9 – Downloading thoughts with brain-machine and brain-brain interfaces (Elysium / The Matrix)

"I know Kung Fu," said Neo in *The Matrix* after uploading a program to his mind that permitted him quickly to be a karate master. The brain communicates through a combination of electricity and chemistry, through micro-bolts of lightning and moving cocktails of ions. These are the measurable substrates that comprise the mind; with this knowledge at hand, several recent studies have been able to successfully build brain-machine and brain-brain interfaces that permit the live measurement of these substrates, which then permits the decoding of certain thoughts or even *transplantation* of information from one brain to another. For example, in one of three studies that we'll discuss, one group recently connected the brains of two live mice (even wirelessly) and transferred information from one to the other; the neural activity of one mouse was capable of affecting the other mouse's behavior. In a second study, one group hooked up a device that could read out human brain activity and use this activity to activate parts of a live mouse*;* the activity of the former indeed could influence the behavior of the latter. Finally, we'll review a study allowing non-human primates to control computer cursors with just their minds' "eye." If this sounds familiar, it may be because *Elysium's* central character, Max, too was tasked with hooking his brain up to an enemy's brain to "download" or steel a secret that could change life on earth thereafter. In this class, we compare and contrast the brain-machine interfaces portrayed in *The Matrix* and *Elysium* with three recent studies that have come the closest to making these worlds materialize as our reality.

Primary reading - Nicolelis et al.: *A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information*
Primary reading – Donoghue et al.: *Brain-machine interface: Instant neural control of a movement signal*
Primary reading - Seung-Schik Yoo et al. *Non-Invasive Brain-to-Brain Interface (BBI): Establishing Functional Links between Two Brains*

Week 10 – Mind control: present and future (Dark City; Source Code)

What if mysterious men in black coats and top hats meandered in and out of the night to take people's memories and replace them with new ones? What if a company could put you—your consciousness—into another person's body temporarily? *Dark City* and *Source Code* give us a glimpse into the dystopian future that many believe will be our inevitable outcome if mind control falls into

the hands of the army or rich, evil-doing corporations. If neuroscience is our arc for the semester, then this class represents the arc bending towards responsible policy and legislature. Governments' today cannot patent genes or discriminate against people with particular genetic predispositions because the dialogue between scientists and the public regarding the human genome project started in the 1980s—decades before the genome was sequenced—which gave science and the law ample time to learn from each other and enable forward-thinking, precautionary lawmaking. Analogously, with all the seemingly futuristic neuroscience being carried out today, especially the kind discussed in week 9, this class seeks to start a dialogue among students about the future of mind control; we will discuss what we find acceptable and what we think should be discouraged or pursued. In this discussion-heavy class, we will begin by focusing on Obama's recent support for the Brain Project, continue by dissecting both its promises and shortcomings, and end by determining whether or not the Brain Project's outline prevents or inadvertently encourages the environments seen in *Dark City* and *Source Code.*

Primary reading: *http://www.whitehouse.gov/the-press-office/2013/04/02/fact-sheet-brain-initiative*
Primary reading: Alivisatos et al.- *The Brain Activity Map Project and the Challenge of Functional Connectomics*

Background: *http://www.technologyreview.com/news/513011/why-obamas-brain-mapping-project-matters/*

Week 11 – Free will, neuroscience, and the law (Minority Report)

Modern neuroscience has taught us that our idea of "self" is inseparable from the brain—it *is* the brain. When someone commits a criminal offense, then, it is he or she who willfully steps out of the line of the law. But what about the serial killer with enlarged "rage centers" of the brain? What about the pedophile with a tumor growing in his "impulsivity centers." Chief John Anderton, the teeth of the pre-crime unit, has an answer: he prosecutes criminals by arresting them *before* they commit their offense. Welcome to a future where determinism rules and technology enables police departments to eliminate crime in the world by incarcerating those who are *predetermined* to break the law. Interestingly, the cultural antecedent of this fictitious future is already in place: in the courtrooms, fMRI images of abnormal brains are being used more often to exonerate—or at the very least explain the motives of—criminals ranging from sleepwalking murderers to psychopathic serial killers. Here, we will use *Minority Report* as a symbol for legally implementing biological determinism under the guise of social change, as a representation of what happens when a culture accepts that we are all "just" the products of neural activity—nothing more, nothing less. We will analyze the movie with two readings at hand from the burgeoning field of neurolaw. Throughout the class, our discussions will address "how new discoveries in neuroscience can improve the way we make laws, punish

criminals, and develop rehabilitation… with the goal of running experiments that will result in modern, evidence-based policy" as the field's motto puts it. Did your brain *make* you do it? Or did *you* make you do it? Is this even the right question to ask? As we near the end of the semester, this class will bend our arc of neuroscience further than before by tensing it towards our ideas of free will.

Primary Reading: David Eagleman – *The Brain on Trial* (link: http://www.theatlantic.com/magazine/archive/2011/07/the-brain-on-trial/308520/)
Review: Joshua Greene - *For the law, neuroscience changes nothing and everything*
Supplementary reading: Daniel Dennet's *Elbow Room*. (One chapter on the compatibility of determinism, indeterminism, and free will).
Supplementary reading: *http://www.samharris.org/blog/item/free-will-and-free-will*

Week 12 – He who controls the past controls the future; he who controls the present controls the past (Trance).

In week 5, we toured the concept of false memories as portrayed in *Inception* and related them to the kinds of false memories artificially generated both in mice and men. This week, however, we are finally equipped to revisit the concept of changing the contents of our pasts, but through a movie that doesn't involve futuristic technology to do so. For centuries, society has had a machine that permits us to enter someone else's mind to alter its contents at our own leisure: hypnosis. Indeed, every time we recall a memory, it is constantly updated, revised, modified, and sometimes completely writ anew with misinformation—it is a *re*construction of the past, not a veridical representation of our previous experiences. "What we are is the sum of everything we've ever done, which is constantly being revised and remembered," *Trance* reminds us. This week's movie offers a dramatic window into the world of hypnosis and depicts how easy it is to let our recollective process of mental time travel go awry. We will review two primary sources on the topic to critically discuss how the fields of hypnosis and repressed memories have progressed, as well as how *Trance* contains elements from both sources.

Review: Elizabeth Loftus – *The reality of repressed memories*
Primary source: DS Lindsay - *Psychotherapy and memories of childhood sexual abuse: a cognitive perspective*

Week 13 – Class summary, perspectives, and speculations.

"Life imitates Art far more than Art imitates Life," Oscar Wilde pointed out. Throughout this class, we have taken a far more balanced approach: life and art are repeatedly intertwined in a flowing tango that necessitates reciprocated imitation. Cinema is art, and life is the product of our brain's activity; by giving a

cinematic context to the study of neuroscience, we have built a bridge between two seemingly disparate disciplines to reveal some of their inner-workings that could have otherwise remained unseen. Our final class is a combination of reflections, perspectives, and speculations on the future of *cinemeducation.*

Perspective - David Eagleman: *Why public dissemination of science matters*

Alternate or in addition to Week 13 – Sheep Brain Dissection Laboratory

Our journey through the systems of the brain is augmented with a hands-on dissection of the areas we've explored in a sheep brain. The mammalian brain is remarkably homologous in terms of both structure and function to species ranging from the mouse to the sheep to the human. In this class students working in teams of 2 will be guided through a dissection to reveal and highlight those structures that have been the focus of this class.

Dissection equipment can be provided from the MIT Neuroscience Teaching Lab and students can meet for class at this location or at a TBD lab space at Tufts.

Reading/Reference:
Cooley R, Vanderwolf CH. The Sheep Brain: A Basic Guide. London: Dobbyn Creative Printing Limited. 1979.

Assignments

Presentations: Throughout the semester, students (in teams of 2-3) will prepare two 20-minute presentations of either a primary scientific paper or a scientific review paper. These can be selected from among the weekly readings, or in close consultation with Steve or Emily. It is highly encouraged to choose a primary paper that can be directly related to a piece of cinema of the students' choosing or the assigned movie for that particular week. Ideally, these presentations should highly encourage discussion among the class to actively examine the topics at hand.

Reflection papers: After two classes of their choosing, students will write a 500-word reflection paper on the reviewed material, the movie discussed, and how the two are related. Attention should be given to comparing and contrasting the science in the film with the assigned readings for that week. The paper should end with speculation on how the technology portrayed in the film can be improved to more accurately portray what modern neuroscience is capable of, or what kind of improvements would be needed to enable the technology depicted.

Quizzes: Just like using flash cards to study, neuroscience and educational psychology research have demonstrated the power of recall, rather than simply recognition, in facilitating learning and memory of a subject. Quizzes (4 total) will be given to encourage recall of the broader material that is essential to deriving the most benefit and insight from this class. All quizzes will be announced ahead of time and will only cover material directly discussed in class.

Final Paper: Science fiction can inspire wonderful, and sometimes terrible, self-fulfilling prophesies in scientific innovation. In a final group project, students will work in pairs to write a 1000 word paper, or present a 30 minute presentation. For this project, students will 1) identify an idea from a movie, science fiction book or article that relates to human behavior or neuroscience or brain technology. 2) They will use this fictional inspiration to investigate and review a primary literature source or secondary literature review on the existing state of relevant science and technology. 3) Students will formulate a hypothesis about how a brain system could be involved and/or manipulated. 4) They will either propose an experiment or a technological development that would a) further scientific understanding of the brain, b) advance or improve the human condition in some way, and c) discuss associated ethical ramifications. For example: a sci-fi depiction of never needing sleep, which inspires a review of how existing cognitive enhancers work, and a subsequent proposal for a study of where in the brain the drug modafinil works or for novel brain targets for cognitive enhancement, and a discussion of the realities and ethics of not needing sleep: eg. Military or civilian pilots using modafinil to expand their capacity for flying beyond normal human boundaries).

Grading
20% Group presentations (2 total):
20% Reflection summaries (2 total)
20% Participation in class
20% Quizzes (4 total)
20% Final group presentation or paper

5. Bibliography of Sources that Relate Specifically to the Course
Books (All books are supplementary as our readings will be mainly from primary literature)
1. Erik Kandel's *Principles of Neural Science* (general reference).
2. Daniel Schacter's *The Seven Sins of Memory*
3. Daniel Dennet's *Elbow Room*
4. Steven Pinker's *How the Mind Works*

Articles:
1. David Eagleman – *The Brain on Trial* (link: http://www.theatlantic.com/magazine/archive/2011/07/the-brain-on-trial/308520/)
2. DS Lindsay - *Psychotherapy and memories of childhood sexual abuse: a cognitive perspective*
3. Han et al. *Selective erasure of a fear memory*
4. Howard Eichenbaum: *What H.M. taught us*
5. John Donoghue et al*. Brain-machine interface: Instant neural control of a movement signal*
6. Liu et al*. Optogenetic stimulation of a hippocampal engram activates fear memory recall*
7. Miguel Nicolelis et al. *A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information*
8. Paul Alivisatos - *The Brain Activity Map Project and the Challenge of Functional Connectomics*
9. Ramirez et al: *Creating a false memory in the hippocampus*
10. Robins L, et al: Drug use by U.S. Army enlisted men in Vietnam: a follow-up on their return home.
11. Schiller et al. *Preventing the return of fear in humans*
12. Seung-Schik Yoo et al. Non-Invasive Brain-to-Brain Interface (BBI): Establishing Functional Links between Two Brains
13. Tang et al: *Genetic enhancement of learning and memory in mice*
14. Eric Vermetten: *Hippocampal and Amygdalar Volumes in Dissociative Identity Disorder*
15. Wilder Penfield: *Stimulating memories in humans*

Reviews:

1. Barry Everitt. *Neural systems of reinforcement for drug addiction*
2. Benjamin Motz: Cognitive science in popular film
3. Brenda Milner et al. *Cognitive Neuroscience and the study of memory*
4. Elizabeth Loftus. *The reality of repressed memories*
5. Joan Ellason. *Positive and Negative Symptoms in Dissociative Identity* Disorder and Schizophrenia: *A Comparative Analysis*
6. Joshua Greene. *For the law, neuroscience changes nothing and everything*
7. Larry Squire. *Memory Systems of the brain: a brief history and current perspective*
8. Leshner. *Addiction is a brain disease, and it matters*
9. Lisa Saksida. *Shining a light on memory representations*
10. Maxwell Mehlman. *Cognition-Enhancing Drugs*
11. Rachel Bernstein. *Science on Set*
12. Thomas Insel. *Rethinking schizophrenia*

Supplementary material:

1. Bridging psychiatry and biology: http://www.nytimes.com/2013/09/08/opinion/sunday/the-new-science-of-mind.html?pagewanted=all&_r=0
2. Commentary on smart mice: http://www.nature.com/news/2008/080409/full/452674a.html
3. Daniel Dennett's *Elbow Room*. (One chapter on the compatibility of determinism, indeterminism, and free will).
4. Daniel Schacter: *The Seven Sins of Memory*. (Two chapters on suggestibility and misattribution)
5. Dennett's *Elbow Room* commentary: http://www.samharris.org/blog/item/free-will-and-free-will http://www.nature.com/news/2009/091014/full/461862a.html
6. Kristin Leutwyler – *Making smart mice*
7. Obama's BRAIN project: http://www.technologyreview.com/news/513011/why-obamas-brain-mapping-project-matters/
8. Obama's BRAIN project: http://www.whitehouse.gov/the-press-office/2013/04/02/fact-sheet-brain-initiative
9. Steven Pinker's *How the Mind Works.* Opening chapter.

6. Statement Describing Our Role in the Classroom

Our general aim in this course is to use cinematic representations of brain-related functions and behavior as a springboard to 1) introduce a memorable tour of the major systems of the brain and the current state of neuroscientific technologies and innovations, 2) to provide the neuroscientific expertise that will help students to evaluate common media portrayals of neuroscience and 3) to encourage a creative approach to seeking inspiration in scientific inquiry. To our knowledge, the cutting-edge methods covered in this class (i.e. optogenetics, brain-machine interfaces, artificial false memory formation), and their application to basic brain systems, as well as the dissection of media representations of this widely popularized scientific field, are concepts not yet offered in the Tufts' biology or psychology curricula, nor at most area universities. Indeed, studies have repeatedly shown that movies can be used to teach course-related material more effectively and promote a deeper understanding of the material. Accordingly, we're thrilled by the prospect of bridging the camps of neuroscience and cinema to offer to the Experimental College a progressive, multi-disciplinary course that focuses on class-wide critical discussions, all with the overarching goal of exploring the brain's inner workings and their relationship to the big screen.

Our aim is to provide students with the necessary background material—taught as a combination of primary research articles and reviews—to foster discussion about various scientific and cinematic questions posed. The lectures will be balanced by active discussion among and with students; indeed, 20% of their grade will be determined directly based on contributions to our Socratic style seminar. We will primarily steer the conversations to weave between neuroscience and cinema, between the assigned readings and clips/discussions of the movie at hand. We choose this approach because inviting Hollywood into the neuroscience classroom is a multi-layered endeavor that requires all of us—ourselves included—to be curiosity-driven students of our craft. This approach, we strongly believe, will enable a deeper understanding of the unifying principles that govern the brain, which simultaneously prepares students to dissect the science as portrayed in popular culture.

We have carefully chosen the movies for each week to fulfill two criteria: they must use neuroscience as a central plot mechanism and these concepts must have a substantial primary literature context. This was meant to directly contemporize how students are taught neuroscience, which in my opinion candidly embraces the mission of the Experimental College. To augment the readings, we plan to provide concise and well-crafted 30-minute introductions to the scientific material each week as brain systems and techniques are introduced. We will also play the most relevant short clips from each week's film throughout our class time to conjure up discussion, refresh everyone's memories

of poignant scenes, and to interrogate the science behind each scene judiciously and methodically.

Moreover, we will happily meet with students individually during office hours and by appointment to assist in preparing them for their presentations, to explain further any topic that may be the source of confusion, or simply to follow up class material with curiosity-driven questions. Furthermore, if a student's reflection papers do not meet the criteria described below, we will meet with them individually to discuss the merits and shortcomings of their summary to ensure that subsequent reflections show a strong grasp of the material at hand.

Our goal first and foremost is to teach neuroscience, and to this end, this class will use cinema as a pedagogical vehicle through which complicated neuroscience topics can be vividly portrayed and deeply understood.

7. Statement Explaining How Students will be Evaluated

Presentations 1 and 2 (20% - worth 10 points each)
Presentations of research or literature are an important and frequent part of contributing to the scientific community. Students will prepare two 20-minute presentations to introduce, convey and evaluate the substance of two primary scientific papers or scientific review papers. Students will be evaluated on how they frame the material in an introduction (3pts), how well they convey and evaluate the experimental design in each article (4pts), and how they connect the material to the week's film (3pts).

Reflection Papers (20% - worth 10 points each): Each student is required to write two 500-word reflection papers on the class of their choosing. The assignments will be due the following week, and a calendar will be made available online for students to sign up for their papers. Our discussions will often zoom out to the level of societal implications and zoom in to see how these are portrayed in cinema. In these reflections, an effort should be made to continually return to evaluating the representation of science in each film; after all, the scientific method depends heavily on distilling seemingly fantastic scenarios into tractable problems. Students will be evaluated based mainly on the accuracy of their summaries (2pts), how well they understand the connection between the week's assigned readings and film (4pts), and for demonstrating a firm grasp of the neural principles discussed in class (4pts).

Quizzes: There will be four quizzes administered throughout the semester (20% - 5pts each)—one for the first three lectures, one for the next three, and one for the final three. These quizzes will each contain 15 multiple-choice questions that cover the material for each third of the class; they are not cumulative. They will also contain two short answer questions, of which the student can choose one to answer, that will directly encourage students to intertwine the knowledge gained from our assigned readings and the movies assigned thus far.

Participation: This class aims to be a discussion-heavy dialogue between the students, our sources of literature and cinema, and me. As such, each week is structured to be a Socratic-style seminar, encouraging discourse that meanders between our primary sources and their cinematic influence (or vice versa). Each student's grade—20% of it—will be determined by his or her spoken contributions to the class. All ideas, opinions, and ruminations will be treated with balance and I will referee all discussions to ensure that they steer between our neuroscience topic of the week and movie of choice. Grading for participation will be based on the quality of input and the frequency with which someone proposes a meaningful contribution to the discussion.

Final Group Paper or Presentation (20%): Often methodical rigor is the emphasis when teaching the scientific method, but creativity is an important and necessary component to making meaningful scientific progress. This project

aims to engage students in the process of seeking inspiration from a movie, science fiction book or article that relates to human behavior, neuroscience, or brain technology. They will be evaluated on the topic that is chosen (4pts), the literature review on the existing state of relevant science and technology (4pts), the hypothesis that they formulate regarding how a brain system could be involved and/or manipulated (4pts), the experiment or a technological development that they propose (4pts), and the discussion of potential outcomes (4pts).