[SQUEAKING]

[RUSTLING]

[CLICKING]

NANCY KANWISHER: All right. It's 11:05. I'm going to try to start promptly at 11:05 each time.

So welcome. Is everybody psyched? I'm psyched. This is 913, the Human Brain.

I'm Nancy Kanwisher. I'm the prof for this class. And lest, you were wondering, I have a brain, and there it is.

That's me, with some bits colored in that you will learn about in this class. OK. What I'm going to do today is I'm going to tell you a brief story for around 10 minutes. And then I'm going to talk about the why, how, and what studying the human brain, why it's a cool thing to do, how you do it, and what in particular we're going to learn about in here, and then we'll do some mechanics and details of the course, and allocation of grades, and all that. It's on the syllabus anyway. Cool?

That's the agenda. All right. So let's start with that story. And for this, I'm going to sit up here.

The story isn't that long, but it has a lot of interesting little weird bits. So I have cue cards to remind myself of all the bits I want to remember to say. So you can put away your phones and your computers. And you don't need to take notes.

This is just a story. It's going to foreshadow a lot of the themes in the course, but it's not stuff you're going to be tested on. OK. So this is a true story, and I've changed only a few tiny little bits to protect the identity of the people involved. But otherwise, it's an absolutely true story.

It's a story about a scary medical situation that happened to a friend of mine a few years ago. But at the same time, it's a story about the nature of the human mind, about the organization of the human brain. And it's also a story about the ability or lack thereof to recover after brain damage. It's also incidentally a story about resilience, privilege, expertise, and all of those things that are characteristic of many people in Cambridge society, not so relevant for the course, but, all right, here goes.

So a few years ago, a friend of mine was staying over at my house in Cambridge en route to a conference in a nearby state. And this guy, I'll call him Bob, was a close friend of mine. I'd known him for years and years. We talked regularly. We went on hiking trips together. We were pretty close.

So he's en route to this conference. He's staying over at my house the night before. The plan was for him to get up early the next morning and drive to the conference. So we hung out the night before and chatted.

And the next morning, he's sleeping in the next room over from mine. And early in the morning, I hear some shuffling. I think yep, OK, Bob is packing to leave and thank, God, I don't need to get up.

I'm only dimly awake. And so I'm not paying that much attention. Shuffle, shuffle, shuffle in the background. And then I hear a crash.

And I think, what the hell is that? And I get up and I go into the next room. And Bob is lying on the floor, not moving.

I say, Bob, and there's no answer. And then I shout, Bob, and there's no answer. And then I dialed 911. While we were sitting there waiting for the ambulance to arrive, Bob starts to wake up.

And he's very woozy, but he's alive. And he's making a little bit of sense. And he can't figure out what's going on, and neither can I. And so we're talking and chatting, and he's making a little more sense, but we still don't know what's happening.

So then the ambulance arrives incredibly fast. I felt like three minutes, boom. There's three EMTs rushing in the front door, rushing up to the room where Bob was. And they take all his vitals. And they can't find anything wrong.

And so they're really casual. I guess they confront stuff like this all the time. I don't. Bob doesn't, but they're very calm about it. And they're saying, well, go take him to the hospital or not.

And I was like, I think we need to know what just happened, even though we seems OK. We kind of need to know what this is all about. Don't you think? They're like, yeah, you could take him to the ER.

And I said, well, do we need to waste ambulance resources, or do you think it's safe if I drive him myself, since there's a hospital not far away? They say you could drive him yourself. So I drive Bob to the Mount Auburn Hospital ER, which is like less than a mile from my house.

And we do the usual ER thing, which is mostly waiting, and waiting, and waiting, but various docs come by. And they take all these tests. And they take all these history questions, and it goes on and on. And basically, they're just not finding anything.

So after about an hour or two of this, they're still doing tests. They don't want to quite let him go yet, because they don't know what happened. Everybody's calm about it.

I figure, OK, fine, I got work to do. And I tell, Bob, text me throughout the day, and I'll come get you whenever they're ready to release you. And so I go into work, but just before I go into work, a thought flashes through my mind, and I say to the ER, doc you should check Bob's brain.

And the reason that thought flashed through my mind is that actually I had been worrying about Bob for a number of years. And I hadn't really-- it hadn't quite registered consciously, It was kind of too horrifying a thought for me to really allow myself to realize I was worried about Bob's brain, but I was worried about a very particular thing and that is that Bob had been showing these weird signs that he often got lost and didn't know where he was.

And on the one hand, this just didn't make any sense, because he was fine in every other way, but it was really pretty striking. So one time, I was over at Bob's house with some other friends of ours. And the friend asked, Bob, how do we get-- how do I drive from your house into Cambridge? And Bob said, well, you go to the end of the driveway, and you turn left.

My friend and I looked at each other like, Bob, what? And Bob thinks about it for a minute, yeah, end of the driveway, turn left. I just had this like sinking feeling of dread in the pit of my stomach, but we sort of made light of it, and made fun of it, and it went by. It was like, no, you turn right, and we gave the directions.

Another time a friend of mine was driving with Bob in Bob's hometown. And notice that like Bob didn't seem to know how to get to the grocery store in his hometown, where he'd lived for a really long time, a trip he'd made hundreds of times. Another time, I was at a conference in Germany. And I saw there are these arrays of posters of people presenting usually pretty dry scientific things.

And out of the corner of my I see the title of a poster and it says navigational deficits colon, an early sign of Alzheimer's. And I saw that, and I just saw ah, and I just kind of suppress the thought. I thought, oh my God, Bob, wasn't that old.

I know Alzheimer's can very rarely strike early. I didn't want to think about it, but it was like rattling around in the back of back of my consciousness. So there had been these signs, but as I say, it didn't make sense, because Bob was holding down a very high-powered job. He was writing beautiful prose.

He was the life of every party he was at witty, funny. Everybody's like favorite life of the party. So how could that be? It just didn't make sense that there would be anything wrong with Bob's brain.

So I managed for a few years to notice these signs and ignore them and not pay any attention. So the killer thing is, I should have known better. My research for the last 20 years has been on the very fact that there are different parts of the brain that do different things.

And one of the corollaries of that is you can have a problem with one of those parts and the other parts can work just fine. And so I, if anyone, should have realized, yes, there's something really wrong with Bob's navigation abilities. And the fact that he's smart, and witty, and funny and holding down a high powered job doesn't mean there isn't something wrong with his brain, with a part of his brain. But I didn't realize that.

But then, as I'm leaving the ER, they kind of all collect. And I said to the ER doc, you better check his brain. I thought Bob was out of earshot when I said that.

He heard it. He's like what? I was like, oh, never mind.

Anyway, the ER doc with the kind of confidence that only dogs can muster said, no, not a brain thing. This is a heart thing, which wasn't exactly reassuring, but I set aside the brain thought. And I went off to work.

So throughout the day, I texted with Bob a few times. Things seem to be fine. They've done more tests. They weren't finding anything.

We just got calmer and calmer about it. I guess sometimes weird stuff happens, and you just move on. But then that night around 7:00 or 8:00 at night, I was over at a friend's house, and the phone rang. And it was Bob.

I picked it up and Bob says, get over here. They found something in my brain. So I ran out of the house, grabbed my phone. And as I'm driving to the Mount Auburn ER, I called my trusty lab tech, an amazing guy, who keeps track of all kinds of things much better than I do, and I said, I remember that we scanned Bob a bunch of years ago for a regular experiment in my lab.

And I don't remember the date. I don't remember anything about it, but dig around in the files and see if you can figure it out. It might be useful to have that scan. So by the time I get to the ER, my lab tech has already texted me back and said found the scans.

I'm putting them in a Dropbox for you. So I go into the ER, and there's Bob and the ER doc. And Bob says to me, do you want to see it? The ER doc or the radiologist has already shown Bob the picture of his brain.

And so they take me in there. And I look at it. And I gulped. There was a thing the size of a lime smack in the middle of his brain. Pretty terrifying.

So this lime in the middle of Bob's brain was right next to a region that my lab had studied in great detail. In fact, my lab had discovered that a brain region right next to where that line was located was specifically involved in navigation. How could I not have put all this together?

But I didn't until that moment I thought, of course, of course, there's a thing in his brain right next to the parahippocampal place area, which I discovered, and a nearby related region called retrosplenial cortex, of course. And how the hell could I not have known? But I didn't know.

In that earlier work, it had been nearly 20 years ago, I had a postdoc named Russell Epstein. And Russell was a computer vision guy. And he wanted to understand how we see by writing code to duplicate the algorithms that he thought go on in the human brain when we understand visual images.

And that's a very respectable cool line of work, which we'll learn a little bit about in here. And Russell was really a coding guy. At the time, we were just starting doing brain imaging, but Russell was like pooh poohing it all.

It's like the flash in the pan. It's going to go by. It's trashy. So you guys get nice blobs on the brain. I'm not having any of it.

And I kept saying, Russell, you need to get a job. Just do one experiment so you can show in your job talk that you can do brain imaging. It might help you.

You don't need to do a lot of it. Just do one dumb experiment. Russell was interested in how we recognize scenes, not just objects, and faces, and words, but how do we know where we are and how do we recognize if the scene as a city, or a beach, or whatever it is? I said, OK, Russell, we'll just scan people, looking at pictures of scenes, and looking at other kinds of pictures.

And we'll just kind of see if there's any part of the brain that responds a lot to scenes. It really was not well thought out. This is not how you should do an experiment. It shouldn't be based on political calculations, lack of theory, any of the above.

But the fact is that's why we did that experiment. Russell needed to be able to show a brain image in his job talk. So we scan some people looking at scenes. And the results knocked our socks off.

We found a part of the brain that responds very selectively when you look at images of scenes, not when you look at faces, objects, words, or pretty much anything else. And so we'll learn more about that later in the course. We called it the parahippocampal place area. And that launched a whole major line of work in my lab and now dozens of other labs around the world.

Backtrack-- we'd already found that region. And here's this lime in my friend Bob's brain, sitting right next to the parahippocampal place area. Then I remembered, let's look at the scans from my lab from a few years ago in Bob's brain. I fiddled around and managed to download the files. And there it was. You could see that same blob. But in the scans from a few years before, it was much smaller. It was the size of a grape.

That told us a bunch of things. Most importantly, it told us this thing is growing really slowly. And that was hugely important, because brain tumors are very bad news. And they usually grow really fast. And the fact that it grew really slowly told us that this was not one of the kind of worst, most invasive, most horrible ones. It was clearly a problem. It was big. But at least it wasn't growing hugely fast.

But how poignant that there was in my own damn data, and I hadn't seen it in my friend's brain. Well, I'm not a radiologist. I'm a basic researcher. And I didn't look, and I didn't see it. Indeed, the next day, the docs told us that they thought this was meningioma, not cancer. Who knew that you could have tumors that weren't cancer? But you can. And they still need to come out, if they're big enough. And that's very serious. But it's not as bad as having a cancer in your brain.

As we're collecting information, the next day, I'm hanging out in the hospital room. And there was an amusing moment when one of the residents came by. And he's taking the history and asking all of the basic questions. And I said kind of sheepishly-- because you don't want to seem like more than the residents. And in fact, I didn't really know more, but I just thought I'd provide a little information.

And I said, he's actually had symptoms for a bunch of years, and there's a region of the brain nearby that I've actually studied a little bit. And the resident says, like, we know who you are. So much for my trying to stay under the radar.

That afternoon, I talked to a neurosurgeon friend of mine, because I figured, OK, we need advice. We need help. And the neurosurgeon friend said, quote-- it got branded in my brain-- she said, "it is of paramount importance that you find the best neurosurgeon. It's the difference between whether Bob dies on the table or goes on to live a normal life." This is the privilege part of the story. I'm not that well connected, but I'm a little bit connected. And I kind of dug around, and did what I could. And we spent a couple of weeks, and we found the best neurosurgeon.

And the night before the surgery, Bob is staying over at my house, because the surgery was in a Boston hospital. And I thought, I've been dancing around this for years, but now it's all out in the open. We know there's a problem. And I'm going to test him. I'm going to find out what the hell's going on.

This is, after all, one of the basic forms of data that we collect in my field-- that is, testing people with problems in their brain to try to figure out what things they can do and what things they can't do. It's a way of figuring out what the basic components of the mind and brain are. It's actually the oldest, most venerable method in our field, and it's still a hugely important one. So I thought, what the hell.

So I said, OK, Bob, draw me a sketch map of the floor plan of your house. Bob takes a few minutes and he draws this thing. And it was shocking. There weren't even-- the rooms in a rectilinearly arranged house, they weren't even aligned.

There was, like, a soup of lines. There was no organization from one room to the next. And Bob kind of realized, this isn't right, is it? But he didn't know how to fix it. And he said he just couldn't visualize what it looked like to be in his house, and so he couldn't draw the floor plan. And I thought, OK, he hasn't been there in a couple of days.

So I gave him another piece of paper and I said, OK, draw the floor plan of my house, where you are right now. Bob took a couple of minutes and delivered a similar mess. He couldn't even imagine the layout of the room next to him, that he'd been in a few minutes before. And then, trying to channel my inner neuropsychologist, I thought OK. Gave him another piece of paper and I said, OK, Bob, draw a bicycle.

Why did I choose a bicycle? Because it's a multi-part object that has a bunch of different bits that have a particular relationship to each other, just as the rooms in a house have a particular spatial relationship to each other. And I wanted to know, is his problem specifically about places, or is it about any complex, multi-part thing that you have to remember the relationships to? Bob is no artist, to put it mildly. But his bicycle was clearly recognizable as a bicycle.

It had the two wheels in the right relationship, and it had all of the basic parts in roughly the right place. I then had him draw a lobster, another multi-part object. And also, his lobster was not beautiful, but had everything in the right place. That's very telling he had a specific problem in-- I don't know-- imagining, reproducing, remembering? It's not totally clear. The arrangements of parts in a room, but not the arrangements of parts in an object. And we'll get back to that more in a few weeks.

What do I want to say here? I said all of that. The next day, Bob has an 11-hour surgery. Major, hardcore, extreme neurosurgery. Remove a huge piece of bone from the back of your head, pull apart the hemispheres of the brain like this, go in multiple inches and remove a lime. Holy crap, right? Said lime was right near the vein of Galen. Galen lived, what, a couple of thousand years ago?

The fact that there's a vein of Galen means it's a big-ass vein-- the kind of vein that even Galen would have found with dissection 2,000 years ago. This line was all wrapped around and interleaved with the vein of Galen. Not good. But because we found the best neurosurgeon, and because we have extreme privilege and all of the possible medical resources and expertise you could possibly hope for, Bob sailed through the surgery. And an hour after the surgery, I'm chatting with him and he's making sense. Amazing, right?

And literally, two days later, they sent him home. And a few days after that, he's back at work. No problem. Totally fine. But now we get to the question you're probably thinking about. What about his navigational abilities? The sad answer is, nothing doing. None of it came back at all. Thank god for iPhones. If Bob lived 30 years ago, he wouldn't be able to function. But he goes everywhere using his iPhone GPS-- everywhere.

And this fact that he didn't recover his navigational abilities is consistent with the whole literature that we'll consider later in the course-- that, often-- not always, but often, if you have brain damage, especially to some of these very specialized circuits that we'll talk about, you don't recover later. If the damage is early, you may well recover-- early in life, you may well recover. Children have much more plastic brains that can adjust after brain damage. Adults, not so good. Bob's doing fine. That's my story. Any thoughts or questions? Yeah?

AUDIENCE: Can he tell the difference between right to left [INAUDIBLE]?

NANCY KANWISHER: Yes. Yes. And it's very interesting. There are many of his spatial abilities that are absolutely intact, and yet the ones related to navigation are not. Yeah?

AUDIENCE: Can he drive?

NANCY KANWISHER: Yeah, no problem. But he's always looking at his damn phone to get directions, or to listen to the GPS directions system. Driving is no problem. It's another kind of left-right-- the immediate spatial orientation abilities are absolutely fine. But knowing, where am I now, and how would I get there from here, is blitzed. Other questions? Yeah?

AUDIENCE: Can he recognize familiar places?

NANCY KANWISHER: Great question. Yes, he can recognize familiar places. What he can't do is, he can say, oh, right, that's the front of our house, or that's such-and-such cafe that's near our house. What he can't do is say, which way would you turn from there to go home?

AUDIENCE: Can he can he string together multiple [INAUDIBLE]?

NANCY KANWISHER: Great question. Great question. A little bit. He can navigate a little bit with his GPS. And because he's learned certain routes as a series of almost verbal commands-- if you're here, turn right, then there, nur, nur, nur, nur. That whole kind of thing. It's not what any of you guys could do. If you guys are driving around in Cambridge or walking around campus-- remember when they blocked off this whole middle of campus a couple of years ago?

It was so irritating. I would like go there, and it's like, oh god, they've blocked it off. I can't get over to lobby 7. Well, you immediately come up with an alternate route. It's like, OK, I guess we're going to have to do this. You come up with an alternate route. This is a normal navigation system can do. Bob can't do that at all. He's like, route blocked? No idea. Get out the phone. Yeah?

AUDIENCE: Is he good at estimating distances? Does he know something is a certain number of miles away, or?

NANCY KANWISHER: Yes. Yes, he is. And that's very interesting. But that seems to be kind of a different thing. You could think about all of the different kinds of cues you have for distance beyond your kind of literal navigation skills. Yeah?

AUDIENCE: [INAUDIBLE]?

NANCY KANWISHER: A little bit. A couple of minutes, yes. The next day-- I mean, it would be kind of like this thing. It's like, I sort of vaguely remember that when I was here, I turned right, so I'd better do that again. Yes, did you have question?

AUDIENCE: Can he navigate within buildings?

NANCY KANWISHER: No, not very well. And this is a problem, because iPhones don't usually-- yeah. New hotels, big problem. Finding the bathroom down the hall, or the front door in a hotel, big problem. Yeah. I mean, these are problems you can-- you can come up with workarounds. It's not life-threatening, but it's extremely inconvenient. Yeah?

AUDIENCE: Is it the case that those navigational skills that develop long-term, like a long time ago are stronger? So he has a harder time developing-- for example, you said new hotels are a problem. But if it is places that are more familiar, like his home, is it easier for him to navigate?

NANCY KANWISHER: It's a great question. And you might think that the kind of navigational maps you laid down long ago would be intact. So is it just that you can't learn new ones? It's a great question. The answer is kind of complicated in this case. For routes that he's memorized-- there's a whole different system for knowing a route, and really having an abstract knowledge of a place that enables you to devise a new route if something is blocked on that route.

For highly over-learned routes, he's OK. He remembers the [INAUDIBLE]. It's like a memorized motor sequence. You do A, and then B, and then C, and then D. He's OK with those, with routes he learned long ago. But he is not good at coming up with a new route in a place that he learned long ago. We'll take one last question.

AUDIENCE: Does he have conscious access to past knowledge that [INAUDIBLE] And does he have conscious knowledge that [INAUDIBLE]?

NANCY KANWISHER: No, he knows-- well, he knows, because when he tries to figure out which way to head, he has no idea. He's extremely aware of it, and very articulate on precisely what happens. What he says is, if he's looking at a place-- here's something he says. He's looking at a place. He knows where he is, because there's all kinds of other bits of information that tell you where you are, because you intended to go there, and the relevant things are happening, and all. So he knows where he is. And it looks familiar.

If he tries to imagine what's behind him, he says that he starts to get it and it just kind of vaporizes. He just can't hang on to it. He can't kind of construct a stable mental image of nearby places. I don't know exactly what that means, but he's very articulate, and can report what happens-- what he experiences when he tries to access this kind of information. What you guys-- we'll go on. But what I want to say is, what you guys just did is exactly what we do in my field.

We try to take a mental ability and tease it apart and say, is it exactly this or is it exactly that? And you guys all just did it beautifully. A lot of what we do in my field is kind of this common-sense parsing of mental abilities. What is a particular mental ability-- how does it relate to some other one? Are these things separable ? Can you lose one and not the other? Do they live in different parts of the brain, et cetera? All right. That's the story.

I'm going to cache out some of the particular themes that came out from the story that will echo through this course. And the first and most obvious one is, the brain isn't just a big bunch of mush. It has structure. It has organization. The different bits do different things. Importantly, when Bob had this big lime in his head, he didn't just get a little bit stupid. No.

His IQ, if he'd take an IQ test, would be unchanged. He lost a very specific mental ability. And that is fascinating, but it's also good news for science. Because often, when you try to understand a complicated thing, a great way to make progress is to first figure out what the parts are, and then later try to figure out, how does each individual part work and how do they work together? But if there's part structure, there's at least a place to start.

Second theme is that some parts of the brain do extremely specific things. Not all of them. Some of them are quite general, and are engaged in lots of different mental processes. But some are remarkably specific. We'll talk a lot about that.

Third big theme. The organization of the brain echoes the architecture of the mind. And I would say, the fundamental pieces of the brain are telling us what are fundamental parts of the mind. And that's why I'm in this field. That's what I think is cool. The brain is just a bunch of cells. It's a physical thing. Who cares about a physical thing?

The reason we care about it is, that's where our mind lives. And if we study that physical thing, we can learn something about our minds. And that's pretty cosmic, I think. The point of all of this kind of work is not to say, oh, that mental process is here, not there. Who cares? I don't really care. I mean, at some point, you need to have a ballpark sense. You need to know to study the things.

But the interesting question is not where these things are in the brain, but which mental processes have their own specialized machinery, and why those? Another important theme. How do brains change? Bob didn't recover after his brain damage, in that very particular mental function that he lost. If all of that had happened when he was five years old, he probably would have. How do brains change over normal development? How do they change from learning and experience? How do they change after injury?

And the final theme echoed in that story is, there are lots and lots of different ways to study the brain. There are the simple behavioral observations. Bob can't navigate, but he can do everything else. OK, that's really deep and informative-- low-tech, but really powerful. The anatomical brain images that showed where the lime was in Bob's brain, that gives you another kind of information.

What's the physical structure of the brain? The functional images that we had done in my lab to discover the parahippocampal place area, and the studies of what mental abilities are preserved and which are lost in people who have alterations of their brain. Those are just a few of the kinds of methods in our field, each of which tells us about a different kind of thing about the brain. Those are the themes I was trying to get at here.

Let's move on to the why, how, and what of exploring the brain. I'm going to assign the TAs to get me to shut up at-- let's see. We're supposed to end at 5 minutes before the end of class, is that right? Is that the MIT tradition? OK, so at-- oh, my, shockingly soon-- 11:45, you're going to--

AUDIENCE: [INAUDIBLE]

NANCY KANWISHER: Oh, great, thank you. Thank you. This is one of the many things TAs are for. They pick up the hundreds of typos and "mindos" and all of that. Excellent. I'm thinking, how the hell did I so mis-time this? Thank you, Heather. OK, good. We'll go on.

Why should we study the brain? First, most obvious reason, know thyself. Know what this thing is that's operating in our heads. This is who you are, is your brain. There are lots of very fine and important organs in the body, but the brain is special. So, a heart is important. You'd die without it. But it's the brain that's your identity. There's a reason that surgeons do heart transplants. That makes sense. Something wrong with your heart, you need another heart, OK.

But why don't they do brain transplants? That wouldn't make sense. If there's something wrong with my brain, it doesn't make sense to take someone else's brain and put it in here, because then I'd be that other person. It doesn't make sense, because the brain is who you are.

So the brain is really special. It's not just another organ. That's why, a few years ago, we had the decade of the brain-- not the decade of the pancreas, or the liver, or the kidney. People need to study these things. They need to know how to fix them. They're important. But they're not as cosmic as the brain.

Second reason why we should understand brains, and that is to understand the limits of human knowledge. The more we understand about the human mind, the more we can actually evaluate how good our knowledge is. Are there things that we might not be able to think? Possible through scientific theories we might not be able to understand, ever? You can think of studying the mind as a kind of empirical epistemology, a way to actually know about the knower so we can figure out how good the knowledge is in that knower. That's another reason.

A third reason is to advance AI. Up until a few years ago, I used to give lectures on vision, and they would all start with some version of this. You guys all have amazing visual abilities in the back of your brain that does vision. You can do all of this incredible stuff that no machine can touch. Hats off to you. You have an amazing visual system back here, and those guys in AI-- it is mostly guys. Guys, gals, whatever.

Those people in AI could only dream of coming up with algorithms as good as the one that's running in the back of your head. You can't quite start the lectures that way anymore. If any of you have been living in a cave and not heard about deep nets, there's been a massive revolution. And all of a sudden, deep nets are doing things that are really close to human abilities, particularly in vision.

For example, in visual object recognition, machines were way far behind human vision until very recently, especially when this paper here came out-- was published in 2012. First author, Krizhevsky. It has now been cited an astonishing 33,000 times. Actually made this slide a couple of weeks ago.

It's probably been cited 36,000 times by now. You could look it up on Google Scholar and find out. That is a huge number of citations. The influence of this paper is ginormous. Probably half of you have already heard about this paper. Raise your hand if you've heard about this paper. Oh, OK. All right. Major, big news.

What's so important about this paper? Well, they trained-- as, probably, most of you know-- they trained a deep net on the over 1 million images in ImageNet, a massive computer database of images. And they basically taught it to do object recognition. And it performed much more accurately than any previous system, and it approaches human abilities. This is major. This is a radical change in the situation that we were in five years ago. Things have changed radically.

Just as an example, here's one of the figures from that seminal paper. Here is one of the images from ImageNet that AlexNet, this trained network, was tested on. And the correct answer, according to ImageNet, is that that's a mite. And here's what AlexNet says. Its number one first answer is mite, and its second, third, fourth answers are black widow, cockroach, et cetera.

Pretty damn good. The mite is even sticking off the edge of the frame, and it gets it. Container ship. First choice, container ship. Pretty good. Second choice makes sense. Lifeboat. Not bad. Look at that-- motor scooter. I can barely even see the motor scooter in there, but AlexNet, awesome. Right? Leopard. Awesome.

Even when AlexNet makes a mistake, the mistake is totally understandable. Like, according to ImageNet, that is a picture of a grille, and AlexNet calls it a convertible. I'm siding with AlexNet on this one. This, the correct answer is mushroom, and AlexNet says agaric. I had to look that up. It's a particular kind of mushroom. This one's pretty funny. ImageNet says that's pictures of cherry. There's cherries in the foreground. But AlexNet says dalmatian. I'm siding with AlexNet on this. And Madagascar cat, et cetera. Pretty amazing.

And nothing even close to this was possible before 2012. This is very recent history, and it has totally shaken up the field in lots of ways. That's been transformative not just for computer science, but it's also been transformative for cognitive science and neuroscience.

Because now, we have algorithms-- like, here's this deep net, and it does this thing. That's a possible theory of how humans do it. It's a possible, computationally precise theory of what's going on in here. And we didn't use to have those, and now we have those for a number of domains. And that's shaking up the field.

There will be a whole lecture on deep nets and how you can use them to think about minds and brains toward the end of the course-- guest lecture by my postdoc Katharina Dobbs. And we'll hear more about that. But let's first step back a second and say, OK, do they really perform as well as humans, even on just object recognition?

Well, what if we tested it on images not in ImageNet? ImageNet is a pretty good test because these things, as you can see, are highly variable. They have backgrounds. They're complicated. They're real-world images.

But they were photographs taken by people in a particular way, with a particular goal. And most of the photographs you take, you throw out. They don't end up in ImageNet. ImageNet is a weird little idiosyncratic subset of the kind of visual experience that we have.

So would this really generalize? It so happens that Boris Katz and Andrei Barbu, across the street in CSAIL, have been doing some very interesting studies. This stuff isn't published yet, but I got their permission to tell you about this cool stuff they're doing. And they're saying, hey, let's test AlexNet and other similar deep nets since then on a more

Realistic, harder version of object recognition that's more characteristic of what humans do. They're generating this huge data set of stimuli that they crowdsource. Workers on Mechanical Turk go on there and create images for them. They get instructions like, hold an object in this particular location, or at this angle, or move it here, and send us the images. They are getting, I think, hundreds of thousands of images to test this on. And they're much more variable in the location of the object in the image, and its orientation, and so forth.

For example, you guys have no problem telling what that thing is, but it's a slightly atypical example. Likewise, what's the object on the floor there? You can tell what it is, but it's a slightly atypical example.

What Boris and Andrei are finding is that human performance is still pretty good on these images, but the deep nets are terrible at this stuff. ResNet, one of the more recent ones, drops from 71% correct on ImageNet to around 25% correct on these images. And the other similar, fancy, more recent networks, do similarly badly.

On the one hand, AI, the deep nets, are awesome and transformative. No question about it. But on the other hand, despite all the hype, they're still not quite like human object recognition. They're a whole lot closer than they used to be, but they're not really there. And more generally, what about harder problems, like image understanding-- not just labeling and classification, but understanding what's going on in the image? You guys have probably seen image captioning bots. There are lots of these around now.

This kind of hit the scene in 2016, when Google AI came out with a captioning algorithm. And of course, right around the same time, Microsoft had a captioning algorithm. And let's see how they do. This is an example. You give this algorithm this picture here, and it says, that's a dinosaur on top of a surfboard.

That's pretty damn good, right? OK, wow. Let's look more generally, how well this thing works at other examples. It looks at this and it says, that's a group of people on the field playing football. Like, wow. OK.

A snow-covered field. Pretty good. Liu Shiwen and Ding Ning posing for a picture. I don't know, but these things are very good at face recognition. That's probably exactly those two people. A car parked in a parking lot. Pretty good. A large ship in the water. Pretty good. A clock tower lit up at night. Awesome, right? A vintage photo of a pond. Well, the vintage part. I don't know where the pond is. There's a little water in there. I don't know. Not way off.

A group of people that are standing in the grass near a bridge. Not really. There's grass. There's a bridge, sort of. There's people. But not really, right? A group of people standing on top of a boat. Definitely not. A building with a cake. What? A person holding a cell phone. Not. A group of stuffed animals. I love this one. A necklace made of bananas. Wow. We've really landed on Mars here. A sign sitting on the grass. Talk about missing the boat.

Now, look at this picture for a second. Just figure out what's going on here. Takes a couple of seconds. Everyone got it? There's a lot going on here. This algorithm says, I think it's a group of people standing next to a man in a suit and tie. And the algorithm is correct, but the algorithm has profoundly missed the boat. I'm channeling-- actually, I stole these slides from Josh Tenenbaum. But let me channel him for a moment and say what his big idea is, which I think is really important.

And that is that both humans and deep nets are very good at pattern recognition-- pattern classification. This is a cat, or a dog, or a car, or a toaster. What they're not good at-- what humans are good at, but the deep nets are not, is building models to understand the world. When you look at this picture, there are all kinds of things that are crucial for really understanding, at a deep level, what's going on in here. We need to know why some people-- what some people here know, but the guy on the scale does not know.

Namely, even if you don't recognize that that's James Comey-- I think it is-- here's Obama with his foot on the scale. You need to know that people find it embarrassing if they weigh too much. You need to know that he can't see that Obama's doing it. You need to know that they can see it, even though he can't, and that's kind of the essence of humor. There's just a whole universe of rich structural information going in here that is part of what it means to understand this picture. And no deep net is even close to doing that kind of thing.

Bottom line of all this is-- or let me just go on more generally-- AI systems can't navigate new situations, infer what others believe, use language to communicate, write poetry and music to express how they feel, or create math to build bridges, devices, and lifesaving medicines. That's a quote from our leader, Jim DiCarlo, head of this department, published in Wired a year ago in a beautiful article on the limitations of deep nets.

But more generally, the point is that, yes, AI is taking a massive leap now. We're right in the middle of it, and it's super exciting, and it's helpful to neuroscience and cognitive science. But AI has a lot to learn from us too-- a lot to learn from what's going on in here, and how this thing works that those AI systems still can't touch. All of that was my third reason for studying-- we're still in the, why are we studying the human brain?

The fourth reason to study the human brain is the one most compelling to me, and that is that it is just simply the greatest intellectual quest of all time. We could fight about cosmology. I'm not going to fight with you about anything else. I don't think there's any contest. It's the greatest intellectual quest of all time. And that's why I'm in it, and that's why I hope it'll be fun for you. That was the why. How are we going to study the human brain?

Here's this thing. How are we going to figure out how it works? Kind of daunting, not totally obvious. The first thing to realize is that there are lots of levels of organization in this thing, and hence, lots of ways of studying it. We could look at molecules and their interactions. Lots of people in this building do that.

We could look at properties of individual neurons. We could look at circuits of neurons interacting with each other. We could look at entire brain regions and what their functions are. We could look at networks of multiple brain regions interacting with each other.

All of those things are possible. But actually, what we're going to do in the course is none of those things in particular. Instead, we're going to ask a somewhat different question. And that question is, how does the brain give rise to the mind? And to understand that question, we're going to do more at this level, and less at the upper level.

To answer this question, we need to start with the mind. We need to-- if we're going to understand, how does this thing produce a mind, we need to first figure out, what is a mind? What do we know about minds?

We need to start with the various mental functions that minds carry out-- things like perception, vision, hearing, aspects of cognition, like understanding language, thinking about people, thinking about things, et cetera. For each mental function, what we're going to do in here is start by trying to understand how it works in minds as well as we can, or what it is that we're trying to understand that minds can do. What is computed and how? And then we're going to look at its brain basis and try to figure out what we can figure out about how that mental function is implemented in a brain.

The first question we'll ask for all of these domains is, is there specialized machinery to do that thing? And then we'll ask, what information is represented in the relevant parts of the brain, and when is that information represented, and how? How are we going to answer those questions? Well, there's lots and lots of methods in our field. The first set of methods-- if we want to understand minds, the first set of methods are the basic stuff of cognitive science, psychophysics.

That means showing people visual stimuli, or playing them sounds, and asking them what they see or hear. Nice and low tech, but lots has been learned from those methods. You collect reaction time and accuracy, and it's amazing how much you can learn from these methods that have been around for a hundred years or more. Perceptual illusions are similarly very informative about how minds work.

Now, let me say an important thing that arises here. Last year was the first time I taught this course, and I would say it went so-so. I'm aiming for it to be much better this year.

And one of the ways I'm trying to do that is to be responsive to the student evals I got last year, which were not fabulous across the board. Hurt my feelings badly. But once I got over myself, I decided to just listen to them and try to fix it. And one way to fix it is to be honest with you today about what this course is going to cover. In my evals, student 50458, bless them, offered this comment.

"This class was not sold in the correct way. It should not be called the Human Brain, because it was basically just a cognitive science, not a brain class. I expect it to learn very different material." I don't know who this student is. I wish I could apologize to them. But I will say to you, sorry, student 50458-- sorry I didn't make that clear.

The fundamental the reason the brain is cool is that gives rise to the mind. And that means that studying the biological properties of the brain without considering the mental functions it implements it would be kind of like trying to study the physical properties of a book without considering the meaning of its text.

We're going to spend a lot of time doing cognitive science in here. And if you had a different impression, sorry about that. But that's what we're doing here. How are we going to answer this? Lots of cognitive science.

How are we going to look at the brain basis? Well, we're going to look at neuropsychology patients-- people like Bob who have damage to the brain and what functions get preserved and lost. We'll look at a lot of studies with functional MRI.

Neurophysiology, where you can record from individual neurons in animal brains, and in rare cases, even in human brains-- under clinical situations where they need to have electrodes in their brain anyway for neurosurgery. We will look at EEG recorded from electrodes on the scalp and MEG recording from magnetic fields from squids placed next to the scalp.

We'll look at connectivity measures with a method called diffusion tractography, et cetera. Lots of methods. Which mental functions will we cover? Well, to tell you about that, I need to tell you about the huge progress that has happened in our field in the last 20 years. All of this is quite recent.

Let's back up to 1990. Here is approximately what we knew about the organization of the human brain in 1990. The black ovals are the bits that are primary sensory and motor regions that have been known for a long time, even by 1990. And the colored bits are the bits where we had some idea that face recognition might go on somewhere in the back end of the bottom of the right hemisphere because of people who had damage back there and lost their face recognition ability-- sometimes, preserving their ability to visually recognize words and scenes and objects, only losing their ability to recognize faces.

The language regions we had known about for nearly 200 years, from Broca and Wernicke and others, who had studied patients with damage in those regions and noted that they had problems with language function. And similarly, many people had reported that if you have damage up here in the parietal lobes, you sometimes lose your ability to direct your attention to different places in the visual scene. That was approximately what was known in 1990.

And here's what we know now. We now know, thanks largely to functional MRI, that for dozens of regions in the brain, in every one of you, we have a pretty good idea of the function of that region. This is major progress. This is a kind of rough sketch of the organization of the human mind and brain that we have now, that we didn't have 20 years ago. And that's awesome. That has made possible a lot of progress, building with other methods.

What we'll study in this course is, we'll focus on those mental functions where the brain bases are best understood. And that will include things like the visual perception of color, shape, and motion, visual recognition of faces, places, bodies, and words-- and scenes. Didn't make it on the slide.

Oh, yes, it did. Perceiving scenes and navigating. Understanding numbers. Yes, there's a whole lot about the brain basis of understanding numbers. Perceiving speech and perceiving music. Understanding language. Understanding other people and their minds.

Those are the kinds of topics where there's been a lot of progress recently in understanding the brain basis of those mental functions. Those are the ones we'll focus on. And that means there's going to be a lot on perception, high-level vision and high-level audition, because that's one where a lot of progress has been made, and it's also a lot of the cortex.

As I mentioned a moment ago, the whole back part your brain does vision, construed broadly. Some people might say, well, why is she spending all of this time in vision? Well, it's a big part of what your brain does. We are very visual animals. So we'll spend a lot of time on vision.

For each of these functions, we will ask, to what extent is this mental function implemented in its own specialized brain machinery? Are there multiple different brain regions that carry out that function? What does each one do? Is there a division of labor between those different regions? How does that system arise in development? Does it have homologues in other species? Are these things uniquely human, or which of them are?

And also, along the way, other side cool questions that will come up. What, if anything, is special about the human brain? How come we are taking over-- and largely destroying-- the planet, and other species are not? Besides destroying the planet, we're doing some other cool things, like inventing science, and engineering, and medicine, and architecture, and poetry, and literature, and all of these other-- and music-- all of these other awesome things that other species aren't doing.

How come our brains are doing that and other species aren't? Where does knowledge come from? You guys know all of this stuff. How much of that stuff was wired in at birth and how much of it did you get from experience? How much can our minds and brains change over time? Can we go study a new thing and get a whole new brain region for that thing? Can we change the basic structure just by training, or after brain damage?

Can we think without language? How many of you have wondered about that question? Yeah, really basic question. Anya is answering it. Anya and some others. But Anya is doing a lot to answer that question. There are actually empirical answers to these long-standing, deep questions that everyone wonders about. That's pretty cool.

Somebody back there asked a while ago about awareness. Can we think, perceive, understand without awareness? How much can go on in the basement of the brain when we don't even know what's going on down there? We'll consider all of these other cool questions.

There's a bunch of things we won't cover in this course for various reasons, that could have been in here and just aren't. There's only so much time. Motor control. It's really important to know how you do things like pick up objects and plan actions. And we're just not covering that. Something had to go. Subcortical function. This is a very corticocentric course. Most of the course will deal with the cortex. That's where most of conscious thinking and reasoning and cognition happens.

There's a lot of good stuff down in the basement of the brain, and it's going to get pretty short shrift. Not for any good reason-- just what it is. Decision-making. Important field, not getting much coverage in here. Importantly, circuit-level mechanisms-- explanations of cognition.

If you think that we're going to understand not only what it means to understand the meaning of a sentence, but that I'm going to give you a wiring diagram of the neurons that implement that function, sorry to be the bearer of bad news, but nobody has a freaking clue how you could get a bunch of neurons to understand the meaning of a sentence.

That's exciting. That means there's a field for you guys to waltz into. And probably, in your lifetimes, people will start to crack these things. But just to know what we're headed into, rarely, for almost no high-level mental functions, do we have anything like a wiring diagram-level understanding of any perceptual or cognitive function. That's not in the cards for this course, because it doesn't exist in the field.

For that kind of thing, there are cases where you can make progress. You can understand, say, fear conditioning in a mouse. Those circuits are being like cracked wide open by people in this building, people all around the world, with spectacular precision.

They know the specific classes of neurons, their connectivity. They know every damn thing about them. But it's like, how does a mouse learn that this thing is-- to be afraid of this thing? OK, that's important. But for more complex aspects of cognition in humans, we can't usually have that kind of circuit-level understanding.

Lots of other things that will get short shrift. Memory, not for any good reason. I mean, there's a lot of coverage of memory in 900 and 901, and it's just somehow off a blind spot for understanding-- for knowing how to talk interestingly about memory.

So I'm not going to give you a boring lecture on memory. Instead, I'm not going to give you any lecture on memory until I learn how to talk about it interestingly. Reinforcement learning and reward systems. I'm going to try to pull some of that in, but it's not going to be a major focus, even though it's a really important part of cognition. Attention. There might be some at the end.

How many of you have taken 900? Looks like a little over a half. How many have taken 901? Yeah, a little over half. OK, good.

If you have, great. Good for you. This course is designed as a tier two course for people who have taken 900 or 901. If you haven't, you're probably OK, but you might need to do a little extra work. I've already posted online, and in the syllabus, information about, actually, a lecture I gave a year ago on some of the background stuff that is no longer taught in this course.

People hated it when I taught them stuff they'd already encountered before, so I'm trying to minimize that. That's a backup for those of you who haven't taken these courses. If you're worried about this, chat with me afterwards. I think it will be OK, just count on doing a little bit of extra work-- not much. For those of us who have taken it, there's going to be a little bit of overlap. It's simply impossible to have zero overlap.

I mean, what does John Gabrieli in 900 and Mark Bear in 901 do? They survey the whole broad field, and they pick the coolest stuff out of every little bit, and they teach it to you, exactly as they should. But that means that when I come along and try to say, I'm going to do a more intensive coverage of the coolest things, there's going to be a teeny bit of overlap. But I'll try to not make it too much-- just because the coolest stuff is the coolest stuff.

Also, the spin and the goals of this course are quite different from both 900 and 901. You will have to memorize a few things, but not much. My real goal in this course is to have you understand things, not memorize a sea of disjointed facts. A little more on the goals. Really, what I want you to get out of this course is to appreciate the big questions in the field and what is at stake theoretically in each. I want you to understand the methods in human cognitive neuroscience, what each one can tell you, what it can't, how different combinations of methods

Can work synergistically and complementarily to answer different facets of a question. I do want you to gain some actual knowledge about some of the domains of cognition where we've learned a bunch, both at the cognitive level and the brain level-- things like face recognition, navigation, language understanding, music, stuff like that.

And crucially, I want you guys to be able to read current papers in the field. If you look in the syllabus, the first few papers are, like, 20 years old, but it's going to accelerate quickly and you'll be reading papers-- I'm trying to choose mostly papers published in the last year or two. I'm trying to take you straight to the cutting edge of the field. Yeah?

AUDIENCE: Are the papers going to be straight out of research labs, or are they going to be, like, the annual review [INAUDIBLE]?

NANCY KANWISHER: No, straight out of research labs. You're going to read the real deal, not someone else's blurry, they just read the abstracts and put in some stuff in the review article. No, you're going to read the actual paper. That's the whole deal. Those are the goals. Good. A few things. Why no textbook? This field is moving too fast for a textbook. Plus, I have strong opinions, and I don't like any of the textbooks.

Any textbook is out of date. We're going to be reading hot stuff that's hot off the press, and so that's not in the textbooks yet. And so we're skipping that, and you're going to go straight to original research articles. There will be occasional review articles where relevant, but mostly, part of the agenda of this course is to teach you to be not afraid of and able to read current articles in the field. All right.

You've all been waiting for this. Details on the grading. Pretty standard. Midterm, 25% of the class-- of the grade. Final, 25%. It will be cumulative, but weighted toward the second half.

There's going to be a lot of reading and writing assignments, approximately two papers to read per week. And for, usually, one of those papers per week, you will have a very short written assignment in which, usually, I ask a few simple questions and maybe one paragraph-level think question. The essence of these tasks is not the written assignment itself.

The essence of the task is to understand the paper. If you understood the paper as you read it, then you should be able to answer those questions pretty straightforwardly. And let me just say that understanding a scientific paper is not trivial. When I write a scientific paper, right in my area, where I have all of the background, it takes me hours-- hours.

It may be five pages. It still takes me hours. It's just how it is. So when I assign a paper and you say, oh, it's only three pages, I could do that in 20 minutes. Oh, no, you can't. No, you can't. And that's part of what I want you to learn how to do, is how to really read and understand the scientific paper. Allocate the time it takes to really get it.

That's a big part of the agenda in this task. All of the stuff-- the assignments and the submission of the assignments-- will all happen on Stellar. Your first written response to a paper is due February 12 at 6:00 PM on Stellar. But there are other readings that are assigned before that. A note about the schedule. I struggled a lot trying to both have the assignments happen when you had already learned enough in lectures to know how to do it, but have it close enough to the topic at hand so it didn't seem, like, no longer relevant. It's hard to do both of those things.

So the compromise is, all of the assignments are due at 6:00 PM the night before the class in which they're assigned. If you see that it's assigned on the 13th-- if it's listed on the lecture for the 13th, check carefully. It's probably due the night of the-- I'm getting this wrong-- the 12th. The night before. And that's so that we and the TAs can look at it, figure out what you understood, what you didn't, and how to incorporate and explain whatever you didn't get in the next lecture. All right.

Quizzes. I haven't done this before. New thing I'm going to try. There are going to be about eight of these. They're going to be very brief. They're going to happen at the end of class, in class. And you will do them on your computer or your iPhone using Google Forms. If anybody doesn't have a computer or an iPhone they can bring to class the days of those quizzes, let us know after class and we'll come up with a solution.

And the idea of these is not to fish out an obscure fact that was in one of the reading assignments and ding you on it. I'm not interested in that. The goal of this is just to keep you up to date, keep you doing the readings, keep you up with the material. And if you basically are understanding what you're reading and understanding the lecture material-- maybe you glance at it briefly before-- you should do fine on the quizzes. They're just kind of reality checks for us to know what people are getting and not. First quiz is February 20, blah, blah.

There is one longer written assignment that is not due with the usual schedule, with all of the other things, to do near the end. And in that one, you will actually design an experiment in a particular area. And that will be-- I don't know yet-- three to five pages, something like that. We'll give you more details on exactly how you want to organize this. And it will be very specific-- like, state your exact hypothesis, state your exact experimental design, et cetera. And you'll get practice with those things in advance.

Those are the grading and requirements. And this is the-- you have this all in the syllabus in front of you. This is the lineup of topics. But very briefly, let me try to give you the arc of the class. So this is the introduction. Next time, we're going to do just a teeny bit of neuroanatomy. There will be a teeny bit of overlap with 900 and 901 there. I'm going to whip through it in very superficial form.

I'm doing that largely because on the following class, we have an amazing privilege, which is that one of the greatest neuroscientists alive today, Ann Graybiel's, will be doing an actual brain dissection, right here in this class, right in front of you. It's going to be awesome. I can't wait. It's an incredible privilege. It will be a real human brain, and you guys will be-- Ann will be here with all her apparatus, and you guys will be clustered around.

And if it's this many, god help us, but we'll figure out how to make it work. I may-- let me just say, if there are listeners in here, I may have to tell listeners they can't come, because very sensitive about not having too many people. Stay tuned on that. I haven't quite decided yet. It depends how many people are taking the class.

But it's going to be amazing. And I want to remind you of just some basics so you're not asking her, like, what is the hippocampus? I should all know that, but we'll just do bare basics. And then we'll have the dissection. That will be great.

And also, another thing to say is, I mentioned that the subcortical regions are going to get short shrift in this class. That's true. But a lot of what you see in the dissection is the subcortical stuff. Cortex is great but, it kind of all looks the same. You kind of can't say, oh, that's this region. That's the other region. Well, you can, but it doesn't look any different from any other region.

That's where the subcortical stuff will happen. Then I'm going to do a couple of lectures that focus on high-level vision, perceiving motion, and color, and shape, and faces, and scenes, and bodies, and stuff like that. And we will use those both to teach you that content, and also to teach you vast array of methods in this field.

We will then have a lecture on the kind of debates about the organization of visual cortex in humans. I have a particular view. I'm very fond of views that some patches of cortex are very, very functionally specific. Not everyone believes that. So I have assigned readings of people who have different views, and we will consider that. I will try to expose you to the alternate views and tell you why I'm teaching-- why I still believe mine, but why other smart people believe different things.

We will then move up the system from perception, and we will spend two meetings talking about scene perception and navigation. You got a hint about what an interesting area this is from the story of Bob. We'll consider more what we've learned from studies of patients with brain damage, from functional MRI, from physiology in animals, from cognitive science, from the whole glorious menagerie of methods to understand navigation. It's a really fascinating area.

In the two lectures after that, we'll consider development. How do you wire up a brain? How much is present at birth? What is specified in the genes? What is learned? And a lot of that will focus on the navigation system and the face system, simply because that's where there's a lot known. We'll consider some other things, but those are two areas where there's super exciting work from just the last three or four years. That's what we'll focus on there.

I'm then going to do a lecture on brains in blind people. How are they different? How are they the same? What does that tell us? And then you have the midterm. Then we're going to move on and consider number. How do you like instantly know that that's three fingers and that's two without having to do anything all that complicated? And if I had 25 fingers and held them up, you would immediately get a sense that it was about 25. You might not know if it was 22 or 28, but you would know it was about 25.

And there are particular brain regions that compute that for you. And we will consider all of that. And there's a very rich array of information from studies of infant cognition, from animal behavior, from brain imaging, from brain damage, from single-unit physiology, and from computation, all of which inform our understanding of number. Those are my favorite lectures, where we can take one domain of cognition and inform it with all of the methods. And numbers are a really great example.

Then we'll talk a little bit about-- one of my TAS said, call it neuroeconomics. That will sound good. But actually, what I'm going to try to do is sort of neuroeconomics. But it will be about pleasure, and pain, and reward, and how we think about those things. And then that's down to April 3. Just as a side note, all of these things are things that are pretty similar between humans and-- at least primates. And some of them are shared with rodents. And most of the things after that are things that are really uniquely human.

We'll be really moving away, with less available animal literature to inform the stuff we're looking at, because animals can't do these things. And so necessarily far from the details of individual neurons and circuits, but there's still lots cool that can be said about how you understand speech, how you appreciate music.

There will be a guest lecture, just for fun, on brain-machine interface by Michael Cohen, who's working in my lab now, and who has a great lecture on this topic. Then we'll spend a couple of lectures on language-- how you understand and produce language, and what the relevant brain regions are, what we know about it from cognition, and lots of other methods-- and what the relationship is between language and thought.

Then we'll think about how we think about other people. This is called theory of mind-- how I can look out at this lecture and try to evaluate from your facial expression. Are they bored, sleepy, overworked, fascinated, excited? All of this kind of stuff that all of us do moment-to-moment in any conversation, and that, yes, lecturers are doing all of the time, even if I know that you guys have too much work, and that's why you're sleepy, and I shouldn't take it personally. I'm still noticing.

Anyway, then we'll go on and consider brain networks. Of course, brain function doesn't happen in just a single region, even if we spend a lot of time studying individual regions. There's considerable work trying to figure out which sets of regions work together, and how could we discover that, and what are those broader networks of brain regions? And then on May 6, you will have turned in your longer written assignment designing your own experiment. And then on May 6, we will work together in groups to refine those experiments and really hash out the details so you actually know how to design an experiment.

And then we will have this guest lecture from my postdoc, Katherina Dobbs, on deep nets and what they can tell us about cognition and brains. And then we'll talk about attention and awareness. And then I'm not totally sure what we're going do in the last class, but what I'm voting for is that the amazing TAs each give a short talk on the cool stuff they're doing. But that's under discussion.

OK, that's the arc of the class. Questions? All clear? Great. Well, if I have five more minutes, maybe I'll do one other little thing.

Let me try this. You asked-- I'm going to try to learn everybody's names, but I'm not doing that yet, because some of you might not show up and I will have wasted a whole piece of my brain encoding it. I'm just kidding. But anyway, I remember that you asked, are you going to read current papers? Yes, it is-- and you're right. It's daunting. But let me just say a little bit about how to read papers. This is not a stats course, and we haven't prerequisited stats. Neither is it a course on the physics of MRI.

There will be parts of every MRI paper that have a lot of gobbledygook. We scanned with this scanning procedure. We used this kind of scanner and this kind of blah, blah, blah. Lots of gobbledygook. You guys don't need to worry about that. About the stats, it's kind of a judgment call.

Everyone in here should have an idea of what a P level means, and I hope, a sense of what a T-test is and an ANOVA. If you don't, I should probably tell you that offline, because that's pretty basic. And what a correlation is. Beyond that, just use your intuitions about those things. And this is not of course about understanding the details of the stats in each experiment. There just isn't room to cover all that in the substance of the studies, as well.

When you read a paper-- for example, here's a paper-- a very old paper. You come across this, and it was like, OK, here are all these words. And it goes on for 20 pages. And how do you even dig in? Well, the way to dig in is to start by saying, what question is being asked in this paper? If the paper is well written, you'll be able to find that in the abstract. Blah, blah, blah, to study the effect of face inversion on the human fusiform face area.

We'll talk about that more later. But if you fish through the abstract, you should be able to find what question is being asked. And it's the first thing you should figure out about a paper. You don't necessarily read a paper start to-- beginning through the end. I think it's better to start with this list of questions in your head and look for the answers to those questions.

Second question. What did they find? If the abstract is well written, you can find that in the abstract as well. Signal intensity from the fusiform face area was reduced when grayscale faces were presented upside down. Kind of boring, but there it is. That's the finding of this paper.

What is the interpretation? In other words, who cares? Why-- who cares about this? If you look in here, in the abstract, FFA responds to faces per se rather than to the low-level features present in faces. We'll talk more about what that means. You guys have an assignment about that-- probably, several assignments about that kind of question.

Next question you want to ask yourself is, what is the design of this experiment? Often, for this, you have to go beyond the abstract. And I should say, for even these earlier questions, sometimes you won't find them in the abstract. That just means the abstract is not well written. But that exists. To get the design-- like, what exactly did they do? Usually, you have to fit in what exactly was done, and how were the data analyzed? You need to fish farther. You need to fish around other parts of the paper.

And of course, all of those questions-- I just said, what question-- I circled this part. But there are many levels to one question. You can get more on, why is that inverted question important? You look through, usually, in the introduction to the paper. Does the FFA respond to faces per se, or to a confounding visual feature which tends to be present in faces?

Second, is it true that inverted faces cannot engage face-specific mechanisms? Blah, blah, blah. That gives you a little more background on what the question is. There are different levels of depth. These are all things you want to be looking for when you read a paper.

What exactly was done? We measured MRI responses in the FFA to upright and inverted faces. I don't expect you to understand all of this. These are just giving you, schematically, how you proceed when you're reading a paper. More on the interpretation, or who cares?

This result would show that face-specific mechanisms are engaged only or predominantly by upright faces, blah, blah, blah. You can fish through for those things. The point is to have those questions in your head when you read a paper. It's much more easy and engaging to read something if you have an agenda when you read it. Your agenda, in reading scientific papers, is to answer those questions for yourself.

More stuff. What was the design and logic? Often, that's deep in the methods. You have to fish around and find it. There will be some set of conditions and designs. We'll talk more about all this kind of stuff. What exactly was done, blah, blah, more details.

And this is an example of the kind of gobbledygook that you can ignore. Subjects were scanned on a 1 and 1/2 T scanner. And there are all these-- here's an example of said gobbledygook. You can ignore this, in this class.

Every method will have different kinds of gobbledygook. This is MRI gobbledygook. You can ignore it. It matters a lot, but not here. What else? How are the data analyzed? If you look in the-- sometimes, there's a data analysis section, or a results section, or a methods section, that will tell you. You can find that, figure it out. What was the finding? Here's more on the finding. Again, you just fish through for these things.

The point is just, when you're reading a paper, it's not necessarily-- what I do is, I read the title, I read the abstract. And then I start answering those questions for myself. And sometimes, at that point, I'm skipping to figures. I'm skipping to methods. Any of that is fine. Don't feel like you need to understand each word, especially deep in the methods.

I don't know. Was that helpful at all? We'll try it, and you guys will give me feedback, and if it works, great. And if not, we'll do more on how to read papers. All right, it's 12:25. See you on Monday.