JEREMY WOLFE: OK. Are there any of those forms still out there? Now that we've done the really exciting part, let's try saying something about what this course is about and why you bothered to try to get yourself lotteried in. Many, many-- whoop. Many, many-- any other forms? Last chance.

Many, many, many, many MIT courses are of the form-- when you go to the first class, you get the syllabus. You look at the list of topics. You say, I don't know anything about these topics. But I sure hope that by the end of the course I know something about these topics.

An intro psych class is different from that because if you take a look at the list of topics in the course, which you can find, by the way, on the back page of the syllabus-- but you don't need to go looking for it right now-- you will discover memory, learning, cognition, emotion, personality, intelligence, a whole set of topics that you already have some notion about. They're terms that you use in everyday speech that you can converse about perfectly happily. The job of this course is to dig behind what you would know in what's known as folk psychology.

Folk psychology is a term coined in the 19th century to refer to the psychology that folk know as opposed to the psychology that one would learn in the academy like you are here. What we used to say-- actually, when the term was defined for me in graduate school, I think, somebody said folk psychology, that's the psychology that your grandmother knows. That doesn't work so well because your grandmother may well have a PhD in psychology these days.

Folk psychology is what the psychology that you would know without bothering to take a course like that, the psychology you just pick up on the street. This course is designed to go beyond that. Well, let me dig up an example. Let me close the door. Uh.

As an example, I could assert-- oh, let's see. I need a person. Well, this is why one sits in the front row. You're a person. That's very good. What's your name?

AUDIENCE: Hi. I'm Mark.

JEREMY WOLFE: You're Mark. OK. Who is that woman sitting next to you?

AUDIENCE: Lara.

JEREMY WOLFE: This is Laura, OK.

AUDIENCE: Lara.

JEREMY WOLFE: I could say that Mark loves Laura. It may or may not be true. For all I know, Mark-- it is true.

[LAUGHTER]

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Well, this is going to be a more interesting example than sometimes. But all right, if I assert that Mark loves Laura without much knowledge of either Mark or Laura here, you had-- this it's not a sentence that's hard for you to understand. But what is it that we're actually talking about?

All right, what's love? I didn't check. I was going to check this morning, but I didn't check. I think that probably the line you would get in a dictionary would assert that love is an emotion. And then it would go on to describe what kind of an emotion it. But it's an odd emotion if it is an emotion.

If you think about other emotions that are pretty straightforward, let's say sadness or happiness to give two straightforward examples, you know what sadness and happiness feel like. They have a distinctive feeling to them. There is a distinctive feeling to being in love. There's no doubt that there's a feeling aspect. It's actually an interesting question why we use the same word feeling to talk about feeling in love and feeling the table.

What is it? What's the commonality there? But the feeling of being in love is not is not simple in the same way that the feeling of sadness or the feeling of happiness is.

For instance, you can be sad or happy in love. You can be in love, and the experience of that could be either sad or happy. The experience of being sad cannot be either sad or-- sad is sad. It's, in some sense, an atomic sensation in a way that love does not appear to be.

You can wake up in the morning feeling sad, disembodied sadness or disembodied happiness. You can't really-- it's hard to imagine what it would be to wake up and say I feel love. It's not clear that that makes sort of a quasi religious sense that you could get to it. I feel love for the whole universe or something. That's lovely.

[LAUGHTER]

You see the distinction. So maybe it's not an emotion in the simple sense that sadness or happiness is. Maybe it's a way of thinking about your current state. I feel happy, and my heart is pounding. And I'm sitting next to-- oh God, I've forgotten her name already-- Lara.

AUDIENCE: Lara.

JEREMY WOLFE: Lara, no "u," L-A-R-A, Lara, and Mark. They both have two-- they have two letters in common. That's the basis for this relationship.

[LAUGHS]

Anyway, where was I? You're not going to wake up feeling a disembodied sense of love. Maybe you're thinking-- maybe what it is is a thought about the state that you are currently in. So maybe it's a cognition rather than an emotion, but if it's a cognition, it's a different kind of cognition from what you might think of as an atomic cognition, because it has this aspect of feeling to it that other cognitions don't.

Like what's the capital of Equatorial Guinea? I have no idea, but it's a thought that I can think about that fact. It doesn't carry with it any deep feeling unless it turns out to be a question on the final exam. But you can have thoughts that aren't colored in this emotional kind of a way.

So it's not a simple cognition. It might be more useful to call it a motivation than to call it an emotion. Motivations are like emotions in the sense of having this affective-- affect is the jargony term for feeling-- this affective component to it, but the sorts of things that get talked about as motivations are things like thirst.

So it being warm, I'm thirsty. That's a faintly unpleasant state, and a motivation is something that motivates me to do something to change my state. And you know hunger, another good example.

So what kind of motivation would love be? Love might be a motivation. That it's directed to an object of some sort and, it's-- [COUGHS] I knew I shouldn't have caught that cold from that third grader in my house. That's better. It's a motivation that, if love is a motivation, what it's motivating you to do is to perhaps get closer to possess the object of desire.

Now Mark and Lara are busy sitting there saying, oh boy, that doesn't sound so good. But love, of course, can be used not just in the Mark and Lara sense, but you can love your laptop or something like that and have--

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: We won't go there, Mark. It's OK. But that does lead you-- so those are two clearly of different senses of love, and/or at least your chortling suggests that you think of them in different senses. You might ask, what love is for if thirst is a motivation? It's because you need liquid in order to be alive. And you don't drink stuff, you're going to be dead.

What's love? Well, the usual answers to that these days-- in psychology would come out of the chunk of psychology that's called evolutionary psychology that sees these core motivations, if you like as, things that evolved over the history of the species and of life in general to serve useful purposes for the organism.

In this case, love is presumably in service of that great evolutionary good, which is to get your genes into the next generation. That your goal, if you're a thoroughgoing evolutionary psychologist, your goal in life basically is to get genes into the next generation, to perpetuate your genes. And the sex and reproduction thing is a good way to do that.

It's not the only way to do that. It's important to note. How many of you are only children? Well, actually let's go the other way. How many of you have siblings? One way for you to gain this evolutionary immortality, of getting your genes into the next generation is to be a really good aunt or uncle.

You protect and preserve that little niece or nephew of yours, and they're carrying a bundle of your genes too. So it's not that having and raising children is the only evolutionary root to the future, but it is a good one. And the love business would seem to be related to that, but it's not necessary.

If you think about it-- well, all right, spiders, let's think of spiders. Spiders, the reproduction thing works fine with spiders. It's not clear how much love and romance there is involved here. It's not clear for a couple of reasons. One of them is it's very unclear what's going on in the mind of an animal in general. You just don't have any access, or at least you have only the barest of inferential access.

In fact, I don't have any access to what's going on inside your mind. It is an assumption on my part that you guys have mental lives like mine. You could be what the philosophers-- in philosopher jargon, you could all be zombies, which if you're doing philosophy means you're things that look human, behave like they're human but aren't human because there's nothing happening in there.

You could be cunningly designed machines. I don't know that, but it's a useful assumption that your mental life and my mental life is similar. It is not a terribly useful assumption that my mental life and the spiders mental life are similar.

And in any case, if you look at spider behavior, it doesn't look much like romantic love. I mean, the guy spends most of his time trying to avoid being killed by the female spider, who is typically much bigger. He does a variety of courtship sorts-- we'll talk about this later in the term-- but I cannot resist there are variety of spider species where the spider does engage in a lot of courtship behavior.

The male spider, he brings her presents, like he brings her a dead fly. The reason he brings her a dead fly is if she's busy chowing down on the dead fly, she doesn't bite his little head off, and it's not desperately romantic. But in any case, it does work perfectly well for reproduction.

It suggests that there might be-- even when you're talking about love between potential mates that there might be a distinction to be made between love and, well, lust or some sex drive or something like that. There is evidence at a neurochemical level that these are distinct.

The chemical pathways in the brain that are involved in romantic love seem to be those that are also involved in parent-child bonds of attachment. They involve chemicals like-- well, your brain generates opioid chemicals, which are like opium, which is why opium is a powerful drug when taken externally or taken from the outside. But in any case, the bonds of love involve those chemicals.

The bonds of lust involve things like testosterone and other androgens and estrogens that they may have talked about at endless length in high school biology or something of that. But there's evidence that these are separate. How did they come to together?

Well, evolutionary psychologists suggest that the link might be that if you bring love to bear, this romantic bonding, this attachment to bear, then you've got pairs of people who stick around, stick to each other in ways that are good for the begetting and raising of children. And that maybe this bonding between parent and child got co-opted into being romantic love between potential mates.

Another way of putting it would be to say, well, maybe romantic love exists because straight out, just regular old lust is not compatible with civilization. If people are just simply acting on their evolutionarily based desire to mate, it's hard to run a civilization. It's hard to run a university, for instance, because people are busy.

So what you've got to do is, if you're going to run a civilization, you have to find some way to channel that sex drive into other activities so that the rest of civilization can keep going. Now, if you start talking in those terms, you're talking in terms that you will see are very much like what Freud said.

Freud argued that things like romantic love are necessary in order to have a civilization and the absence that-- if you're a spider, you don't need romantic love, but you're also not going to have-- spider civilization is somewhat more limited.

Now how does Lara know that Mark loves her? Well, he said so. Well, that's cool. I can say so too. I love you. I might even mean it in this generic I love all of humanity kind of sense, but it's obviously different.

Now, there are various other ways that he can be indicating the fact that he is in love with her, but she's got to figure this out. Is he really in love with me or is he just kind of-- actually, he's got to figure it out too. Am I really in love with her? Her act of perception would be perfectly possible for her to be wrong, right? She looks at him, she thinks, he's in love with me. And he's thinking, I'm not in love with her. I'm just faking you know. Could be.

Now, could it go the other way. Could he be thinking, I'm in love with her, and it not be true? Is that logically possible? And who could tell you that it wasn't true? Your mother? You don't really love her. Well, you probably wouldn't buy that anymore, but you would have once.

If you plot-- let's see. How are we going to do this? All right. Well, this is age. I know this axis is age. So if you plot the percentage of people who say-- you ask kids, who knows your inner emotions the best? You? Or you can give it an open-ended question, but the real categories are you or mom and dad.

It turns out-- so if this is you and this is mom and dad, that function-- crosses the 50% point at the surprisingly late age of early adolescence. Before that, the majority of kids will assert that mom and dad know their emotions better than they themselves know it. How could that be the case? Well, it's hard to get yourself back into that mental state at this point.

It gets easier again once you have kids of your own because you're looking at your kid, and you're like your four-year-old kid, and your kid is doing. And you say got to go to the bathroom? No, I've got to go to the bathroom. You've got to go to the bathroom? I don't have to go to the bathroom. You sure you don't have to go to the bathroom? No. No. OK. I guess you don't have to go to the bathroom. Let's all get in the car. I got to go to the bathroom.

And so if the kid is a little self-reflective, he thinks, hey, wait a minute. First of all, not only do I have to go to the bathroom, but you know, mom and dad, they knew that before I did. That's cool. That's also a little scary because I thought a whole bunch of other things. I wonder if they know those things too. Eventually, you figure out, no, they didn't know that stuff, which is just as well for all concerned.

But returning to the love example, the point is that you need to perform an act of perception to decide that somebody else loves you, and you need to do an act of self perception to decide that you love somebody else.

You might also ask yourself at that point, well, what is it that you love? Physical attributes? That's considered crass. And even worse would be to say, I love her for her money and possessions. That sounds terrible. But if you ask yourself, what are you watching on TV? There's a continuous pairing of love, sex, and cars, soda, anything.

Well, I can't think of any particular ads at the moment because I don't watch enough TV. I'll ask my kids if there are any good sex and soda ads on at the moment, but there certainly have been. In any case, typically, we say things like, I love her for her mind or something like that. Now, you could love your laptop for its mind too. It doesn't seem to be quite the same thing.

Now, all right, so the question of what it is that you might love. Where is that love in you? Does that question make any sense? Well, there's a traditional answer to that. If you ask where love lives, the conventional out there in several hundred years ago, probably would be simpler kind of answer would be?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Heart. Well, yeah, liver is good too, but that's only if you're-- the cool white virgin snows upon my heart have abated the ardor of my liver, says the Prince guy in Shakespeare's *Tempest.* There's this notion, very much a folk psychological notion that emotions are resident in the viscera, and that makes a degree of sense because when you see the object of your heart's desire, you know it's your heart's desire because your heart goes thump, thump, thump.

Now, you think that if love is localized, if there is some chunk of you that is your love for whoever this significant other might be, where is that likely to be? Brain, somebody muttered up there. Yeah, it's probably in your brain. You can imagine why that was a hard notion to come by because you look at the object of your desire, and you don't suddenly say, oh my head.

And you probably won't be sending brain-shaped chocolates to anybody at Valentine's Day either, but it is an interesting question to ask whether or not, all right, brain maybe, is it localized enough that there's some little piece of brain that we could go to and say Mark's love for Lara is there? And if we went in and pulled that board out of his out of his computer, that he'd know who Lara was. And he'd know everything else, but he just wouldn't be in love anymore.

Is that level of localization plausible? Is the love normal? Mark loves Lara for her mind, is that normal? Suppose he loved her for her foot. Would that be normal? What's the difference? Why would one be-- and if it wasn't normal, who gets to decide that it's normal? Do we as a community get to decide? Does the family get to decide? Is there some objective way to decide whether something is or is not normal?

And if it's not normal, what do we get to do about it? Do we get to-- if it's not normal, would drugs fix it? Would surgery fix it? Would some therapy fix it? Well, you look, you could see what's going on here. From a simple statement like Mark loves Lara, we can get to essentially any of the topics that will show up in a course like this, and you could have done-- we wouldn't have had to use love as the particular example.

Behind any of these things that we use perfectly comfortably in everyday life is a large set of very interesting questions, only a very few of which, of course I can manage to address in introductory level course. But the goal here would be to give you some sort of overview of the sorts of topics and the sorts of answers that modern academic psychology has come up with.

The way that we do that is through lectures, through recitations, which should not be treated as optional. We expect you to be there. They're not just like reviews for the exam or they're not problem sets in an introductory psych class the way they would be in chemistry or something. You're expected to be there. They're an integral part of the course. And there's the textbook. It's a good idea to look at it.

I won't go into a lot more detail about the mechanics of the course. The syllabus will tell you most of what you want to know, and it's a really good idea to actually take a look at the syllabus and to take a look at the writing assignments because they have due dates attached to them and things like that.

I will answer any blazingly mechanical questions about the course if they have occurred to anybody at the moment. Otherwise, I will plunge into the brain in a moment after satisfying my thirst motivation yet more.

Let me say that the ideological grounding of this course is that the course, like academic psychology, generally is materialist in its ideology. What does that mean? What that means is that the mind is what the brain does. That if you have thoughts, if you have feelings, if you have memories, that these things arise out of the brain.

This is not to say they are necessarily-- that if we wanted to teach a straight neuroscience course, we just teach you about the brain. But it is to say that it is in distinction to another old philosophical position, which is dualism, which says that the mind is somehow an immaterial something that is separate from the brain. It interacts with you, it interacts with your body, but is separate.

The reason for talking about the brain for this lecture and the chunk of the next lecture is this notion that the mind is what the brain does. And well, if we want to find out what the brain does, let's see. We could make a little bit of a list here. You go up. Oh, we got to get rid of a little more of whatever that was.

So do I have a copy of the handout here somewhere? Yes. So I can ask because it just has four broad classes of methods on the handout without describing them. How might we go about finding out what the brain does? Oh, this reminds me to say anytime during the course of the term, if you've got a question, comment, or whatever, feel free to raise your hand, and I will attempt to answer it.

If I think we're being hopelessly diverted from where I think we need to get in the lecture, I may have to cut off discussion, but I'm more than happy to have the opportunity. So just because it's a great big lecture, don't feel that you just got to sit there and not do anything interactive like raise your hand.

Of course, if you raise your hand, you might end up exposing the details of your romantic engagements with the person sitting next to you, but that's a risk you'll have to take. Anyway, if you wanted to find out how the brain worked, what the brain did, how can we go about doing that? Anybody got-- yes.

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: You could cut the brain open and look at it. OK. That's option 0 on my list of 1 to 4. No, it's not because it's trivial in any sense, but I'm looking for techniques that get more at the function than at the structure. But there is a certain amount that you do learn from just looking at the structure.

In fact, Descartes, one of the founders of the dualist view, looked at the anatomy of the brain, thought, if the immaterial mind and soul are interacting with the brain, well, the brain is a double structure. It's got these two symmetrical hemispheres. That interaction between the immaterial soul and the body must be at one point.

He looked at the anatomy, saw the pineal gland, which is a piece of brain lying on the midline, and thought, because there's only one of those, that must be the point. So you can make inferences from structure alone. That particular inference is wrong, but you could do it. Yes, the person in front there. Yes, you.

AUDIENCE: MRI.

JEREMY WOLFE: MRI, we will make that into the larger category of imaging techniques. For psych purposes, the most dramatic version of this is so-called fMRI for functional magnetic resonance imaging. This is the new entry on the list really. Remarkable breakthrough in the time that I've been teaching this course is the ability to now look at the structure and some aspects of the function of the brain in intact, alive, awake human beings. You simply couldn't do that anymore, and that's a remarkable-- well, it's a remarkable boon for psychology and a huge advance for medicine.

So for instance, if you had a brain tumor, there are symptoms of having a brain tumor, but the only way to find out if you actually had a tumor-- because you'd want to take this tumor out if you could-- the only way to find out a generation ago was to do exploratory surgery and open up the brain and see where the thing was. Now you'd be in an MR scanner by the end of the day, and we'd know.

So yes, very useful technique. You're going to offer me another one?

AUDIENCE: Yeah. You can study people that have had like brain deformities and have been in accidents and things like that.

JEREMY WOLFE: OK, so we'll put this under the category of lesions, brain damage. If this is the newest that-- this is probably the oldest of the basic techniques. If you damage brains in the same way, you end up getting symptoms that are similar across people and even across species, in many cases.

And that is a tip-off that, first of all, that the brain has something to do with mental life and that specific bits of brain have specific things to do with specific aspects of mental life. The real advances in this sort of research and this sort of understanding of the brain came, oh, I'd guess mid to late 19th century when-- with advances both in medicine and in, I suppose, what you could call military technology.

In earlier times, if you got a penetrating wound to the brain, odds were that you were simply going to be dead. But by the mid to late 19th century, people were surviving with penetrating brain injuries. And it became clear-- and bullets could be leaving comparatively small lesions. And so it became increasingly clear that different bits of brain damage did different things.

Let me find myself a place to draw another picture here. I need-- I need a brain. So here we go. One quick [WOOSH]. This is your brain, just to orient things here.

[LAUGHTER]

OK, so-- woo. Front, back, bottom, top. If I'm facing that way, this would be looking at the outside surface of the left hemisphere there, right? You've got two cerebral hemispheres about this size stuck inside your head.

This is-- the brain's got lots of wrinkles. There are a couple of large ones that I'm drawing here for my purposes because the cerebral hemispheres are conventionally divided up into four lobes, the terms for which are written on the handout, so I can just give you the initials rather than writing out the whole thing.

Conveniently, the frontal lobe is at the front. After that, you just simply have to learn them. Temporal lobe down at the bottom, occipital lobe at the back, and the parietal lobe on the other side of this big central sulcus that divides the frontal from the parietal lobe.

What was found-- I think originally in the Franco-Prussian war, if memory serves, 1870s-- was that if you got-- whoops-- lesions to the back of the brain here, to the cortex-- so the wrinkled outside surface is known as cortex. That's from the Latin word for cork, which is what anatomists thought it looked like.

If you get lesions back here, you get problems with your vision very specifically. And if you get-- if you got a great big lesion that took out the entire occipital cortex on both sides, you'd be functionally blind. But if you got a small lesion, let's say in the left hemisphere, you would have a small region of blindness, and it would always be on the right side of the visual world.

And that's relative to where you're actually looking, fixating at the moment. So if I fixate on this guy there, who I'm now staring at, then if I had a lesion in my left hemisphere, some region out here, I would be blind. If the lesion was in my right hemisphere, the blind region would be on the opposite side, on the left. That's the sort of thing that you could discover from lesion studies.

And so lesions happen when you get brain injury from, say, a bullet. Lesions happen from strokes. One of the great advantages to imaging technologies is that in the 1870s, or even until quite recently, the only way you knew about where the lesion exactly was was if the patient died and came to autopsy. You could look at the brain and look what was damaged. Now you can look at that brain in an intact individual and see where the damage might be.

So damage to the brain can tell you something about-- it's got the drawback that you're trying to infer normal function from an abnormal brain at that point. And that's not perfectly straightforward. But it does provide-- and is perhaps the oldest technique for providing lots of information. Yes, you're about to give me another method?

AUDIENCE: Behavior?

JEREMY WOLFE: OK, behavior is item-- well, if that's zero, then behavior is going to be 5. And we'll spend an awful lot of the course talking about behavioral measures. But in behavior-- without going in and doing something with the tissue of the brain, you're essentially treating the brain as a black box at that point. It may tell you something about the brain in connection with the rest of this, but we're looking for techniques that are specifically about studying brain itself. Yes.

AUDIENCE: Wake surgery? You know, like some experiments. Wake surgery.

JEREMY WOLFE: Wake surgery.

AUDIENCE: Yes. [INAUDIBLE].

JEREMY WOLFE: I don't know. This sounds cool.

AUDIENCE: To identify.

JEREMY WOLFE: Yeah, yeah, yeah. Keep going. I'm-- what did you have in--

AUDIENCE: They pretty much experience [? stimulating ?] [INAUDIBLE]

JEREMY WOLFE: What's the surgery part?

AUDIENCE: They--

JEREMY WOLFE: I can feel it. And I'm just trying to see if there's a 6 here that I'm just not thinking of that would be cool. Otherwise, I can sort of--

AUDIENCE: [INAUDIBLE] experimentation [INAUDIBLE]

JEREMY WOLFE: Oh yeah, actually that's one I didn't put in, typically, which is that you can go and start infusing stuff into-- chemicals into the brain and changing behavior. Do I want to say anything more about that at the moment?

AUDIENCE: [INAUDIBLE] stimulation.

JEREMY WOLFE: Ah, good. I'll use that one. Thank you. We'll call this stimulation in general. Stimulation. You can go in and stimulate brain. I was going to do that and segue from the chemical stimulation to electrical stimulation, but you got there for me.

You can go in and stimulate the brain electrically in rats, but you can also do this in humans. In fact, so back in the 1950s, Wilder Penfield, psychologist, was working with some neurosurgeons up in Montreal. And what they were doing was-- they were doing neurosurgery on patients with intractable epilepsy.

Epilepsy is an electrical storm in the brain, basically, and often is started by a piece of abnormal or damaged tissue that acts as a generator. And then what happens is there's sort of an abnormal electrical activity spreads from that point of generation across the brain, or across some chunk of the brain, and causes a seizure, a lapse of awareness, the symptoms that you get in epilepsy.

Often this is controllable by drugs, but in some cases it's not. And one of the treatments that can be tried is to go in and try to lesion this little chunk of brain. If you take out the generator, you can often reduce the severity or eliminate the seizures. But if you're going to take brain tissue out, you've got to be really careful.

Because-- well, actually, where I put this is a pretty good example. We knew from lesion studies-- going back, again, into the 19th century-- that areas around here were-- that go by names like Broca and Wernicke's area, which are the names of 19th century neurologists, actually-- vitally important in the production and understanding of language.

If you are right-handed, those areas exist in the left hemisphere of the brain. So this is a left hemisphere of the brain. That'll work fine. And if they're damaged by stroke, you will have trouble with understanding language or producing language or both. Depends on the exact nature of the stroke. But very-- very bad lesions to have.

So if you were to discover that the epileptogenic focus, the piece of bad tissue was sitting in there, you would say, look, I'm sorry. We don't want to do this surgery because while I could perhaps reduce the frequency of your seizures, it's going to mean that you've got real problems with language. And that trade-off is not worth it.

On the other hand, if the generator was here, say, look, I can reduce the frequency of your seizures and you'll have a relatively small area of blindness out in the right visual field somewhere, say, look, I'm not thrilled about being blind in some part of my visual field, but that trade-off is worth it. So you need to know where you are in the brain in order to do this sort of surgery.

And what Penfield did was to stimulate the brain of awake individuals in effect to ask, what's this bit of brain doing? Now, how can you do that? Doesn't that kind of hurt a lot? The answer is that they're under local anesthetic to get through the skull and the outer surface-- the membranes across the surface of the brain because in case you hadn't noticed, digging holes with a sharp stick in your skull really hurts.

But once you get to brain, there are no pain receptors in the brain itself. There's nothing-- once you've got the brain exposed, you can do anything you want to the brain and the brain won't particularly complain. I don't suggest you try this, but you could. Now, why-- well, let's step back. Why have pain receptors at all? What's pain good for? Yeah. OK.

AUDIENCE: Well, pain receptors are very helpful if you, like, lean on a hot stove or something.

JEREMY WOLFE: Yeah, Yeah. Pain is there to keep you from hurting yourself. Yeah. If you don't have pain and your hand's on the hot stove, you say, oh, I'm cooking my hand. That's, you know, big deal. In fact, people who are-- there are rare cases of people who are congenitally insensitive to pain, and it's bad news. They end up injuring themselves.

That being the case, why not have pain receptors in your brain? Yeah?

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Yeah. By the time-- if you're sort of thinking evolutionary terms, by the time the bear is chewing on your brain--

[LAUGHTER]

--you might as well just kind of go with the experience because it's not going to matter much. So the advantage here is that you can go in and stimulate brain tissue, and it's not a bad-- it's a somewhat-- from the sound of it, somewhat uncanny experience. But it's not an unpleasant experience. And so, all right.

So what Penfield did, you know, stick a little electrode, say, here, and put a little electrical current there. And what the patient would report-- if it was here, this is to the parietal side of this big central sulcus-- what the patient would report is, I feel-- it feels like you're touching my foot. OK?

Move the electrode a little bit. Oh, now it feels like you're touching me in the middle of my back. You know, now it feels like you're touching my hand. No, no, that's the end of my nose. And what Penfield found was that the surface of the body was laid out across the surface of the brain. And the left hemisphere would actually be the surface of the right side of the body. Whoosht.

I don't know what that is. And it is feet up, head down, as I recall. But that chunk of brain, which is called somatosensory cortex-- the term is on the handout somewhere-- represents the sensations coming from the skin. Now, I haven't drawn a terribly realistic picture here. But the actual map is hugely distorted. Yes? Is something--

AUDIENCE: [? Computed. ?]

JEREMY WOLFE: OK.

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: I'll do that. Pay no attention to the man behind the curtain. Anyway, OK. So this map, known as the homunculus, for the little man in the head, the sensory homunculus, specifically, is massively distorted. Some chunks of your skin are heavily overrepresented in the brain. Some are heavily underrepresented. So what's overrepresented? Hands. And?

AUDIENCE: Face.

JEREMY WOLFE: Face. And on the face-- lips. Lips and tongue and things like that. So somewhere in Gleitman-- like in the chapter you'll read tonight, with luck, there's a picture people love making little models of the homunculus, right, so to project it back out into the world. And what would it look like if this was a one-for-one mapping? And you get this guy with huge lips and huge hands and a little tiny back.

And the way to get a feeling for this is to ask yourself, if you were trying to figure out what something felt like, how would you go about doing that? Well, you would go and explore it with your hands. A little kid less restrained than you would also probably put it in its mouth and feel it that way. What you wouldn't do is rub it against your back or something like that because it's the hands and the lips and stuff that have the very dense sensory skin receptors. And it's sparser on your back.

Now, you will also-- you can test the prudery of your introductory psych text by checking out whether the homunculus is anatomically correct. The genitalia are well represented in the sensory homunculus also. My recollection is that they are well represented in Gleitman. There are texts where it's kind of-- oh, actually there's one great version where the homunculus is wearing like a little towel.

[LAUGHTER]

I've seen that once. That was cute.

OK, so stimulate here, and the person feels like you're touching them on their skin. If you go around to the right hemisphere, they'd feel the stimulation down the left side of the body. Go to the other side of this, into the frontal lobe, and instead of saying, oh, I feel like you're touching my leg, the leg would twitch.

Basically this. Right, yes, left hemisphere, right leg. Or move a little further, the arm would twitch or just one muscle in the arm or something like that. Here you've got a motor homunculus laid out across motor cortex. And this chunk of the brain is important in the generation of voluntary movements.

Again, it's a distorted map. Hands very overrepresented. If you're a monkey, feet are very overrepresented. But you, who cannot hang upside down from a tree by your feet or your tail or whatever, and your feet are comparatively impoverished in their representation. Tongue and vocal apparatus, heavily overrepresented. So same story, sensory and motor.

Now, these days you don't even need to go and cut open the skull to do this sort of thing. Transcranial magnetic stimulation, or TMS for short, involves generating a large magnetic field close to the skull. As your physics background will tell you, that generates an electrical field. If you shape the magnetic field right, you can generate an electrical field in the brain tissue and basically produce the same brain stimulation that Penfield was producing in an open skull, with the same results.

Nancy Kanwisher, who's a professor in the department here, used to be up at Harvard, got on the front of the *Harvard Gazette* for teaching her intro class with a TMS stimulator in hand and said, you want to see where my motor cortex is? [SQUISHING SOUNDS].

[LAUGHTER]

See, no, I'm not going to do that. Sorry. The reason I'm not going to do that, by the way, is I'm a chicken. TMS is undoubtedly-- almost undoubtedly safe. Lots of people do it. But it sounds too much like things that I learned about when I was taking intro psych that were used to generate epileptic foci in, like, rats, you know. Let's stimulate-- boomp-boomp-boomp-boomp-- And now the rat's got epilepsy. I don't-- it doesn't seem to happen in TMS, but I'm a chicken when it comes to my brain. Yes.

Could I-- Yeah, it's--

[KNOCKING]

Well, we'll find out if I can spell homunculus. Paul, is it a U or an O? Ho-mun-- ho-- U. Ho-munc-- yes, it must be. Ho-munc-u-lus. One of the reasons for handouts, by the way, is so that when people ask me, can I please spell it, it's on the handout somewhere because the answer is, no, I can't.

So the homunculus, derived from the Latin for a little man in the head. And I apologize to the women. I was trying to figure out today what the little woman in the head would be. But my Latin has waned since I took it in college. Maybe it's the "femunculus." I'm not sure. But in any case, that's the homunculus.

So-- and the stimulation-- that's stimulation techniques. I'm shopping for one more useful technique here. Anybody care to offer me another technique for figuring out what's going on in the brain?

OK, well the case studies are typically these lesion studies, right? Somebody has something wrong with them, and we try to figure out what's wrong with them. That goes way back, by the way. The early efforts to figure out what bits of brain did come from the phrenologists, early 19th century phrenology.

If you know anything about phrenology, you learned it from the Cartoon Network because you watched Bugs Bunny beat Elmer Fudd over the head, right? And then the bumps showed up and you felt the bumps? Ehh. Looking at me like, what's he talking about? Or you know it because there's a wide-- any of these umpteen cartoons or sculptures where you have a head that's got little functions all over it. Right? Like this is-- yeah, yeah, OK. Good. Somebody's-- I'm not just making up weird stuff.

The phrenologists believed that the shape of the skull reflected the underlying shape of the brain, that bigger meant more of that particular function, which is rather like this. I mean, it's not a completely wacko assumption. And they then used a case study system to try to figure out what different parts of the brain did.

So if you wanted to know where criminality was in the brain, you'd go and find yourself some criminals and check where they got big chunks of their brain. And that's where those maps came from. It's a rather ad hoc-sounding kind of process now.

So amativeness, lust is typically located back here. The reason it's located back here is because Spurzheim, one of the founders of phrenology, had in his care a-- how did he describe it? I think she's described as a passionate widow. And every time he puts-- he, Spurzheim-- put his hand on the back of her neck, it became red and inflamed. And he therefore concluded that that's where lust lived. Eh.

It turns out, though, that if you read old phrenology texts, the original phrenology texts, they read not unlike introductory psych texts or introductory brain science texts, with a few unfortunate assumptions, like the notion that skull shape reflects underlying brain shape, which it does not very well. There was-- yes, pink person.

OK, well, that's-- so we'll put the looking at the cells part under the anatomy. My wife would hate this. My wife is a neuroanatomist. That's what she does for a living. She would want many categories for that all by itself. But yes, so you can go look at-- certainly as-- well, you can use this in a number of contexts. If you're going to go stimulate-- these days, if you're going to go stimulate brain cells, you might be doing it on a slice of brain in a dish to see how it's connected to the next one. And you would be looking at the individual cells under a microscope while you were doing that. Yes.

Oh, yeah. That's a-- genetics is another candidate for 5. But I will-- actually, if you take a look at-- that allows me to make a somewhat different point. On the handouts, the writing assignments that you get in this course this year will have, as their starting point, readings that live on the stellar website for the course. Or they particularly will if I ever give Mara the disk to put them up there. I'll have to remember that.

The one that's on for this lecture, if one wanted to write starting from this lecture, is actually a genetic study. Turns out that there are two flavors of vole out there, a little rodent-like animal. Some voles are promiscuous. Some voles are not promiscuous. They just hang out with one-- I guess Lady Vols, that's a basketball team, isn't it? Anyway-- I guess they're Vols, not voles.

Anyway, the claim of a new paper this year is that manipulation of a single gene is able to turn promiscuous voles into faithful voles. So in that sense, yes, absolutely. Genetics are a new tool for getting to this. It's not what I'm fishing for. I'll take one more bit of fishing expedition, and then I'll just-- All right. That's fine, too.

In vole land? Yes, it's the male voles who are promiscuous. Yeah. They're manipulating the sexual behavior of the male voles. The female voles don't have the big asymmetry-- the two species of voles don't have the big asymmetry in their behavior to start with, apparently. So yeah, I think it's a guy thing. More on that later in the term. Yes.

Yeah. Reading brain signals. We'll call that recording in some fashion or other. If you can stick an electrode into the brain and stimulate, you can also stick an electrode into the brain and record from brain tissue and ask what a particular cell or bunch of cells are doing. You can do this at a large-scale level in walking-around human beings or animals by putting electrodes on the skull.

You can read massed activities of large numbers of neurons off the surface of the skull. And that's a so-called electroencephalogram, EEG. And that's very useful, for instance, in telling the difference between different wake and sleep states.

If you are deeply asleep, the sort of sleep that when the alarm clock goes off, you're bu-u-u-h, you know, where am I? If you look at the EEG, you find big, slow waves. All the cells are active. And then all the cells are quiet. And they're all firing together.

When you're looking at an awake individual, the waveform is much smaller amplitude and higher frequency because the calculus piece of your brain is currently napping, and the psychology piece is wide awake. And various bits are doing things out of synchrony with each other. So you can see that from massed recordings.

But if you now go and stick an electrode-- let's suppose we go and stick an electrode into-- well, let's take this same cell that-- stimulate here, and if the patient said, I feel that in my toe, if instead of stimulating, you record, you find out that that cell doesn't change its behavior at all over a huge range of possible things that the organism could be doing. But if you poke the toe, that cell says, shoop, here I am. I'm interested in that and exactly that.

You go poke the armpit or something, the cell doesn't care. You poke the other-- the next toe over, the cell doesn't care. You poke one particular toe, let us say, that cell will care. Take a cell out here somewhere, and that cell will care only if you put visual stimuli in a particular little spot in the right side of visual space, in a very particular part of visual space.

Move over a little bit, and it'll want stimulation in a different piece of visual space. Move elsewhere in the brain and now, rather than liking, say, just something simple like a line moving around, a cell down here-- this is typically done in things like monkeys, and so that cell might be very interested if you show it the hand of a monkey. Right?

[GROWLS] Ah. Cell's thrilled. Show it a hunk of chalk-- I don't care. Nearby one might like the face of a monkey, and so on. So you can find out what individual cells are interested in by recording their activity. There are some significant drawbacks to this, which is that you can only-- one of them is that you can only sample from a tiny fraction of the cells, even in an area that you are interested in.

How many cells do you think-- how many neurons do you think there are in the brain? So the answer is-- yes, a lot is a good answer. But the answer is going to be expressed in terms of 10 to the x. What's x, would you guess?

Yeah. Well, the 24s are a little high and the 9s are a little low. When I asked this question when I was in graduate school, I got the answer that there are-- nobody knows the answer for sure because who's going to go and count-- that there are 10 to the 12th neurons in the brain. And of these-- I didn't even tell you on this picture, but [SCRIBBLING SOUNDS] yeah, we can draw a tail on this thing.

Hanging off the back of the brain, sort of underneath the back, is the cerebellum. It means little brain. Important in learning and motor control sorts of things. We're not going to say much about it here, sadly. But what my professor said was there are-- oops-- 10 to the 12th neurons in the brain. Of these, 10 to the 13th are in the cerebellum.

AUDIENCE: [INAUDIBLE]

JEREMY WOLFE: Ah, the quick-on-the-uptake crowd picked up that there's a problem here. What he was trying to tell me was not that he didn't understand math, but that, look, we don't even really know to an order of magnitude how many cells there are in the brain. But that lots on this order.

How many cells can you record from in a study of some function in the brain? You know, heroic single-unit, single-cell recording studies might have on the order of 10 to the second hundred cells recorded from. Moreover, if you're going to stick an electrode in the brain, the cells that it encounters are going to be biased by things like size. You're more likely to get big cells than little cells, and big cells do things that are different than little cells do in the brain.

So it's not-- you can imagine that it would be difficult to figure out what your laptop did by recording from single components on the motherboard. That wouldn't be particularly easy. It gets significantly worse when you try to do that in the brain as a whole.

The things we know best about in the brain are things where we can bring all of these techniques to bear and get what would be called converging evidence, converging data on it, evidence from multiple different sources, and then corroborate that by looking at behavioral measures.

Oh, let me say-- oh, well, all right. This is the moment in the lecture where my wife-- where I really feel my wife looking over my shoulder. In two minutes, I will polish off the rest of the brain. So that's just the surface of the brain, right? The brain is a 3D structure. One way to very grossly think about the overall structure of the brain is that if there's cortex, that lying underneath cortex is what are a bunch of structures that often get called limbic structures.

This is really an outdated term. It comes from the word for ring, and it was the notion that there was a circuit of structures lying under the cortex. But there's a collection of structures who will show up later in the term with names like the amygdala, from the Latin for almond. Hippocampus-- is it Latin for almond or Greek for almond? I'm not sure at the moment.

Hippocampus, from the word for seahorse. Not because you have almonds or seahorses in your brain, but because the shapes of these things are faintly reminiscent of such things out in the real world. And other structures that turn out to be vitally important in your emotional life and in memory. Hippocampus will show up later as critical in memory.

Lying underneath there and heading on down into spinal cord-- oh, I don't know, let's call it the core today or something-- are a set of structures that-- well, we tend to spend a lot of time in psychology talking about the cool stuff happening up in the cortex and stuff like that.

But the stuff you really don't want to lose, the stuff we don't know about from lesion studies, is down here because something in your brain has to say to your heart, beat, beat, beat. If that piece of brain goes, you've got really big trouble. There's another piece down there that says, time to breathe, time to breathe again. I mean, it's not glamorous work--

[LAUGHTER]

--but you know, somebody-- so there's a whole set of stuff here running vegetative processes.

And also important, not just for pacemaker kinds of things, but also for general issues of arousal and sleep and wakefulness, those sort of things. So that is an embarrassingly brief tour of-- you can spend your life on neuroanatomy. Trust me, my wife does. We'll come back and talk about single cells on Tuesday.