JEREMY WOLFE: What I want to do for the first couple of minutes of today's lecture-- well, I guess looking at the handout, what I want to do is play fill in the blank with this great picture of a neuron. I got to talk about the gross structure of the brain last time, but I didn't get to say anything about a neuron.

Neurons are brain cells-- not all of brain cells. This is going to be a neuron. At least half the cells in the brain would be in the category of glia.

That's a word that comes from the word for glue. And all the years I was learning about this stuff, glia kind of got shoved into the category of support staff. These were the guys who cleaned up after the neurons who were doing all the cool stuff.

But it's becoming increasingly clear that glia have many functions to play in brain function beyond the merely vegetative. And if you go into neuroscience, odds are that you'll end up learning a lot more about glia than I did when I was taking the equivalent course.

But the main units-- the main, if you like computational units-- for the brain are neurons. And so here's a quick tour of a canonical typical neuron. A typical neuron would collect information, either from other neurons or from sense organs through, its dendrites. The word comes from treelike because it's branching structure, so all these little branches are making connections with lots of other neurons or with sense organs in, say, the skin or something like that.

And the information that the dendrites collect you can think of as being in the form of little pulses of excitation or inhibition. They can be either positive or negative in nature. They flow down towards the cell body.

Here, the neuron is a cell like other cells. It does all those good cellular sorts of things. But for our purposes, its big job is to act as a sort of a summater, and to ask, how excited am I? If I sum up all these pluses and minuses, am I excited enough to want to tell other neurons about my level of excitement here?

If the excitement passes a threshold, the neuron sends an action potential, a signal. Action potential-- no, that doesn't look right, does it? Well, potent-- there we go. This is why there's a handout, because I can't spell under good circumstances, and I can't spell online at all.

Anyway, that should say "potential." It sends a signal down the axon. The long wire of the neuron is the axon.

That action potential has a couple of important properties. Property one is that it's of a single polarity. There aren't pluses and minuses, there's just a single polarity.

And it's a fixed size. A more excited neuron does not produce bigger action potentials. So how is a neuron going to tell another neuron that it's more excited? Would you guess?

It's going to make more action potentials. So it's frequency coding its level of excitement. But action potentials are fixed size and fixed sign-- electrochemical signals powering their way down this axon.

These bumps wrapping around the axon are actually another cell type. They're a form of glia known as myelin. It acts as insulation, keeping the signal in one neuron separate from the signal in others. And it also acts to speed transmission.

There are a number of neurological diseases whose cause is not a problem with the neuron but a problem with the myelin. Demyelinating diseases like multiple sclerosis, for example, have their effect because the insulation is breaking down, not because the nerve cells themselves are breaking down.

That signal reaches the arborization of the axon. It then goes off and talks to a bunch of other neurons. Or if this was a motor neuron, it would be talking to muscle.

Typically, it does not make a direct electrical contact. If you look at connections between stuff in your computer, those are direct electrical contacts-- not the way things work in the nervous system. In the nervous system, there's a small gap called a synapse.

And to signal from one neuron to another, an electrical signal coming down the axon causes chemicals to be released into the gap. They diffuse across the gap and bind to receptors on the other side. And that binding either produces a little plus or a little minus, depending on the nature of the chemical, the nature of the receptor.

And then, the whole process starts again. So you go from an essentially electrical signal to a chemical signal, then back to an essentially electrical signal.

These so-called neurotransmitter chemicals are the targets of lots of the drugs that are used to modulate mental states, like antidepressive drugs, for example. And not just drugs over the counter, or not just prescription drugs. Let's see, what are you drinking there? Oh, that's just tea. How boring.

Well, I wasn't actually thinking she was probably putting away a margarita, but that drug would be working on a synapse. That caffeine that you are pouring into your brain is working on neurotransmitter and synaptic properties. That's where you get your chance to affect large numbers of neurons at one time. We'll talk more about that later.

Now, if I look at my cute little diagram, yes, you should have been able by now to fill in all the-- I wonder what that interesting thing is at the top, actually, the middle one at the top. What do you figure? Cell?

It's not axon. It's not myelin. Those are the two at the bottom, right, and center.

The one on the top right is pointing to synapse. The one at the top left is pointing to dendrites. And the one at the bottom left is pointing to the cell body.

So well, the one on the bottom left, I figure, is pointing to the soma or cell body. I think the one at the top middle is pointing to the whole thing. Neuron. Yeah.

STUDENT: [INAUDIBLE].

JEREMY WOLFE: Oh, maybe, yes, thank you. Oh, somebody's been doing the reading. Yes, OK, you are correct.

So the top middle is almost undoubtedly pointing to the axon, that whole long thing. And the bottom-- what she's pointing out is that that bottom middle one is pointing to the valleys amongst the bumps. And those are called the nodes of Ranvier, undoubtedly named after Joe Ranvier, who I don't know anything about.

But the way that myelin speeds up transmission is it makes it possible for the action potential-- rather than just going down the axon in a nice, smooth fashion, it jumps from node to node. And so that's why the nodes are interesting. OK, I'm glad we've solved that. You would have thought I would have thought about that before putting the thing on the handout.

OK, any other questions about neurons or things? Yes.

STUDENT: So soma-- is that where all the boring cell stuff happens?

JEREMY WOLFE: Well, there's boring cell stuff happening all over the place. I mean, we shouldn't, of course, call it "boring cell stuff," because then guys in like course 7 come and put a hit on us and things. But yeah, neurons are cells like other cells, and they have to do all the respiratory things that other cells have to do. But our interest in them, of course, is as little communication and computational units. Yes.

STUDENT: What is the myelin, exactly?

JEREMY WOLFE: It's another cell type that wraps around the axon and acts as insulation and speed bumps, I guess. Think of these as the speed bumps, except that they speed things up rather than slowing things down. Boy, I bet that just confused matters.

OK, that said, what I want to do today is to talk about why we do anything. It's the general topic of motivation. But you ask a question, like why do you eat? And you say, well, you've got to eat because if you don't eat, you die.

STUDENT: Prove it.

JEREMY WOLFE: Prove it, right. That's not a stupid point. He meant it as a stupid point but it's not a stupid point.

Why does a rat eat? Does a rat know it's going to die? Is a rat sitting there with existential concerns about it? I don't think so, particularly.

And even if it were the case, if you don't eat you're going to die. Well, so what? I mean, why you do anything is a question that requires some sort of an answer.

And I will give a three-part answer. Part one of the answer will be that you are a slave to-- you do things as a slave to the environment. Part two will be that you do things as a slave, in fact, to your own brain.

And part three will be to say, well, parts 1 and 2 seemed a little simple minded. We'd better try and get to a somewhat richer explanation that might explain why you're sitting here in a classroom doing this rather complicated activity, since what we'll be talking about is-- one of the things we'll be talking about-- is the obvious fact that I am a psych professor and not an artist. So you will have to bear with the fact that for present purposes, that is a cat.

[LAUGHTER]

And that is a rat. You are neither. And the third part of the lecture will be devoted to trying to talk about the richer set of motivations that you might have, and that even animals might have.

Well, a good starting place, even if it's a bad bit of art, would be-- this is an unusually pathetic cat, even for me. Back shortly before the turn of the last century, Edward Thorndike up at Harvard was doing experiments of the following form. He would take cats who were hungry cats and he would throw them in a box that looked sort of like a packing crate kind of thing, slats all over the place.

And outside of the box is a-- well, a bit of fish, but if I drew a bit of fish, you'd never know what it was. This at least looks a fish. So there's a bit of fish.

You've got a hungry cat. You've got the fish. Cat wants fish. What's the cat going to do?

Well, the cat is bouncing off the walls, being annoyed and agitated. And the way this box is set up is they're called puzzle boxes because there's-- in effect, there's a trick to getting out. It might be that there's a lever back here that's attached to some string and pulley arrangement that lifts a gate over here.

And if the cat happens to bounce into this lever, the gate goes up. Cat goes out, gets the fish. Great. Well, it's a little piece of fish and he's a hungry cat. And what happens to the cat immediately thereafter is Thorndike grabs the cat again, throws him back in the box.

What's the cat do? Well, whatever the cat is doing, what Thorndike is doing is measuring the amount of time that it takes for the cat to get out of the box as a function of the number of times that the cat's been chucked back in the box. So you've got time as a function of-- we can call them trials, the number of times the cat's been in the box.

Initially, it takes the cat some amount of time. The next time, maybe he's a little quicker. And you get some sort of a function that eventually gets to some asymptote where you chuck the cat in the box, the cat looks at you in a disgusted kind of way, goes over to the lever, says [VOCALIZES] goes, eats the fish, says, OK, we've got to do this again. Fine.

This is a learning curve. In fact, this is the original use of the term learning curve. When you talk about going up the learning curve and stuff like that, you are invoking Thorndike.

What is the cat learning? In the 19th century, and even today if you go to the Animal section of Borders or something like that, there are lots of books that will tell you about the rich mental life of your cat and so on. Thorndike wasn't buying it.

What Thorndike said was that there are good things in the world. We'll call those reinforcers. They come in two forms.

There are positive reinforcers. Well, here, as an example, if you tell a joke and people laugh, that's a positive reinforcer. You did something, something good happened.

There are also negative reinforcers. Those are also good things. The jargon is unfortunate, but a negative reinforcer is a good thing. Focus on the reinforcement part, not the negative part.

A negative reinforcer is the car alarm is going off, you do something that makes that noise stop. That's a good thing. The cessation of something unpleasant, like hunger, for example, is a negative reinforcer. It's also a good thing.

A bad thing in this jargon is called punishment. You tell a joke. The person you're telling the joke to takes offense and smacks you. That's punishment.

What Thorndike formulated, which is undoubtedly on the handout somewhere, is the Law of Effect. Yeah, it's top of the second page. He proposed what he called the Law of Effect.

And he said that something that's followed by a reinforcer-- a behavior that's followed by a reinforcer-- is more likely to recur. Take the joke example. If you tell a joke, and people laugh, the next time the opportunity presents itself, you are more likely to tell that joke.

The negative Law of Effect is or is not on the handout somewhere. Well, yes, there it is a little further down under where it says "punishment." The negative law of effect says if you do something and something bad happens, you're less likely to do it again.

You tell a joke. Somebody smacks you. The next time the opportunity presents itself, unless you're a teenage male, odds are that you won't tell that joke again.

Well, this is a separate problem. This is the burping problem. When you were 12, maybe, you discovered you could burp the alphabet or something and your 12-year-old guy friends thought it was really great. And so the behavior got reinforced.

And unfortunately, it takes a lot of smacks before you unlearn that. But that's actually the next lecture. We'll talk about that next week.

I'm looking at the handout and realizing that I failed to give you the great bunny example. And you're going to look at your notes later and wonder what this is. But I can use that to illustrate the same point.

I have a rabbit. Anybody want a rabbit? We have a rabbit. It's an accident. You can have him.

But anyway, this rabbit, when I go down into the kitchen in the morning, goes berserk. He's thumping up and down in his cage. Why is he? What's he doing?

Well, basically, he's signaling that it's time for breakfast-- not just any breakfast. You give him Rabbit Chow, he keeps thumping. He's addicted to Reese's Pieces-- not Reese's Pieces, the Reese's cereal. It's very sad. He's a sugar cereal junkie.

And in these terms, what's happened, where his behavior is coming from, what's driving his behavior, is he was making some arbitrary noise at some point when we fed him, and perhaps when we fed him Reese's cereal the first time. It was really good. It was a positive reinforcer.

It made more likely the behavior that he had just been doing. So the next time the opportunity presented himself, he went thump, thump, thump. Being the right time of day anyway, he got more Reese's stuff.

And now, by this law of effect training, he has learned that if he goes thump, thump, thump, we'll remember that it's time for the sweet cereal. And he gets very disappointed when it turns out that the sweet cereal supply has run out and we're trying to feed him some health food stuff. He's not interested. Carrots are OK, but only barely.

So why is it that animal-- how many of you have cats and dogs, cats or dogs, one or the other? You don't have to have both. Almost all of you can probably tell me something about the brilliant, intelligent behavior of this dog or cat that doesn't sound like this accidental learning of an association between a behavior and its consequences.

This sort of association learning, by the way, is what I'll talk about. The rules of it I'll talk about extensively next week. But why is it that we're so convinced that animals have a much richer intellectual life?

Well, one possibility is that they do have a richer intellectual life than this. The other, the one that Thorndike thought he was seeing, was what really boils down to selective reporting. Did I put the whole quote on the handout? No.

What Thorndike said is, dogs get lost hundreds of times and nobody ever notices it or sends an account to a scientific magazine. But let one dog find his way from Brooklyn to Yonkers, and that fact immediately becomes a circulating anecdote. Thousands of cats, he says, sit on thousands of occasions helplessly yowling and nobody ever writes to his friend the professor about it. But let one cat claw at the knob, supposedly as a signal to be let out, and straight away that cat becomes the representative of the cat mind.

What Thorndike thought was that you are that-- well, at least the cat and perhaps by extension, you-- are a slave to your environment. The contingencies in your environment shape what you do. If the environment rewards you for pushing this lever, you'll push this lever.

And the cleverness, the seeming content of that, is imposed from the outside. It's not there. It's not necessary.

You can explain it all-- you can explain why you do things-- purely in terms of this law of effect, suitably elaborated. And as I say, the suitable elaboration on that will come next week. The elaboration, by the way, is known as behaviorism, a school of scientific of psychological thought that says that the explanation for your behavior can be found in the contingencies that relate your actions to their consequences in the world and the relationships between stimuli in the world.

That gets you some distance. But what is it that actually makes something reinforcing? Why should something be reinforcing at all? What is it about, say, food that-- why does the cat care that he gets out and satisfies his hunger?

For that, you want to switch to the second form of slavery, which is this notion that you are slave to your own brain, in a sense. And the emblematic experiment for that is done some 50 years after Thorndike is working with his puzzle box. And that comes from an experiment done by Olds and Milner. It actually started as a mistake done by Olds and Milner.

Here's what they were doing-- they were sticking electrodes into the brains of rats down into the brain stem because what they wanted to do was to study arousal. Centers down in the brain stem, I mentioned last time, are intimately involved in things like sleep, and wake, and some general level of arousal.

How do you know if a rat is aroused or not? Well, one of the ways to measure arousal in a rat is just to look at the amount of activity that rat is emitting. A rat that's just sitting there is not very aroused, and a rat that's running around is presumably aroused. Great.

So they're going to stick an electrode into the rat's brain and look at general levels of activity. There's a problem that requires a control experiment first. What other than generalized arousal might get a rat to run around, would you think?

STUDENT: Inside their brain-- sticking an electrode [INAUDIBLE].

JEREMY WOLFE: Sticking an electrode in their brain-- yeah, well, why might sticking an electrode in their brain make them run around?

STUDENT: Pain.

JEREMY WOLFE: Pain. It might hurt. So suppose all that happens when you turn on the electricity to stimulate the brain of the rat is it hurts. The rat's going to run around, but you wouldn't want to argue that this is a center for generalized arousal. Plus you might not really want to be hurting your poor rat.

So anyway, here's the experiment that they did. What they did was they watched the-- electrode's in the rat, and they're looking at the rat. And they only turn the electricity on when the rat's over in this part of the cage. So turn on the electricity. If it hurts, what does the rat do?

STUDENT: Runs around.

JEREMY WOLFE: Runs around, but--

STUDENT: To the other side.

JEREMY WOLFE: To the other-- no, no, no, oh, hey, it stopped. I'm going to wander back over here. [MUTTERS] Oh, no.

Everybody knows rats learned this. They knew that. Nobody had done this with stimulation of the brain.

This is so-called aversive learning that one of the typical ways of doing it is you electrify the floor of the cage. So the rat goes over here, discovers that when he puts his little rat toes on the cage floor over here, there's electric current running through it. And [VOCALIZES] and he's over here. So that's what they did.

And so the rat goes over here. And on comes the juice for a little bit. And the rat doesn't go anywhere. And then the juice goes off and rat's wandering around.

And the rat comes back over here. Juice comes on for a little bit, rat doesn't go anywhere. In fact, the rat comes back over here. The rat's hanging around over here. Yeah, let's do that again.

Turns out that the rat was behaving as though the stimulation was reinforcing-- we could say as though he wanted to be stimulated. But it's a little dicey to talk about what a rat wants or doesn't want. So you can use this more neutral language of reinforcement.

The rat was behaving as though stimulation of the brain was reinforcing. This was a surprise to Olds and Milner. The next surprise came when they actually looked at where the electrode had gone in this particular rat's brain. That's the mistake part.

It turns out the electrode had bent and instead of being where they wanted it in the brain stem, it was in a chunk of brain known as the lateral hypothalamus. At least we think it was in the lateral hypothalamus-- don't actually know because not only did the electrode bend, but then, they lost the brain subsequently. They did very well for all the mistakes they made here. Hypothalamus.

So what they did, then, was to deliberately stick electrodes into the lateral hypothalamus and to set the experiment up in a more formal fashion, beautifully illustrated here by my rat who's got an electrode in his brain. And that's a battery up there. And that's a lever.

Now, the rat can go off and self stimulate. He can go and choose-- if he pushes on this lever, he gets a little pulse of electricity to his brain. And what's he do? Indeed, rats with electrodes implanted in the right bits of the lateral hypothalamus will sit there and work for brain stimulation the way another rat might work to get rat pellets, or water if it's thirsty, or something like that.

And they'll work hard. The most dramatic version I can recall reading is rats will work bar pressing 7,000 times an hour, I think, for to keep the brain stimulated there. So this is apparently good stuff.

Not everything is good stuff. There are chunks of brain where the rat will work actively to turn off the stimulation. So again, turning on the stimulation would be a positive reinforcer. Turning off an aversive stimulation, whether it's electricity to your feet or electricity to the wrong part of your brain-- that's a negative reinforcer.

So there's current. If you push the button, the current stops. That's good from the rat's point of view.

In various surveys of rat brain, it turns out that there are more positive locations than negative locations. And we don't know if that's true of humans and we don't know if that means anything.

Actually, the study that I noticed this morning that I was thinking of here says that there are 60%-- in this one study-- 60% neutral locations, 30% rewarding locations, and 5% aversive locations. Now, the mathematically sophisticated among you will notice that adds up to 95%. And neutral rewarding and aversive would kind of seem to cover all the possibilities here.

So I have no idea what the other 5% of neurons were doing. That seems a lot for rounding error or something. Anyway, more pleasant locations than unpleasant locations.

Now, around this time, somebody who is a science fiction buff should say, I've heard this before. It shows up in one of several classic science fiction stories. The world is full of science fiction stories written by people just like you, which is to say people who heard an introductory psych lecture, and thought, I can make a story out of this.

Memento is perhaps the most recent movie example of that. We'll get to that lecture later on in the term. Anybody familiar with the sci-fi story that's related to the rats here, any of the various sci-fi stories?

STUDENT: Mrs. Frisby?

JEREMY WOLFE: No, not *Mrs. Frisby and the Rats of NIMH.* No, apart from the fact that NIMH is short for the National Institutes of Mental Health and they don't much care for that. But what are the rats of NIMH doing? Oh, no, they're busy taking drugs and getting smart, right? No, no, no, they're not sitting there stimulating their little selves. Yeah.

STUDENT: *Terminal Man.*

JEREMY WOLFE: OK, yeah, *Terminal Man* sounds right. What's Terminal Man's issue?

STUDENT: He has epileptic fits, so you're [INAUDIBLE] brains now you're [INAUDIBLE] pleasure.

JEREMY WOLFE: And it does give him pleasure. Yes, OK, that's-- yeah, is it--

STUDENT: *Flowers for Algernon.*

JEREMY WOLFE: *Flowers for Algernon,* no, he's doing-- what's he doing? Is he being stimulated?

STUDENT: [INAUDIBLE] on the rat, and he [INAUDIBLE].

JEREMY WOLFE: Oh, yeah, no, but he just becomes a super smart rat like the*Rats of NIMH* one. He's got a different-- we don't know how to make super smart rats. We just know how to make rats who will work hard on pushing levers. *The Terminal Man* one is one of the sci-fi examples that I know about.

Anyway, look-- the critical issue that gets people writing science fiction stories is, suppose we did this to a human. Would that human-- could you kill somebody by hooking them up to self-stimulate their pleasure center and they would kill themselves. How would they kill themselves? By sitting there [VOCALIZES] and forgetting to eat.

Well, nobody's ever done this in humans, of course. It's been done in rats. And if you put a lever that gives food next to a lever that gives stimulation in a good spot in the rat's brain, the rat will sit there and work away on the self-stimulation lever, and, at least in some of these studies, will every now and then say, oh, [VOCALIZES] get a little food. OK, back over here to the video game stuff. This is really good.

This is what your parents thought you were doing. "Come on down and eat dinner." "Oh, mom, I can't put it on pause."

Anyway, would an animal actually kill itself? Gleitman says that hungry rats will opt for self stimulation even though it literally brings starvation. And then, he cites an article that I went back and read.

And the rats in that study didn't starve themselves to death because the researchers wouldn't do it, presumably because it seemed unethical to actually let a rat starve itself to death. But they will certainly reduce. They'll certainly get themselves pretty hungry while amusing themselves by stimulating their brain.

There was a hand up. There still is a hand up there. Look at that.

STUDENT: I read a story a while ago of a guy who played video games for 74 hours straight and he died.

JEREMY WOLFE: I don't know the truth or falsity of-- so the story is a guy played video games for, what was it, 74 straight hours?

STUDENT: In Korea.

JEREMY WOLFE: 74 straight hours in Korea, and then he died. Actually, the Korea part is good here because I have no idea whether this is true one way or the other. It has all the hallmarks of a so-called urban legend.

It has a grain of plausibility and is just one step removed from check-ability. It's like the Kentucky-fried breaded rat. Everybody knows somebody else who knows that their cousin got a breaded rat once. Or there's whole books of these things.

They're great. I don't know. Maybe somebody did manage to play video games till they died. People do all sorts of stupid things. I don't recommend trying this yourself.

In any case, rats will work very hard in order to stimulate different parts of their brain. What is it that they're working for? The evidence suggests that they're not just working for some sort of disembodied pleasure, but that they're working for the reward associated with one or the other of basic, hardwired, innate reward systems that the rat comes with and that you come with, too.

The reason in this aspect of the slavery story-- that you'll work to get the fish if you're the cat-- is that you came predisposed to think that hunger is bad and food is good. Look-- it doesn't take very sophisticated evolutionary psychological theory to think this might be a good idea. Organisms that went into the world thinking that hunger is good and food is bad had many fewer progeny than the ones who thought that hunger was bad and food was good. So it's not desperately surprising that you've got circuitry that says if you're hungry, you want to go and eat something.

And the centers that are being stimulated are in chunks of brain that if you mess with them, mess with the rats' ability to regulate its eating. So there's a wonderful picture in Gleitman of a rat with a hypothalamic lesion, a lesion in this chunk of brain. The specific lesion in this particular rat is in a chunk of brain that seems to be important in telling you when you're full.

So this rat never knows that he's full, and with the result that he just keeps eating. And so there's this picture in chapter 3 of a rat on-- some of you may have already seen it on-- one of those diet scales. And he looks like a furry football. He's just overflowing the-- and that's because he's got a specific lesion in this little specific chunk of brain.

How do we know that that's what's going on here? Well, you've got a rat who's working away to be stimulated in this little particular chunk of brain. And so let's take this little chunk of brain.

If he's a full rat, if you feed him up, he doesn't work as hard. It's just not as interesting. You know this in your own-- so you like M&Ms, let's say. You're willing to push the lever to get the M&Ms. You're willing to put the quarters in the machine.

Will you do that forever? No, because eventually, you get full and the M&Ms kind look disgusting. So the same thing happens here.

If the pleasure that the rat is getting is modulated by satisfying the-- and the thing about direct electrical stimulation is it gives the sensation of the satisfaction without actually satisfying anything. So if you're getting the M&M is good thing without getting the M&M, you can sit there, oh, the M&M is good forever and ever, and keep working at it.

So that's this little chunk of brain. You go over to this other chunk of brain where the rat will also work hard and that rat doesn't care if he's full. That rat cares whether he's made it recently.

So this little chunk of brain is presumably related to the reward systems having to do with sex and mating. Again, it doesn't take an evolutionary psych genius to figure out that this would be sensible stuff for a brain to come with. Organisms that didn't find mating rewarding didn't leave many offspring. It just didn't work out that well for them.

And so there's another reward system. Similarly for thirst-- there are separate reward systems. So in some sense, you end up doing stuff in order to light up little pieces of brain or to turn off little pieces of brain. That's the sense in which you are a slave to your brain.

Now, that only gets you so far because that's fairly simple. Eat food, little hunk of brain says you're happy. Your behavior is somewhat more complicated than that.

How do we get to that more complicated behavior? Well, let's stick with the M&M example. How do you get to the M&Ms? Well, you've got to go down to the vending machine and put the money in.

And how do you learn to do that? Well, maybe you learn to do that by a chain of associations back to the M&Ms. M&Ms-- oh, they're good. Getting M&Ms becomes good in its own right. Somebody gives me M&Ms.

That becomes rewarding by association with the fact that I will now get to eat the M&Ms. This machine will give me M&Ms, but only if I give it quarters. So I learned to give it quarters.

[PHONE RINGING]

That's an interesting ring. It sounded like a regular old phone. Put them on vibrate. That's what I do because-- let's see, oh, yeah, it's just about the right time.

I should be vibrating any time-- whoops, not that one. My 10th grader tends to phone in after school, which is great. The only thing is that after school two days a week turns out to be here. And it's just not a good time to take a call.

Anyway, so the 10th grader-- he likes M&Ms. He needs quarters. So he's got to emit behavior that I like, so I'll give him quarters.

And so you can see how you could build back from a primary reinforcer, like food is good, to something much more remote like cleaning my room is good. Why is cleaning my room-- if I clean my room, daddy gives me quarters. If daddy gives me quarters, I take quarters, I put them in machine. Machine gives me M&Ms, I eat M&Ms, and all is good.

That's OK, but it probably doesn't do quite well. The brain suggests to us that that isn't quite enough for organizing even the feeding behavior of a complex organism like us. Suppose that what gets you to do your complicated behavior around feeding is the fact that you're hungry.

Oh, chapter 3 will tell you all about how that you're hungry. It's lovely engineering work. You've got little detectors, receptors, in the blood.

They're doing things like keeping track of blood sugar levels. When those levels drop, chunks of brain become active. Activity there is apparently aversive, probably corresponding to what you and I think of as hunger. When you get sugar in, activity there drops-- lovely, beautiful control systems stuff worked out in great detail and discussed in considerable detail in chapter 3.

But suppose you're not living in your food. Suppose you're out on the plains of Africa somewhere, and the M&Ms aren't just sitting over there in the vending machine. They're running around and you're going to have to hunt them down.

If you are sitting around until the blood sugar level gets low enough for unpleasant things to happen in these hardwired chunks of brain to make you think, OK, all right, I remember this-- M&Ms or wildebeests, whichever it was. They're good. I can eat them. To get the wildebeest, I've got to go clean my room.

Anyway, there's some complicated thing that you've got to do. But if you wait long enough before starting, you may not get it the job done in time. It's going to take you a while to hunt down the wildebeest.

If you wait till the gas tank is almost empty, you may find yourself flat out on the plains with no food. So it would be useful if something got you up and mobilized for activity before you were actually hungry, before you actually were in some desperate need. And the distinction that gets made, and I trust is bolded on the-- yes, it's down there at the bottom of page two-- is the distinction between consummatory and appetitive behaviors or consummatory and appetitive motivations.

Consummatory ones are the ones we've been talking about so far. Eating M&Ms-- that's good. Appetitive ones are ones where the act of looking, if you like, or getting yourself in a position to consume, is itself rewarding. In the case of food, that might be the thrill of the hunt kind of thing.

Think about your cat, your cat who likes to jump on anything that moves. Why is that? It's because the cat is hardwired to hunting stuff. It's just fun to grab stuff and kill it. Now, that's a useful thing to do if you are a cat-like animal because then, there's going to be something around to eat when those blood sugar levels drop and you need to chew on a wildebeest for a while.

And it's pretty clear that we have similar-- actually, it's pretty clear in yesterday's political news that we have similar sorts of circuitry in ourselves. Yesterday, the assault weapon ban expired. Bush spent a lot of time not talking about it.

Kerry spent a lot of time saying, "I'm a hunter. I love to hunt. I love to jump on moving things," and stuff like that. But I've never done it with an assault weapon you don't need to use an-- he was on this.

But he was very big on pointing out that he loves to hunt because, apparently, there's lots of people who love to hunt, and go out, and shoot things, and sometimes eat things. This is presumably a form of appetitive behavior in humans. If you don't happen to love to hunt, it doesn't mean that you're missing a piece of your brain.

Another realm of where appetitive behavior is important is in the sex and romance department. If it were not the case that the act of looking for a mate is motivating in its own right, what are you going to do? Wait around until all of a sudden, I don't know, whatever levels it is drops low enough. Oh, it's time to mate.

[LAUGHTER]

It's just not the way we organize our behavior. Our social lives suggest that we find a degree of pleasure in the appetitive aspects of seeking a mate, not merely in the consummatory parts of it.

So you come with a set of motivations that get you-- motivations from the sense of getting you to move-- that seem to come with the systems. These can be quite specific, by the way. That's the notion of preparedness that I see, or it's related to this notion of preparedness, that I see is actually above where it says "consummatory and appetitive behaviors" on the handout.

You are surprisingly fine-tuned-- presumably, by the history of the species. So for instance, you're built to get away from scary things that are going to hurt you. And that seems reasonable enough.

And that can be specific enough to the point that it's easier to get you to be scared of spiders and snakes than it is to get you to be scared of bunnies and chickens. That sounds kind of obvious, but there's no obvious reason why. In fact, one of the famous experiments in this behaviorist tradition has a little baby known to history as Little Albert-- there's a great film from the '20s of this.

Little Albert is sitting there. He's playing with a little, white bunny. John Watson, founder of American behaviorism, sneaks up behind Little Albert with a gong and- pow-- rings the gong.

Little Albert goes-- if it was a cartoon, would go straight up in the air, and is scared out of his Little Albert gourd, and is screaming and crying, and stuff like that. And it's kind of harsh for Little Albert. But then, you bring Albert back. You show him the bunny again.

Does he want to play with the bunny? No. Does he want to play with anything that's white and furry, including Santa Claus, apparently I seem to recall-- guys with bushy white beards.

He recovered, by the way. He didn't grow up to be a psycho or anything. But so you can train somebody to be scared of rabbits, but it's easier to train them to be scared of snakes, as if they were prepared by the history of the species to be scared of things like snakes and spiders.

So you're a slave to the environment because your brain responds in rather specific ways to the environment. But you are a lot more complicated than that, or at least you feel like you're a lot more complicated than something that's just a bundle of engineering responses to "glucose level low, must go find wildebeest." And I want to spend the remainder of the lecture talking about some of those complexities. But first, I want to give everybody a chance at least to stand up and stretch a little bit, and fan themselves because it's warm in here.

[INTERPOSING VOICES]

Oh, yes, yes. You want your little form right now?

STUDENT: Sure.

JEREMY WOLFE: Send this form back. And I trust that means that you can be here at 5 of 2:00 and--

STUDENT: Before class? Yeah.

JEREMY WOLFE: Yeah, well, it's not useful after class. OK, this is all the information I have. If there's a problem, let me know. But your name is--

STUDENT: Chee.

JEREMY WOLFE: Chee, nice to meet you. And I trust that you'll be happily erasing my boards. I think out there. OK, let us reconvene here.

Here's the deal-- I will typically try to be good and remember to give you a chance to stretch your limbs a little bit. But it'll be a short stretch. So actually, why am I telling you this? It's the guys who thought they were off for 10 minutes who are now halfway down the Hall to get the M&Ms who have the problem. The ones who are out looking for wildebeest are really in trouble.

You might wonder what the role of emotion is in all of this. Clearly, motivation and emotion are closely related. They both talk about feeling a lot. There's this feeling of hunger.

But the emotion part is-- well, one way to think of it would be as a sort of a language, a symbol system, that's a shorthand, that helps you mobilize your way of talking to yourself about what resources you might want to mobilize. Oh, I feel fear-- that means I should do the following sorts of things. And it helps you generalize from event to event.

I feel fear now. I felt fear before. Maybe there's some relationship that I ought to be noticing.

And perhaps one of its most important uses is as a form of communication between people or between animals more generally. If I'm afraid-- let's go back to the plains of Africa and switch sides. If I'm a wildebeest and I see the leopard over there stalking through the underbrush, I should be afraid. If you're not seeing the leopard, but you're seeing me and I look afraid-- and you're the rest of the wildebeests-- you should be afraid, too. It's a good idea if you pick up on the way that I feel.

Now, we tend to devalue that a bit because we tend to use verbal communication a lot to convey information back and forth. And for some things, it's obviously a much more useful technique. I mean, trying to teach psychology by a set of emotional expressions would not-- I can't even conceive of how I would go about doing that.

However, we probably overvalue the straight verbal nature of communication even between humans. Obviously, nonverbal animals are going to have to use some other form of communication. But even among humans, we underrate the value of this current of emotional information transmission.

Perhaps the clearest example of this is email where-- how many of you at some point have gotten into trouble on email because email has the characteristics of conversation without the tone of voice? You said something that you meant sarcastically or you thought was funny, and somebody else read it as flat prose, and they was not amused at all. And then you got-- actually, that's the root of all these little smiley faces and all these symbols that I don't know from nothing.

You all know this. There's some very elaborate vocabulary of basically emotional tokens for instant messaging or for email. Because it lacks that emotional tone of voice. And without that, the quality of the communication goes down.

But so you've got emotions as a sort of superordinate language that allows you to talk about motivational states, even in the absence of any verbal language. I think you could probably make a convincing argument that basic motivational states exist in very, very simple organisms. I mean, any organism has to figure out-- it has to have, in some sense, the motivation to feed itself and to reproduce.

It's only when you get to more elaborate organisms do you get something that looks like the emotional life that you and I might have, where it's being used as some, in a sense, form of communication. But look-- so far, we're still dealing in pretty simple terms here. We've got sex and reproduction is good, getting eaten by the leopard-- that's bad, and so on.

Where we want to get-- and where the chapter on motivation, for instance, never gets-- is sex and reproduction good, eternal damnation bad, or something like that. Or how do you get from hunger drives and sex drives to "Thou shalt not murder," and "I want to grow up to be a chemical engineer," or something like that? It's those rather more complicated motivations that require more than just feedback loops in the lateral hypothalamus to make a good story.

Now, one step to a richer account of why we do anything is to broaden the set of motivations. I have pointed already in the direction of one act of broadening that set. And that is this notion that if I'm a frightened wildebeest, you should be a frightened wildebeest.

This is the notion that emotions are catching across individuals. We talk about that. On the handout, I put it as empathy and described it as a social emotion. And it's a social emotion in the sense that it helps to organize social behavior, interactions between people.

So let's start with a bit of evidence that this comes with the system, that it's not something-- I mean, you spend a fair amount of time trying to teach people to be more empathic. But the core of it is there from the start. So how do you know it's there from the start?

You take a baby. Here's a baby. Here's a bunch of other babies. Poke this baby. What's this baby do?

STUDENTS IN UNISON: Cry.

JEREMY WOLFE: Cry. What do these babies do?

STUDENTS IN UNISON: Cry.

JEREMY WOLFE: They also cry. Why? You haven't hurt those babies, but those babies have, in a sense, caught the emotional state of the other baby. Not only do babies catch each other's emotional states, but you are all here today because of the same sort of empathic reaction.

When you were a little pre-verbal slug, and you were hungry, what did you do? Waa, you cried. It's all you could do. And how did that make your parents feel?

STUDENT: [INAUDIBLE].

JEREMY WOLFE: Well, some of you are here today because you were lucky. Because apparently, it made your parents feel angry and-- which it probably did, particularly at weird hours. Mara's looking at me, and how old is the kid?

STUDENT: Four and a half months.

JEREMY WOLFE: Four and a half months-- we can check out-- if you haven't met Mara, she's the head TA, so she knows everything about the course and what recitation you're in. And we can also use her all term as the official parent person, at least parent of young child-type person.

She will confirm that when your baby cries, you want to make that baby stop crying. Fortunately, most parents-- the ones who want their genes to make it into the next generation-- make the baby stop crying by doing things like feeding it, and changing it, and stuff like that. If it didn't make you feel bad, if the crying baby wasn't the car alarm of the developmental world-- you know, hey, the baby's crying.

Oh, that's cool. Neat. Didn't know the baby could make that noise. Wonder what happens in a little--

Yeah, the baby cries, you feel bad, you do something about it. And that's how you end up getting to the point where you can take care of yourself. Because somebody else was willing to take care of you at that point.

And obviously, again, in nonverbal animals like the rest of them, it's really useful if when your infant animal is feeling uncomfortable, you recognize the need in some fashion and you do something about it. So in a sense, empathy is a prerequisite for successful parenting.

And this empathic catching of fear is a useful way to keep yourself alive. If you don't see the danger, but somebody else does, that's-- oh, and it's good for keeping you alive in other ways, too. I won't do it, but if I were to suddenly decide to make myself throw up, a bunch of you would feel really lousy, right? You know this.

By the way, this is one that goes away when you become a parent. You can modulate these things. If you felt incapacitating/y nauseous every time your child threw up, your child would never make it because you just got to deal and clean up.

But at this point, if I throw up, you're going to feel sick. Some of you will throw up. I shouldn't keep talking about it because some of you will start feeling gross just thinking about it.

That's also useful. Why? Because if I ate the wildebeest, and it was a bad wildebeest, and we're all vultures on the same wildebeest here, if I'm looking kind of sick, you might as well get rid of the wildebeest now because it's just not going to be doing you any good.

So this catching business has its utility. Now, it's not a uniformly good thing because you can catch antisocial emotions just the way you can catch pro-social emotions. So when you see seemingly incomprehensible events-- like how in the world can you explain something like gang rape or a massacre in a war zone?

Part of what's going on there is the same sort of emotional contagion. If one person is in a murderous rage, people around them, around that person, can catch the murderous rage just the way they can catch the fear or catch the nausea. It's not just a pro-social motivation. But empathy does serve the function of organizing larger scale sorts of behavior.

Now, how does this contagion actually work? How does emotional contagion actually work? Interestingly, part of the reflexive mechanism of it seems to be that when you read my emotion, you also mimic my emotion, most clearly seen with facial expression.

If I smile at you, you will smile. You may not smile much, but I'd be able to pick up-- if I was recording from your facial muscles, I would be able to pick up a transient smile flitting across your face. Why is that important?

Well, how do you know if you are happy? Well, it turns out-- and this is one of the senses in which feelings-- emotions are feelings-- is that you go out and you feel yourself, and ask yourself, how do I feel? Part of that is to feel your face, in effect.

How does my face feel? Well, I seem to be smiling. Why would I be smiling? I must be smiling because I feel good because only dumb people smile when they're miserable. That's unlike, say, well, there are various social circumstances when you might do that. But anyway, it's useful information.

You can actually try to demonstrate this. Here's an exercise for the reader, if you like. I've done it as one of the writing assignments for the course in various years. It's fun.

Take, say, 10 events of about the same duration, say an hour because that works for a lecture, for example-- a lecture, recitation, dinner, a few events, study breaks-- events that are going to take about an hour. Take 10 of them, shuffle them around, put five of them in one pile randomly, five in the other pile. Then deliberately either try to smile or frown through. Smile through pile A and frown through pile B.

And you can ask yourself a variety of questions, the most obvious being, how do I feel? And what's the effect on people around me? If you frown like an idiot, the effect may be to make people smile.

But you've done the experiment. You were doing it when you were early adolescence, as one of the best times to do this particular experiment. You show up at the dinner table. Everybody's in a pretty good mood, but you're not.

[LAUGHTER]

By the end of the meal, you know that nobody's in a good mood anymore. Well, you can still do this. I mean, I'm not sure how ethical it is as an experiment to try out on your friends at dinner tonight. But if you go to dinner feeling like junk and acting that way, you can make everybody else miserable, too. And isn't that great?

But more to the point, for the present point, all that sappy garbage about a smile is your umbrella turn out to be true. And it doesn't even have to be a real smile. If you take-- no, that's somebody else's pen. I'm not going to do it with somebody else's pen.

If you take a pen. This is an experiment that was published a few years ago. Take a pen and hold it like this, that pushes your face into a sort of idiot smile, whereas holding a pen like this does not. In fact, it actually forces it into a bit of a frown.

If you do this-- and I'm already spoiling the control aspect of the experiment. You don't tell people why they're doing this. You just make them do it for a while. The people who do this feel better than the people who do this.

And because the chunks of your brain that are saying, how do I feel, are walled off and encapsulated enough that they don't know, he's smiling. He must feel good. The fact that he's smiling because he's got a pen in his mouth turns out-- it matters, but it doesn't matter that much. So if you're feeling down, bite on a pen. You'll feel much better about it.

[LAUGHTER]

OK well, look-- so you can get a certain amount of work done by broadening the set of available motivations that you want to talk about. Why isn't the world a better place? If you've got this empathy thing going on, and you've got this beautifully wired up brain that you're a slave to, that's designed to make you eat, and mate, and do all those good things, why isn't the world a better place? Why doesn't it work better?

I can't solve that in the remaining 12 minutes or so. I've pointed to part of the answer. Just because you catch emotions doesn't necessarily mean you catch good ones.

It is also the case that not all of your motivations may be entirely benign. So for example, what's it got on the handout? It doesn't have on the handout, but aggression seems to have deep biological roots to it.

It is a not unreasonable reaction to a world of limited resources. It's not necessarily a nice reaction to a world of limited resources. But if there's a limited number of mates out there and you can punch out all the other guys and grab all the women, well, you get to have more progeny than the guys you punched out.

Fortunately, human society is not organized particularly that way. But there are plenty of animal societies that seem to be. Elephant seals-- you've seen these guys on your favorite cable channel. They come up in thousands on the beaches near Antarctica and stuff.

And these huge male guy elephant seals have 1,000 women. What is a woman elephant seal? I don't know. Anyway, 1,000 female elephant seals in their harem. And they have these huge fights over who gets to have-- they can't share. They just never went to preschool and learned how to share properly.

But part of-- there's certainly enough aggression in human behavior to make it clear that that sort of a motivational system is going to lead to a certain amount of conflict in the world. And it's not all going to work out as sweetness and light. People like Freud proposed that there was actually a death wish motivation out there. Thanatos is Freud's term. I may talk about that more later in the term.

So the possibility that there are motivations that themselves are not particularly nice, if you like, is one possible reason that the world is not a perfect place. But perhaps the most useful way of understanding why the world doesn't work out so well necessarily, given all this marvelous motivational hardware, if you like, that you've got, is that look-- most of the time when we study these things, we're studying a motivation in isolation.

You want to study this cat's ability to learn about the puzzle box and the relation to the motivation of hunger. You take a hungry cat, you put it in a box. The only thing of any interest here is how to get out of the box and get to the fish.

The only thing of interest here is there's a rat who's maybe a hungry rat in this case. He's got an electrode now in the feeding centers of his brain. And all the other things that a rat might do are just not relevant here.

You don't operate in a world like that. You operate in a much more complicated space. I mean, we can cartoon that here.

Here's you. If we got in the lab, maybe we can just do an experiment on when you do or do not eat. But that's not what you're dealing with out in your-- well, all right, here's a way to get to this question. How many of you have ever eaten something when you weren't hungry?

What's the matter with you? I just told you you've got this elaborate stuff. I've already erased the lateral hypothalamus. You have the brain full of circuitry designed to make you eat when you're hungry and not to eat when you're not hungry. And you don't look like that furry football with a lesion in your brain. So what's your problem that you're eating when you're not hungry?

Well, all right, let's think about this in metaphorical terms. Let's imagine a situation where there are lots of different possibilities pulling on you. Suppose you're at a social gathering of some sort. There are lots of possible things, lots of motivational systems at work at any one time.

I mean, one of the things you could probably do is eat. Maybe there's the possibility for fighting, mating, sleep, study. You could do all sorts of-- run-- you could do all sorts of stuff.

And all of these things, each of which may have its own beautiful hard-wired core and its elaboration from a lifetime of learning, all of these things are pulling on you at once. And all right, so maybe the sleep motivation and the study motivation are pretty weak at any given moment.

[LAUGHTER]

But let's suppose that there's pretty strong drives in this direction. So if you're sitting in this exciting vector field, where's the resultant?

[LAUGHTER]

Now, I'm not proposing this as a serious model of why you might eat. Well, I am proposing it. I'm not proposing it as a serious mathematical model of why you might eat, but I'm proposing it as a serious metaphor-- that you might engage-- and it's going to be much more complicated than this.

Part of the reason-- it's not just that there's want to mate, want to fight, oh, think I'll go eat instead. But want to mate here? Now? Can't do that.

But there's those brain stem chunks of general arousal. Well, I've got a lot of activity here that I've got to do something. So you end up with displacement activity.

The problem is that the world is a complicated place. And if you were ever going to reduce this to math, it's going to have a lot of variables. It's going to end up with a lot of variables in the equation.

Most of us manage to do OK. We eat when we don't want, but that's all right. Later on in the course, you end up talking about, perhaps, the people where you find that they're fighting too much or something like that.

No lecture Thursday. Just to reiterate, I will sign all those lovely add-drop cards. I'll see you next week.