JEREMY WOLFE: This is the lecture on sleep and dreams. And you want to know about this because it's-- well, at MIT, sleep and dreams is a topic that falls under the heading of abnormal psychology.

[LAUGHTER]

All right. Let us ask, to begin, how many people here got some sleep last night? OK, of those people, how many people went to sleep even though they knew they still had stuff they wanted to get done? All right, so what's your problem?

Well, the typical MIT answer to that is a sort of a moral argument. I'm weak. I'm a miserable human being. If I was a good, strong human being, I would not have gone to sleep. I would have done that problem set, and so on.

And if you were not an MIT-- I mean, MIT is merely at one extreme here. Western civilization in general, increasingly since the invention of the light bulb has been an increasingly sleep-abusing, sleep mechanism-abusing culture. But if you were left to your own devices, or to what Nature had intended, you'd be sleeping about eight hours a night.

And you would be doing this across your lifespan, with the result that you would spend about a third of your life asleep in this altered state of consciousness or unconsciousness. And if you're teaching a course on human behavior and human mental life, that requires some explanation. Why do people sleep?

What is the nature of that behavior left to its normal state? What happens when you abuse it? Why do people dream, which is psychologically perhaps the most interesting piece of sleep.

And is it possible to get any-- do those dreams, do those weird stories, have any meaning? Those are the questions that I'll talk about. I don't know if I'll get to the end of it today. Otherwise, I'll pick up after Thanksgiving.

But let's talk initially about why and how you sleep. Well, look, one level of answer would be you sleep because every so often nuclei, collections of nerve cells deep down in your brainstem, send volleys of signals up to the rest of your brain that basically make like a hammer and knock you out. But that's not a deeply satisfying answer. But it does point to the fact that it's a very basic drive and it's a very powerful drive.

Look-- if you wanted to, you could, for example, as a statement of extreme political conviction, sit right here and starve yourself to death. Hunger is an important drive. There are several people illustrating that at this very moment. But if you wanted, you can override that and not eat, even to the point of killing yourself.

That's not true, for example, about your breathing. If you wanted to sit here and hold your breath until you died, [GASP] it wouldn't work. You may have tried this when you were little.

One of my two sisters used to be a fan of this. If we were teasing her and chasing her, she would just hold her breath until she keeled over, which was very dramatic, but not, in fact, life-threatening except in the indirect sense that my mother was not thrilled with us making my little sister pass out. You could ask her. She'll be here tomorrow, but you'll all be leaving.

Anyway, this drive to sleep is more like the need to breathe than the need to eat, in that sense. If you were to sit here and by an act of will declare, I will not fall asleep-- as you well know, there's a substantial number of you who can't manage to do that for an hour and a half.

[LAUGHTER]

That has to do with how you're abusing the normal mechanism. I used to take this as a-- when I first was teaching, I used to look out at 10 to 50 full of Intro Psych students and they're [SNORES]. And I'm thinking I'm not being lively enough here.

I realize at this point I could be setting off large explosions on a regular basis, and it wouldn't matter for some people. We'll get to that in a minute.

But even those of you who are well rested, you could not sit here and not sleep. Probably you couldn't make it for 24 hours. Absolutely you could not make it for 48 hours without external help, either from drugs like caffeine, or more particularly, from somebody smacking you around to keep you awake.

If you're in a sleep lab and you want to keep somebody awake for 36 hours or something, to see what happens, you sure don't say, "I'll give you $10 if you can stay awake all night." You need somebody there to slap them around and keep them moving, or they'll be out. There's just no way to suppress that.

It's very, very powerful drive. So how come? What's doing this?

Your need to sleep is driven by two primary factors. One of them is a so-called circadian rhythm. The term comes from circadian, is about a day, because it's a rhythm with a periodicity of about 24 hours.

And if you manage to measure it in isolation, and you were to measure something like alertness, it would have a roughly sinusoidal shape to it, this particular drive. And when you wake up, it's actually at a relative low point, about 6:00 AM-- yeah, right. At 6:00 AM on this chart, it's at a relative low point.

Your alertness, driven by the circadian clock, rises systematically during the course of the day until early evening, and then declines to a nadir around 4:00 or 5:00 in the morning. When you're trying to stay up all night, that time in the wee hours of the morning when it's just really, really tough and you're getting the shakes and all, is when this circadian clock is crashing is hitting its minimum.

How do we measure this? How do we measure circadian cycles? Well, if you're a mouse it's actually relatively easy. Stick a mouse in a cage with one of those little running wheels, and put a sensor on the running wheel, and you'll get out a graph that looks like the graph that I put on the handout.

Each of the lines on that graph is one day. So you've got a day here. And the mouse is doing nothing much. And then at a certain point, the mouse jumps on the wheel and does stuff.

Now, the convention of the circadian trade is to double plot their data. So the line is the same data plotted twice. It just makes it easier to see trends over the day. So this is inactivity, activity, same day.

And so this is 24 hours. And you can see that the mouse does this every day for day after day, like clockwork, as it were. Because the mouse has this little clock that's telling it.

Now, the point at which the mouse is firing things up, right about here, is-- the mouse is on a 12-hour light/dark schedule. And when the lights go out, the mouse turns on. It's a nocturnal beastie and when the lights go out, he jumps on a wheel and goes berserk.

Now, what happens halfway down that graph where there's an arrow pointing at the side of the data? At that point, you leave the lights on continuously. And what you discover is that the mouse still behaves in a very systematic fashion.

I'm not going to bother double plotting my data anymore here, but now, the period is starting to drift. The mouse is now doing what's known as free running. And this is a way that you can take a look at the circadian cycle in this beastie because he's now no longer got the light signal telling him what time it is.

And what you discover is that it's advancing by about 30 minutes a day. Because the mouse clock has a period, a circadian period, of about 23.5 hours, not quite 24 hours. If you were in the same experiment and you were inclined to run around in a wheel, the data would actually go this way a little bit because the human clock has a period of about 24.25 to 24.5 hours-- some variation, but it's, again, around a day.

It gets synchronized to the real day by light most strongly. So you know when it's morning because that's when the sun comes up. If you never get outside and you live in constant light, your clock may be drifting, too, in some fashion. But given a normal exposure to light/dark cycles, that sets the clock.

How many people are flying across time zones in the next few days? So you guys are all going to be jet lagged in some fashion because your clock is set for East Coast, US. You'll go someplace else. Get outside because it's exposure to the sun that will reset your-- exposure to these sort of lights will reset you, too, but the sun is sufficiently brighter that it makes a bigger difference.

This clock, by the way, has a home. It's located in the suprachiasmatic nucleus. Looks more complicated than it is. "Supra" for above, and "chiasmatic" for the optic chiasm.

That x where the optic nerves cross on the way from the eyes to the brain-- this sits right on top of that and gets direct input from the retina. It's got its own visual system, in a sense. And now, how do we know that this is where the clock lives?

There are a number of ways, but the coolest way that we know that this is where the clock lives is that there are clock mutants out there-- probably some human, but certainly mouse mutants. And suppose you've got a mouse mutant who, let's say, has a clock running at 22 hours or something like that. You can go in take out the suprachiasmatic nucleus from that mouse, put it into another mouse.

And this is a case where a brain transplant will actually work. The recipient mouse will now start running with the clock timing of the donor mouse. So you want a new clock? You can actually go and get-- I don't know if you can go and get one from a mouse. And probably your neighbor doesn't want to donate.

But there are also other clocks, by the way, that live in places like your liver. But the main clock running your behavior is sitting up there in your brain, and reset by light, and in fact can be transplanted, apparently.

Now, humans don't tend to run in little mouse wheels very much. If you want to measure this in a human, if you stick a human in continuous light and cut them off from the external world, which you can get yourself paid to do if you want-- one of the leading sleep labs in the world, actually, is across the river at Brigham and Women's. My lab actually does some collaborating with them. So if you're interested, talk to me.

People do this as a summer job. You get locked in the lab for the summer. And people think, oh, I'm going to write the great American novel or something like that while I stay up all night or something. But you get paid a decent rate for this.

Now, we're going to want to keep track of what your circadian clock is doing. The sorts of things that vary with your clock are, for example, body temperature. Your body temperature has about a one degree plus and minus swing with the circadian clock.

So if you've got a fever, for example, you probably remember from when you were a little kid that your fever would peak in the early evening. And if you stay up all night, it's 4:00 in the morning where you suddenly feel chilled. That's because your body temperature is actually varying as a function of the circadian cycle.

There are lots of circulating hormones, like melatonin and others in the blood, that also track the circadian clock. So if you're in the lab, somebody is going to be monitoring these various aspects of your physiology in an effort to take a look at where your circadian clock is. This is one of the things that discourages people from immediately signing up because, for instance, if you're going to be taking continuous measures of body temperature, the thermometer is not under your tongue.

[LAUGHTER]

It's a slow group. Anyway, so you've got the circadian clock that's driving your alertness. And the other piece that's driving your alertness, or inversely, this powerful drive to sleep, is sometimes called the sleep homeostasis-- simply a homeostatic mechanism that says the longer you're awake, the more tired you get. This is not a huge surprise.

So we can graph that here. So this is, again, alertness. Let's say this is 6:00 AM again. Now, let's say that you wake up at something like 8:00.

And basically, as a roughly linear function of during the day you get sleepier, and sleepier, and sleepier, and sleepier, and sleepier. This thing builds up pressure to sleep. If you now go to sleep at, let's say, 11:00 that recovers. It recovers, at least initially, rather steeply, and then probably has an exponential tail. It's not absolutely clear.

But if you combine these two, if you were to combine these two in the way that Nature intended, what you get is a sustained period of-- let's look at the course of the day. Suppose you wake up in the relatively early morning. Your circadian clock is relatively depressed, so it's still feeling kind of sleepy.

But your homeostat is fully refreshed. So you're up here, let's say, in alertness land. And now as the homeostat is going down, the circadian chunk is going up.

And so for a sustained period of the day, say until early evening, you have roughly level alertness. Believe it or not that's what really happens to people who are pretty well rested. They are awake during the day.

[LAUGHTER]

Sometime in early evening, when that circadian clock turns downward, things start going downhill for you, when your alertness starts steadily dropping. And at some point, it drops enough that you-- well, that people who are not abusing the system-- go to sleep. At which point-- so now, when you're-- so now you're asleep. So you're not terribly alert.

So what's happening now is-- so you're down here in sleep land somewhere-- now, your homeostat is recovering. But in the early portions of your sleep, or during the course of the night, the circadian thing is still crashing down. So even though you may have climbed up here already on the homeostat, you're crashing down to here.

And the circadian thing is saying, stay asleep, stay asleep. It's good for you. You should be asleep for this sustained eight hours.

And then it turns around in the early morning hours, and 4:00 or 5:00 or 6:00 AM, you wake with the chickens. And you're bright, and perky, and alert like you are every morning. And you know you're back.

So what you get out of this system, if it's being allowed to work properly, is a sustained period of alertness during the day and a sustained bout of sleep during the night. If you crash the circadian system, for instance, you end up with broken sleep. So if you blow up a mouse's circadian clock, then what you get is a mouse who runs and naps, and runs and naps, and runs and naps-- doesn't have this organized pattern to it.

Now, the great tragedy, of course, is that you guys, who are in the peak of your ability to do this, aren't doing it. You're just abusing the pants off it. The structure of sleep changes over the course of the lifespan.

Babies sleep for a lot longer than adults do. After early childhood, they people have a fairly constant requirement for about eight hours. The range is really about seven to nine hours. People who say they require only four hours of sleep or something like that are basically lying to you.

Thomas Edison-- he's always trotted out as an example here. I don't remember what he needed, two hours a night, four hours a night. Well, there was a reason the man had a cot in his office. The people who don't sleep eight hours at night are catching naps when they can and are building up a sleep debt the rest of the time.

And if you are Dement-- William Dement is one of the Stanford sleep researcher coined the term "sleep debt," I think-- argues that it may be the biggest health problem in the US. Why is that? Because all sorts of stuff from traffic accidents to industrial accidents and so on occur in-- well, basically, in the wee hours of the morning when the circadian clock is busy crashing. Because sleepiness is not good for behavior, as you may have noticed in various and sundry ways.

When you get older, it turns out to get harder-- for reasons we don't really understand-- to maintain this consolidated period of sleep. So it is a sad fact that I, for instance, do not typically manage to sleep eight hours solidly-- at anything like eight hours solidly-- at a stretch anymore, even though I have long ago abandoned my various efforts to abuse the system. I'd love to sleep a solid-- well, seven would be happy enough.

But as you get older, it's harder to maintain it. You can do it now and you're not doing it. It's so sad.

So what are you doing and why are you so deluded? Well, in part, you're being deluded by this circadian clock. Because what happens? You stay up all night.

So where shall we plot this? Well, we don't have any color. OK, so you're alert. Here, we'll do this.

Let's assume that you were once well-rested, like before you arrived at MIT or something. And you stay up all night. So you were doing fine till here, and now, you're going to stay up.

[MAKES SOUNDS]

We're getting sleepier here. Well, there's the coffee, and the Jolt Cola, and who knows what else smacking you around, and stuff happens. But you're fighting a losing battle here. And it's 4:00 in the morning and you're barely holding on.

And let me tell you, that psych paper that you're writing at that point is not your best work. So there it goes 4:00 in the morning. But 6:00, 7:00 in the morning-- you've been up all night, and what happens?

The circadian clock turns around. (SQUEAKY VOICE) I did it. I did it. I don't need to sleep, I'm so good. I'm a real MIT student. This is great.

But it's all fake. And you think you're getting back up here-- forget it, man. You're in here somewhere, all [IMITATES BOOM] psych class. [VOCALIZING]. So you're ambling around with this business.

If you think that this is great evidence that "I'm Superman and I don't need to sleep," try it the second night. I don't know how many of you have ever tried staying awake two nights. The way to stay awake two nights in a row is to have somebody shooting at you.

[LAUGHTER]

Leading funders of sleep research are Army and Air Force. And they have a very particular interest. Their interest is-- well, they have two interests.

The Army interest is, we're going to take over this country in 100 hours straight. And our boys ain't going to sleep until it's done. And we don't want any ill effects of this, and got some good drugs for us?

We need drugs. We want good drugs. That's the Army research program.

The Air Force says, we can fly at night. This is cool. We've got really cool toys.

We can fly at night. It's really bad when the helicopter guy falls asleep. So we need him to stay awake at bad times. So they're big-time funders of this kind of stuff.

It is the fact that your general level of arousal will keep you up. And so the panicked sense that you're going to flunk psych if you don't finish the paper will do some good. The panicked sense that if you fall asleep somebody's going to shoot you does a lot of good.

You can stay awake for a long time under that basis. But it's not that you miraculously-- if you just can make it past here, you get back up here. This thing, if you don't keep recovering, it just keeps going. And eventually, you're going to fall asleep. It's just going to happen to you.

So that's the broad 24-hour scale of sleep. Within that, there's a structure on top of that.

Now, I'm not going to draw this accurately, but there's a 90-minute ripple sitting on top of this circadian clock that runs all day, and throughout, and while you're asleep. You know this during the day by the variations-- what you may have noticed were reliable fluctuations in your own alertness during the day. And in fact, you can probably do this-- I should collect data on this some year. I'll have to make up a little questionnaire.

The clock is about 90 minutes. This lecture is about 90 minutes. So sometime during this lecture, you'll hit the nadir of that 90-minute cycle.

And actually, I can at least ask the a general question. How many people think they could identify, within plus or minus 15 minutes, the point during an average intro psych lecture where if they're going to lose it, it's where they're going to lose it?

Many, many of us know that there are just chunks of time that are bad. And you might notice if you check out-- if you were to systematically survey those during the course of the day, of course it interacts with things like when you eat your meals, when you get up, whether you ever got to sleep last night, and things like that. But you may be able to peg a series of these spaced out at 90 minutes or maybe 180 minutes during the course of the day. You see these at night, too.

And let's see. Let's find myself another board here. Go away. What have we got under here?

To talk about that, let's fill out this cute, little chart on the handout. If I just stick a bunch of electrodes on your head and record the electroencephalogram, the massed potentials off of your billions of neurons in your brain, what I will see, grossly, is high frequency, low amplitude stuff while you are awake. So this is EEG.

Depending on where I put my electrode on the scalp, I can get a lot of other interesting information out of it. But for present purposes, the important thing is that the massed activity of the brain is relatively high frequency, low amplitude stuff. If I now take a look at you when you are deeply asleep, what I will find is low frequency, high amplitude waves roughly corresponding to-- what's going on is that in deep sleep, large bodies of neurons are firing together.

Everybody's on then everybody's off. And if you're woken up out of that state, that's the [MAKES SOUNDS] I don't know where I am kind of state. You're deeply asleep here.

The interesting thing, discovered now about 50 years ago, is that every 90 minutes or so, you'll go into what we will call rapid eye movement sleep, for reasons that will be apparent in the next line of this table, where all of a sudden, the brain goes back to this high frequency, low amplitude kind of signal. Now, research over the course of the 50 years makes it clear that this is not exactly the same as this. But it certainly looks awake-like.

But the person is still clearly asleep. The interesting thing is that if you wake somebody up out of this state, they will reliably report that they are dreaming-- not all the time. If you wake people up out of this state, they will reliably report that they are not dreaming-- again, not all the time. Sometimes. It's not a perfect divide, but lots of narrative dreaming here.

Here, you tend to get-- if you wake people up and say, what was going on, you might get an isolated thought or some idea that was rattling around. But you won't get that, "I was flying naked through the Infinite Corridor with a panda on my back," or something. We'll talk about that later.

[LAUGHTER]

And this is the nighttime manifestation of that 90-minute cycle that you also see running during the course of the day. You can pick that up in the movements of the eyes, too. That's the electrooculogram.

While you are awake, your eyes move ballistically. If this is say-- whoops, not to the 4, to the left and to the right. Your eyes are sitting in one place, then jumping someplace else, and moving around like so. And the two eyes are moving together, so-called consensual eye movements.

In deep sleep those ballistic movements called saccades disappear. And the consensual movements are damped down, too, so the eyes are kind of rolling around in your head. And they're not necessarily rolling in the same place.

When you go into rapid eye movement sleep, the reason it was called rapid eye movement sleep is the eyes look like they're awake again. So again, ballistically jumping around and jumping together. Is the pattern of eye movements related to what's going on in your dream?

Well, there's anecdotal evidence for it. But if you think about it, it's very difficult to do the experiment in any terribly meaningful way. Actually, there's some interesting data in animals at this point to suggest maybe it is.

But in any case, the eyes look like they're awake here. The eyes are doing the same thing that they were doing when they were awake. You can see this in your roommate, particularly if your roommate has relatively thin lids.

You can often see the eyes moving around under the lids. And if you watch your sleeping roommate--

[LAUGHTER]

--your sleeping roommate may think you're a weirdo when he or she wakes up, but you can actually see the eyes jerking around under the lids. And if you have an unusual roommate who sleeps with the eyes open-- this actually happens.

The reason for sleeping with your eyes closed has less to do with-- it presumably has something to do with cutting the light out, but it has mostly to do with keeping the cornea hydrated, keeping it moist while you're asleep. If you sleep with your eyes open, you wake up with a nasty, scratchy, itchy eyeballs.

Because if you think about it, you don't sleep with your ears closed. It's perfectly possible to use your brain in some fashion to shut off enough of the ambient outside stimulus to go to sleep, to get rid of the auditory stimulus. So in principle, you could do that with your eyes, too.

But you close your eyes to keep them nice and moist. So some people, that doesn't work terribly well. I traveled across France in a train with a guy who fell asleep, but his eyes were open. And it's like traveling across France with the undead.

[LAUGHTER]

Because at some point, he went into REM sleep. And his eyes are going all over the place. But he ain't looking at nothing that's there. And it was a little strange.

So far, awake and dreaming sleep look the same. There's one place where that-- in case you're having trouble telling whether your roommate's actually asleep, here's how you can tell. You measure muscle tone, electromyogram.

When you are awake, your muscles are on. You have good muscle tone. That's why your head doesn't fall off your shoulders, and I can stand upright, and stuff like that.

When you are in deep sleep, actually, your muscles remain on. The muscle tone remains high. It's when you go into REM sleep that you lose muscle tone.

You can see this in your friendly neighborhood cat. Because all this stuff shows up widely in mammalian species. So your cat who's sleeping like this, that's a deeply sleeping cat whose muscle tone is doing just fine, thank you. Your cat who's sleeping like that is a cat who is in REM sleep and has lost muscle tone.

All right, now, why? Why would you turn the muscles off in REM sleep? Yeah.

STUDENT: [INAUDIBLE]

JEREMY WOLFE: Yeah. If you're busy being Superman and leaping tall buildings in a single bound in your dreams, it's a really good idea if you don't actually try that out. And not only are you protecting yourself. You're protecting anybody else you happen to be sleeping with.

A known sleep disorder in older men is that this blockade of voluntary muscles fades off. And the result-- and this is a known disorder because older women bring the older men to the doctor because their husband is thrashing around in the middle of the night and whacking her. And this is a real problem. People get hurt.

So you want the muscles to go off. There are a number of corollaries here. It turns out that sleep-walking-- Shakespeare has it wrong. Lady Macbeth is clearly dreaming about having murdered Duncan and all that when she's sleepwalking.

Typically, sleepwalking is not acting out your dreams. It is a version of non-REM sleep and much more typical in children than in adults. And I don't know, how many of you know that you used to walk around at night when you were a little kid, wandering around. Their eyes are open, but nobody's home here.

And I don't know how-- I don't actually know that much about it. My theory is that part of what's doing this is it's your bladder telling you to get up, and the rest of your brain saying, we want to stay asleep here. My theory is based on one of the great moments of child rearing in my household, which was one of my children-- we were awakened in the middle of the night, my wife and I, by one of my sons yelling, "No, not here," to the other son, who was about to use a trash can for the wrong purpose.

[LUGHTER]

Anyway, it all worked out in the end. But this is a deep sleep phenomenon. Talking in your sleep is often, apparently, talking out of-- you're not going to hurt yourself too much if you don't blockade your jaw.

It's the main body muscles that are the real threat. And so sometimes, people will end up talking in their sleep, often to the amusement of other people in the room or to the inconvenience of other people or of your own relationships, if what you're talking about in your sleep is somebody else other than the person who's currently present with you.

Anyway, it's not clear this-- well, we get that when we get to meaning of dreams, we can talk about this. Anyway, so within the circadian cycle, this is the structure you get in sleep. And now, there's much more to this than what I'm telling you. Deep sleep can be subdivided into multiple stages that differ in the activity of different parts of your brain, and so on.

So now, between 24-hour cycle and this 90-minute cycle, there is yet another level of structure to a night's sleep, where there's more non-REM, slow-wave, deep sleep early in the night. If you have a consolidated bout of eight hours of sleep, a normal night's sleep, what you will see is more of this stuff early in the night and more of this stuff later in the night. And this is accompanied by systematic changes in the neurochemistry of the sleeping brain, and so on.

So there's an intermediate level of structure to sleep, also. The impression one gets is of a beautifully structured system that is designed to do something. So apart from the obvious-- it's designed to keep you from feeling sleepy-- one wants to know, what is sleep for?

You'd be surprised if a third of your life was spent in this state for no good reason. Look at that-- it says part two, why do we sleep? And it suggests that there are several possible reasons here. Anybody care to offer any possible theories of why we sleep? Nobody's got a clue? Yes.

STUDENT: [INAUDIBLE]

JEREMY WOLFE: OK, so there's a basic rest and regeneration notion. You used your muscles all day, you built up all those metabolic byproducts in muscles that you learned about once upon a time. Sleep, rest, will give you a chance to clear that out.

So certainly one possibility is it's an enforced rest period. You could enforce rest some other way, presumably. Well, it could be good for you to rest, period-- just lie around and do nothing. But sleep kind of enforces that. Yes, there was a hand over there somewhere. Yeah.

STUDENT: [INAUDIBLE] memories.

JEREMY WOLFE: OK, so there's a whole class of theories, and these are actually the ones where there's, I suppose, the most current interest, that have to do with learning and memory-- that somehow what sleep is about is tuning up your memories and/or consolidating memories, improving learning, or something like that. Let's talk more about that in a minute. But if you're sitting there saying, "I'm a real MIT student, I don't need to sleep," you might worry about theories that say sleep is vital to the consolidation of memory. Yeah.

STUDENT: It's a lot easier to test during the day. So we don't need to waste all the energy [INAUDIBLE].

JEREMY WOLFE: Yeah, OK, so another possibility is energy conservation. You could be awake all of the time. But if you can't hunt when it's dark, you might as well go and power down the disk drive or something like that, and not use as much energy.

Your brain's pretty active while you're asleep, as you may gather from this. But the rest of you, of course, is getting some rest. Anything else? Any other good possibilities?

Along with that energy saving one-- well, here-- we can motivate this one related to energy saving by asking, where do you sleep when it gets dark?

STUDENT: In bed.

JEREMY WOLFE: In bed, that seems like a good place. Where did you put your bed?

STUDENT: [INAUDIBLE].

JEREMY WOLFE: [INAUDIBLE]. Anybody big on sleeping on the-- putting their bed out on the sidewalk? Or those of you who are hunter gatherers, when you're tired, you just lie down in the middle of the field? No, because it's not really very safe.

So another possibility is that you want to sleep for purposes of protecting yourself at times that-- as a corollary of this you can't hunt all day thing, there are other things out there that have adapted themselves to the niche that you are not in. They hunt at night. So if you're not going to hunt at night, not only do want to be calm and quiet, you want to be out of the way.

Because otherwise-- oh look, he's asleep. Let's eat him. So there's a safety aspect to it. And the other part of the safety aspect is that not only don't you want to hunt at night, if you just go wandering around aimlessly at night, you're going to fall in a hole and hurt yourself. So you better get in the hole first and go to sleep.

Let's see, do I have any other brilliant theories here that I wanted to mention? That's pretty good. You guys managed to do a quick survey of the leading theories.

As I say, a lot of the cool current data on this issue centers around this idea of sleep having a role in learning. And let me tell you a little bit about that. The picture that's on the handout is an illustration of what looks like a really trivial task.

The question is, is there a little vertical region in that display somewhere? And the answer is, yeah. Now I can make that task arbitrarily difficult by flashing the stimulus very briefly and following it with a mask of some sort. So I can make it hard. I can make it as hard as I like.

And if I do that, what I can do is measure-- let's call it a threshold time. So maybe in order for you to get this task correct 70% of the time, I initially need to have the stimulus on for 200 milliseconds. If you practice it for a while, you'll get better, and that'll level off at some point.

What a number of people have-- well, Karni and Sagi, I think. Dov Sagi is the guy I know. What a number of people found, starting I think with Karni and Sagi is that if you let people sleep-- in particular, if they are allowed to have REM sleep-- that performance gets-- well, here, let's have them sleep for eight hours here-- that performance gets better, as if something happened while they were asleep.

If they don't sleep during this period, they don't get better. So it's a sleep-dependent improvement in behavior. This is a very specific little bit of learning. This isn't just a general overall improvement in behavior.

If you train people with that little vertical patch, so maybe you're doing a task-- is that region vertical or horizontal. You have the three things vertical or three things horizontal. And I'm looking here, and it's always down and to my left.

I learn to be faster here. I don't learn to be faster here. And the improvement in learning is specific to the little piece of retina that I have trained. So it is very, very specific learning that seems to be dependent on getting a decent night's sleep.

Now, interestingly, there is evidence-- how many people here are nappers? How many people here are nappers just because it happens? We can do it this way-- how many people here think that if they take a nap in the middle of the day, they wake up feeling better for the experience?

How many people think if they have a nap, they wake up feeling cruddy for the rest of the day? So we don't quite-- there are people who find naps to be refreshing and useful, and there are people who find it to be disruptive. It was certainly a big improvement in my professional life when I reached the level where I had an office of my own.

And the biggest part of that was it made napping a great deal more graceful. After lunch, I could take the latest issue of *Vision Research,* and prop it up, and stare at the same two sentences for 15 minutes. And I feel much better thereafter.

There is evidence that a properly timed nap is just about as good as a night's sleep for this perceptual learning. This is work done by Sara Mednick originally up at Harvard. And this is new stuff. We don't really quite understand fully how far we can take this.

It's the thing that your average MIT student is tempted to take and run with. Oh, man, I can get the whole benefit of eight hours of sleep if I just go for nine-- I think it's 90 minutes between 2:00 and 3:00 in the afternoon. That works. Great. Now I can stay up all night and do it.

Anyway, we don't know that yet. But Mednick's study is an interesting suggestion that napping sleep can serve this same sort of perceptual learning kind of role. But look-- one might actually wonder whether anybody other than vision researchers cares about whether or not you can find little, briefly flashed lines in one corner of your visual field.

That's not what you want to know about learning and memory. What you want to know is, is anything really useful happening while you're asleep? In particular, one of the things that people want to know is, can you do serious thinking in your sleep?

One thing you can't do is to study in your sleep. So there have been endless efforts, because people smelled money at the far end of this, to produce tapes that you could stick under the pillow, record Gleitman. And why waste precious waking hours reading Gleitman? I'll just have somebody else read it to me while I'm asleep.

Sorry, the overwhelming evidence is that nothing happens. The mild effects that are sporadically shown here come from periodic awakenings during the night. And that also goes for sleeping through the lecture. If you're sound asleep during the lecture, it's lovely that you were here, but you'll have to ask somebody else what actually happened.

So that doesn't work. But can you have insights or can you do your problem sets during your sleep, in some sense? How many people have had the experience of being dead-ended on a problem?

It's time to just give it up. You go to sleep, and you wake up, and somehow, the answer kind of seems to be there. It's a not uncommon experience.

And there are lots of anecdotes in the literature about this. One of the famous ones is the guy who first described the ring structure of benzene claims that he had a dream of a snake biting his tail, and he woke up knowing that benzene was a ring or something like that.

It doesn't always work, by the way. My father spent his career as a physicist and had the same experience. He's working on a problem, not getting anywhere, goes to sleep.

Wakes up in the middle of the night, he knows the answer. And he knows you don't remember stuff from the middle of the night, so he writes it down fast, and goes back to sleep. Gets up the next morning. As predicted, has no recollection of what the great answer was, but he does remember writing it down, which is good.

So he looks at it, and he sees that the answer is, "All the world is suffused with the smell of cinnamon."

[LAUGHTER]

Which I'm sure was an answer, but wasn't necessarily the answer he was looking for. So this notion that you could actually be doing something productive in that sense during sleep was really in the realm of anecdote until this year. I put the reference on the paper by this group in Germany, led by-- I suppose since he's in Germany it must be Wagner, et al.

Beautiful experiment-- you know these number games, where you get a string of numbers and you have to predict the next number in the series? Well, I can't remember the particular one here, which is just as well because at MIT, all that would happen is if I presented it, you'd be sitting there for the rest of the lecture trying to work out what's the rule here. Anyway, it's a clever-- go look at the paper. It's a beautiful paper.

But they picked one of these things where there were two ways to solve it. There is a laborious, multi-step thing-- you add the last two numbers and then divide by the third back number. There's some weird thing and you can do it, but it takes a long time.

And so if you measure the amount of time for-- so this is going to be time again-- measure the amount of time to get the answer, people are initially very long. And then they get better and [INAUDIBLE], and you get better, and you get to some stable level.

But there's a trick. And if you have this flash of insight, you realize-- I don't remember what, but there's some trivial way of knowing what the number is. And if you get it, it's trivial to see in the data because your time drops like a rock and it stays there.

So now, what you do is you take people. You train them on this. And they're sitting there at this high asymptote here. And you send them away.

You either send them away for eight hours of daytime stuff, come back tonight, and we'll test you again. You send them away-- I don't remember, actually, keep them in the lab. You can keep them in the lab and keep them awake, or anyway, you send them away at night.

So you want to make sure that it's not just a day/night thing, but don't let them sleep. Or you have people who go to sleep and have eight hours worth of sleep. And the finding is that the next day, some people are-- eight hours later, rather, some people are here.

Some people are here or rapidly get here. And 50% more of the people who had a night's sleep got here. It's not that everybody went to sleep and had this kaboom of insight. But seemingly, something about that night's sleep produced this rapid burst of insight in many more people in the sleep group than in the two other groups.

And it's, I think, the first really good experimental evidence for an ability to get something more like higher level cognitive thought happening while you're asleep, not just these relatively low-level perceptual learning kinds of things. So the general evidence suggests that sleep has an important role to play in managing your cognitive life in some fashion.

It probably serves a role in consolidating memory. It probably serves a role in problem solving. It's certainly is the sort of thing that one might think about as one is saying, I'm going to stay up all night reading Gleitman because tomorrow's the final exam. Might not be absolutely-- well, if you haven't read Gleitman before the final exam, it's probably true that reading Gleitman all night is better than hoping that eight hours of sleep will produce a flash of insight about the imagined contents of Gleitman.

All right, let us discuss-- all right, I'm supposed to tell you what's going to happen when you're sleep deprived. I see. But let's do that in a minute, after you wake up the person next to you who's dozed off, because they want to hear this piece.

STUDENT: You were talking about this experiment, and you don't really have an insight, you can't really study at night. How are all these stories about Liszt and all these famous composers, who would actually keep their glasses and keep their notepads right next to them because they write half their greatest music [INAUDIBLE].

JEREMY WOLFE: The fact that my father thought that the world [INAUDIBLE] the smell of cinnamon doesn't mean that you don't wake up in the middle of the night with an honest-to-goodness first inspiration. It just means that it's not a privileged state that guarantees it.

Is anybody interesting calling me or just my kid? Since I'm in the middle of a break I'll just check what this is. Hello

[SIDE DISCUSSION]

If you'll keep recharging the homeostat, you're going to still lose it to the circadian piece. But yeah, you can spread out the eight-hour demand over the course of the day. People typically find it harder to fall asleep during the day.

STUDENT: I've had this tendency to actually be able to have conversations [INAUDIBLE] sleep [INAUDIBLE]

JEREMY WOLFE: There are all sorts of liminal borderline states between being awake and being asleep. And when you're talking to somebody while you're asleep, nominally, it's one of these borderline states. I think let's talk after class.

[SIDE DISCUSSION]

All right, so what happens to you? You were clearly built to sleep. What happens if you abuse the privilege and you're running a sleep debt? And the answer is, most people here-- and in fact, most people in America-- are running some sort of a sleep debt. What is the cost?

Well, you can measure costs in a variety of different ways. You can certainly measure costs in terms of things like industrial accidents, car crashes, and stuff like that. The classic sleep deprivation car crash is a crash on a clear, straight road on a moonlit night.

You're a nice long-distance trucker who's abusing the rules about how long you're supposed to be able to drive at once. You're out, there's no car in the vicinity, the road is straight. It's not bright light, but you can see everything. The road turns a few degrees and you don't-- straight out into the cactus or something like that.

Because when you get really sleepy, if you take a look at people's brainwaves, you can watch them flipping into these little micro sleeps that don't necessarily last very long. But at 60 miles an hour, 80 miles an hour, 90 miles an hour, they don't need to last very long for you to end up in the sagebrush.

There are plenty of ways to measure it in the lab, too. If you sit somebody in the lab and tell them, all I want you to do is push a button when I turn on this little light. It's the only thing you need to do. What you discover is that people are about 200 milliseconds slower at adverse circadian phase, at the bottom of that circadian trough, than they are at the top of it.

And on top of that just general slowing, there are also a whole bunch of times when they'll just miss the light altogether. The light will come on and the subject will be just-- uh-- and not do anything about it.

Now, 200 milliseconds-- what's the big deal? It's only a fifth of a second. Well, again, at 90 miles an hour, it makes a difference. And if you're flying your supersonic jet around the skies of Iraq or something, it makes it even more of a difference.

So there's a generalized slowing. There is a tendency to trade off speed and accuracy more than usual, in favor of speed. So people tend, when they're sleepy-- we've actually done this in our lab.

So if you're doing one of these visual search kinds of things where you're looking for something exciting like where's the red vertical line, if you go too fast, you make mistakes. People, when they're sleepy, tend to be willing to tolerate higher error rates. Again, that's the thing that, brought out into the real world, if your error rate goes up by two or three times, that can be a real problem in doing real world tasks.

It is harder to prove, but pretty clear-- perhaps introspectively-- that being sleepy makes you stupid. You just don't think as well. For a long time, it was kind of hard to show any effects of sleep deprivation because people tended to do things like ask you to add up columns of numbers.

And as long as I smack you around enough to keep you awake during the task, you can do that. But if I ask you to do, I don't know, your problem set when you're really sleepy, it turns out that the throughput on more complicated cognitive tasks goes downhill. You're just not as good at it.

Will it kill you? How bad can it be? The answer is, probably yes-- not, obviously, at the level that people inflict on themselves.

But prolonged sleep deprivation will kill you if you are a rat, at least. And what kills you is not that you just get so sleepy that you fall over dead, but that staying awake-- or more to the point, being kept awake, which is, of course what's required if you're going to go for any extended period of sleep deprivation-- is highly stressful. And stress will kill you. The rats who die in sleep deprivation studies die of things like bleeding ulcers and stuff like that, symptoms that look for all the world like the effects of severe stress.

You can also ask whether or not deprivation of particular kinds of sleep is particularly damaging. So for example, it's relatively easy to deprive somebody of REM sleep. You can just monitor their eye movements or their brainwaves, and wake them up every time they go into REM sleep.

And they will sleep for most of the night that way. But they won't have-- or they'll have little or no REM. You do get effects of that on these perceptual learning tasks. REM seems to be important in that.

But you can be REM deprived for an extended period of time without collapsing in a heap. There are two reasons we know that. One of them is that people have done the experimental studies of this.

The other is that one class of antidepressants known as monoamine oxidase inhibitors, MAOIs, systematically suppress REM sleep. And these patients report that they don't dream. But they don't have obvious evil side effects.

We don't quite understand how that relates to these theories. People on these things don't say, oh, my goodness, I can't learn anymore. So there's something we don't understand about the relationship between REM and learning there because otherwise, these antidepressants would have a powerful side effect, cognitive side effect, that we don't see.

The other way to do this in animal studies is to keep an animal REM deprived for months at a time, and see, does the animal show these stress symptoms? And the answer seems to be, well, no, not really. If you get sleep, even without REM sleep, the stress part seems to not be there.

My favorite technique for REM depriving a cat in this case-- this is the low rent. If you want to REM deprive your cat, here's how you do it. Take a flower pot, turn the flower pot upside down, put the cat on the flower pot in the middle of a little artificial lake.

Eventually, the cat goes to sleep. Then the cat falls into REM sleep, falls off into the water. Cat doesn't like to fall into the water. Cat wakes up.

And the cat learns to not go into REM sleep. And apparently, in some sense trains itself not to fall into REM sleep, with the result that you can REM deprive the cat for an extended period of time. And this is a very weird study. I don't know where they got their measure.

But the only thing I can remember, the only thing they found that was unusual about this cat is that a normal cat with cat food, if you put a July the 4th kind of sparkler in the cat food, a normal cat will not eat the cat food, but a REM deprived cat will.

[LAUGHTER]

Why? I don't know. I don't know nothing about this. I only know what I read in the literature.

Which reminds me, however-- actually, this should have reminded me-- that the most practical piece of advice, apart from the fact that you should get eight hours of sleep a night, since you won't get eight hours of sleep a night-- I know this. I've been lecturing to this course for 20-plus years and in spite of my exhortations that your physical and cognitive well being really relies on you going to sleep at night, none of you are going to pay the slightest bit of attention to that. So the more practical piece of advice I can give you is how to sleep in class.

[LAUGHTER]

The trick is-- I mean, obviously, what you want to do is you want to sleep in class in a way that kind of masks that fact. And the difficulty is this REM sleep business. The problem is the muscle tone thing.

And it's the head bob portion of the-- [MAKES SOUND] So I can look out there and watch the whiplash. And so that's not going to work.

So what people figure out on their own is that what you want to do is you want to give the illusion that what I or somebody else is saying is so deep that you have to close your eyes to think about it. Now, there are a couple of important principles here. One of them is that it's less convincing that you're thinking deeply about this if your mouth falls open.

[LAUGHTER]

If you're drooling, it's really bad, but so this is good. Support for the chin is good. And the other thing that you learned in 801 was that three-legged stools stand better than two-legged ones.

And so I favor the-- this is I'm really thinking very hard about what you're saying. That can actually be quite-- in fact, you're not fooling anybody. We know perfectly well you're sound asleep.

STUDENT: [INAUDIBLE]

JEREMY WOLFE: What?

STUDENT: Snoring [INAUDIBLE] opening the airway.

JEREMY WOLFE: Keeping the airway open is good. Oh, that was the winner of the most embarrassing moment in intro psych student experience. This was actually the first year I was teaching the course.

I was co-teaching it with another guy in course 9 at the time. And he was lecturing. I've long ago stopped figuring that this was an editorial comment when people fall asleep.

But anyway, somebody's sitting right about over there fell sound asleep. But nobody was sitting next to them. They fell sound asleep and they started to snore.

And eventually, this got loud enough that my colleague had to say, somebody's going-- do you want the definition of embarrassed? The definition of embarrassed is you're sitting in lecture. Everybody's looking at you and you have no idea why.

[LAUGHTER]

So sitting next to somebody is another good strategy if you're actually trying to stay more or less alert. My old doctoral advisor and I had this as a pact when I was in graduate school during the Friday afternoon-- terrible time-- departmental colloquia. We would sit next to each other.

And if it was actually a talk that we cared about, we had an agreement. If I go out, poke me because I want to know what this guy is talking about. He was department chair. It turns out to be very important because one of the rules if your department chair is you have to be able to ask an intelligent question at the end of the talk.

Really good department chairs can do that after sleeping through the talk. But my advisor, who was otherwise an exemplary department chair, was caught up short on this at one talk where he asked a very good question, but one that he wouldn't have asked had he been awake for those 20 minutes of the talk because the guy had discussed this matter extensively. So we would poke each other to stay awake.

Guy joined our lab and he sat two seats away from me. He went out cold. That's OK, but he started shouting--

[LAUGHTER]

--in Japanese.

[LAUGHTER]

Actually, it was probably a bonus that it was in Japanese because whatever he was shouting was incomprehensible to anybody else. And I made this dramatic lunge to get to him before he could manage to get out too much. So now, if you're worried about that, you want to be sitting with your friends here so that when you start talking in your sleep, somebody can get to you before it becomes really desperately obvious.

All right, I suppose the bottom line is that sleep deprivation will not kill you but it won't do anything good for you, except perhaps getting you through your work. Now, let's see, do I want to-- this looks like a pretty good place to entertain questions. And we'll go on to dreaming after Thanksgiving. Any sleep questions while we're here? We've got a question, then you can run for it.

STUDENT: [INAUDIBLE] 90 minutes, is 9 hours you sleep to multiples of 90 minutes, it's more effective?

JEREMY WOLFE: Well, the piece of that that is right-- so the question is, do you want to sleep in cycles of 90 minutes? Ideally, you want to wake up on your own, typically out of the end of a REM stage would be what would normally happen. And yes, you will tend to feel more refreshed there than if you wake up out of this.

But most of us wake up when the alarm clock goes up. And oh, sorry. But if you can manage to adjust that to wake you up-- even if you have to move it a little earlier, you may feel better if you're waking yourself up out of a REM state. Yep.

STUDENT: [INAUDIBLE]

JEREMY WOLFE: That's the neck bobbing thing. When your muscles are going-- when you're losing muscle tone and drifting off into a REM state, bits of you are going where gravity wants it to go. And that can feel like a falling sensation, which inconveniently, can sometimes lurch you back awake-- or conveniently, if you happen to be going out during class. But I think that's typically an effect of the losing muscle tone part.

All right, last chance. Here we go.

STUDENT: How are humans [INAUDIBLE] by living in really northern latitudes where there's [INAUDIBLE]?

JEREMY WOLFE: Well, if you live in really, really northern-- sleep disorders go up as latitude goes up or way down. But as long as you're living someplace where the sun comes up every day, that's not an issue. But yes, absolutely-- if you go and live someplace where it's dark for six months of the year, people have disruptions of their circadian clock and they start freerunning. All right, drive carefully. Have a good vacation.