JEREMY WOLFE: The midterm marks an interesting dividing point in the subject material of the course. It's not an absolute division by any stretch of the imagination, but it's a division. Up to this point, we've been talking about things that we could measure of various varieties, like your memory span.

You can measure 7 plus-- you can remember 7 plus or minus 2. Color names. You can see these colors. You can do this, you can do that. In these cases, the "you" has been pretty much has been a plural "you." And the data point of interest has been the average data point, the mean data point. What's normal? What's standard?

So-- well, we measure people's ability to memorize color names. The average of that, we've decided, is going to be 7. There'll be some variation around that, but it's the seven that's been interesting.

That turns out not to be the case when you're-- in the same way when you're talking about something like intelligence. Announcing that a particularly-- like intelligence testing. Announcing that on average, people have average intelligence is boring. What's interesting about intelligence and what is interesting about things like personality is the variation around the mean and the explanation of that variation. And that's what we need to start talking about now.

Oh, by the way, while it is, of course, by definition the case that, on average, people have average intelligence, they don't believe it. If you ask people, do you think that you are more intelligent, less intelligent, or about of average intelligence compared to the rest of the population? You'll get some distribution around that, too, but you'll find out that the average perception of intelligence is that we're all above average.

And this goes for a variety of other questions like, how good looking are you? Above average, below average, or average? Well, we're all a little above average there, too. It turns out that there is one group that gets the answer correct, that if you ask this group of people, on average, are you brighter or dumber than average, they'll come out in the middle. You ask them, are you cuter or uglier than average? They'll come out average. Anybody know who that group is?

[MUMMBLING] Hand. We need a hand. No hands. Nobody who cares to speculate-- yeah, yeah? Yes, you with the computer there.

STUDENT: Kids.

JEREMY WOLFE: Kids. No, I don't think so. I don't know what the answer is for kids-- certainly it's not true for parents of kids, all of whom know their children are above average. Yeah?

STUDENT: Depressed people?

JEREMY WOLFE: Yes. It's the depressed. Depressed people have an accurate assessment of their own intelligence and good looks.

[LAUGHTER]

In fact, it has been seriously argued that-- it's been seriously argued that part of what keeps us undepressed is an unrealistic assessment of the world. We're smart, we're good-looking, we're going places. If you knew the truth, we'd all be depressed.

[LAUGHTER]

But that's a topic for another day. What's it like when you get the midterm back?

[GROANING]

Oh, I shouldn't have said that. But the midterm doesn't depress us, actually. It provides a certain amount of lighthearted merriment for us, you'll be happy to know, because people do come up with some great answers to stuff.

All right. If you're going to-- when you talk about-- so as I say, we've been interested mostly in the mean value of measurements to this point. Now we're interested in the variation, the distribution of those points for a wide range of measures.

If you measure a whole population of people and you count the number of people who fall into each bin-- you now have a bunch of bins here. Different scores on a test, let's say. You'll get one of these bell-shaped or normal curve distributions.

The questions that we're interested in here are questions about where does that-- where does that variability come from? The variance of a distribution is the sum of the squares of the difference between the mean and the data points. So you got the mean, got a data point.

Take that distance, square it, sum all those up, and divide by the number of observations, that's the variance. And the square root of that is one standard deviation away from the mean. So this would be-- and those units of standard deviation are the yardstick for how far away you are from the mean of a distribution.

So if you take something like the SAT-- for example, the SAT is scaled in such a way that the mean is intended to be at about 500. At least, that's where they'd like it-- that's where they started. And each 100 points is one standard deviation away.

What that means, for example, is that if you've got 700 or above, that the number of people getting 700 or above on a properly normed SAT-type test is about 2.5% of the population. Actually, that line would be at 1.96 as it shows on the handout if you want the 2.5% point.

But roughly speaking, two standard deviations above the mean gives you about 2.5% of the population. Three standard deviations above the mean-- so that 800 score-- gives you-- I can't remember, It's. A very small percentage, of a normal population above the mean. That's at least the ideal for something like an SAT test. Works well for the SAT 1 math and verbal kinds of things. They are more or less normally distributed.

The place where it's a disaster is things like the SAT 2. How many of you took the SAT 2? There are two versions of it, right? There's the hard version and the easy version? How many of you took the hard version of the SAT 2? What? Oh sorry, the math. Math.

But there are two versions of the math. I got my jargon wrong because they used to be called achievement tests. They're now SAT 2's, right? And there's the-- is it still and SAT AB and BC or something? Well, whatever it is, I don't care what it is.

[LAUGHTER]

This is-- whoa, I'm losing my glasses now. Getting too excited here. The problem is, I took the easy version. I took the easy version of it because I looked at this distribution and I realized that the-- whatever it is. The fancy version of the SAT 2 is actually-- has a distribution that looks like this. Which is to say everybody who takes it gets an 800 on it.

And those of us-- mathematical incompetence, we're going to score, I don't know, 760 or something, we were going to come out in the 5th percentile and not from the good side of the distribution. So I took the SAT-- well, what was then maybe the achievement test because I knew that the Math 1 achievement test because I knew that I could score in the upper end of the distribution. The other people taken that were people who couldn't add and subtract. So anyway, it works for me.

So, where does variability on tests like this come from? There are lots and lots of potential sources of variability. One important point to make at the moment is to note that things that cause variability across groups are not necessarily the same thing as things that cause variation within groups.

Let's give a silly example. If you grow a bunch of tomato plants and you vary the amount of fertilizer you put on them, more fertilizer, bigger plants. So you can have something that shows you that you've got the variability-- and you can account for some of the variability in the size of the plants from the fertilizer.

Now if you grow some tomato plants and some redwood trees, you get very different heights, too. But the source of variability between tomatoes and redwoods is different than the source of tomato variability within tomato plants. This becomes relevant in more subtle and interesting ways when you start talking about variation within group-- population groups and across population groups on a measure like IQ or intelligence.

So IQ is just a number on a test, but it's supposed to be a measure of intelligence. What is it actually measuring? Well, one way-- there's a certain circularity that's popular in the field, which is to say that intelligence is what IQ tests measure. And what do IQ tests-- well, they measure intelligence and-- But it'd be nice to be a little more interesting than that.

A little more interesting than that is to note that you can divide up this intuitive idea of intelligence in various ways. One of the interesting ways to divide it up is into so-called fluid and crystalline-- or crystallized intelligence with IQ tests being a putative measure of fluid intelligence.

Fluid intelligence is the set of reasoning abilities that let you deal with something like abstract relations. It is said to have reached its mature state, its adult state by about age 16 or so. So you guys have pretty much leveled out on that.

Crystallized intelligence is more the application of knowledge to particular tasks and can continue growing throughout the lifespan. A particular example would be something like vocabulary. Your vocabulary is not fixed, and with luck, will continue to grow as you age.

And the idea is that IQ is picking up intelligence tests that are-- IQ like our tests are-- more tests of fluid intelligence than they are of this crystallized intelligence, at least that's the intent. What is it that is this fluid intelligence? One possibility is that when you talk about somebody being mentally quick, that that's literally what you're talking about. That what differs between people who score high on these tests and people who don't is simple speed of response.

And that if you-- and it is, in fact, the case that simple reaction time is related to your measure-- to measures of IQ people who bang a response key more quickly in a reaction time experiment are also people who score higher on IQ tests. Not a perfect relationship. Not even a hugely strong relationship. And in fact, we probably want to look for something a little more subtle than that in understanding what intelligence might be.

More interesting are claims that it has something to do with the constellation of operations we were talking about in the context of working memory earlier in the course. These executive function, the desktop of the computer of your mind kind of functions. How much stuff can you have up there and how effectively can you manipulate it?

So one possible correlate would be something as simple as digit span, or in this class, color span. How many color names can you name? I go, red, green, blue, you say, red, green, blue, that sort of thing. Again, related, it tracks along with intelligence, but not all that well.

People like Randy Engle in Georgia have worked on creating tasks that they think capture this working memory, executive function aspect of it a bit better, and that's-- I think I put it on the handout, this notion of active span tasks. These are tasks that are like the color name task, but a little more complicated.

So the thing that you might do if you were in Randy Engle's lab would be something like this. What I'm going to get you to do is I'm going to read you a list of words, and you're going to spit them back to me in order. And the measure that's going to relate to something like an IQ test score is going to be how many you can get back in order.

But I'm not just going to read you the names, but I'm going to do is give you a pair of the equation and a word on each presentation, either on a computer screen or I can do this orally. So I might ask you to verify, is it true that 2 plus 3 minus 1 equals 4? And at the same time, you see the word uncle. And so your job at the time is store uncle and verify the equation.

OK, next one would be 4 minus 3 plus 5 equals 6, and the word would be fish. So-- no, that one doesn't sound right. OK, now, what were the two words? Uncle and fish. That's good. But if I was to do this without the long song and dance and go up to four or five, six of these, you would discover that you started losing them. And the number that you can hold while doing these calculations at the same time turns out to be a more powerful predictor of things like IQ scores.

Again, not perfect, but getting closer, perhaps, to what the underlying substrate of what we mean by intelligence might be. That it might have something to do with how well you move things around in that mental space that we were calling working memory.

Another possibility-- not necessarily unrelated, but another possibility is that it has to do with the degree to which your brain is plastic. Not in plastic kind of sense, but plastic in the modifiable sense, that maybe the ability to change and modify the structure of your brain is related-- is the neural substrate of intelligence.

In any case, whatever it is, it is a useful predictor of a variety of things. It's a useful predictor of performance in school, which is, in fact, where it started. Binet in France, that-- B-I-N-E-T. But it's French, so it's Binet-- in France started intelligence testing as a way of seeing which kids might need help in school. It is a predictor of a variety of things.

So more IQ points, higher lifetime salary. More IQ points, less of a chance of criminal conviction. Less of a chance of teen pregnancy. So it's related to stuff that you'd like to know something about and you'd like to know as a result where it is that the variability comes from.

The class of-- part of the class of statistical tests for where variances come from, the effort to parse it out, you will have seen in a variety of the papers that you read, probably. Statistical tests called ANOVA, it stands for Analysis of Variance. It's part of the statistical armamentarium that allows you to take the variance apart and say, some of it's due to this and some of it's due to that.

Now this is made simpler by the fact that variances are additive. So if you have two sources of variability that they added in a nice, direct way-- so if we've got the total variation and we are in a psychology course, we are willing to-- one way to divide up the variance, at least theoretically, is into variance that's due to genetic factors, are a nice nativist component, and variance that's due to environmental factors.

In principle, if this is a good way to think about the variance we should be able to go in and do experiments that allow us to see the genetic variants and the environmental variance and see how they add up to make the total variance. What you will often see in papers on intelligence, and actually, widely in the popular literature on the genetic component-- pick your favorite function. What is the genetic component to male fidelity or something like that? You'll often see discussions of so-called heritability, usually written with a big H.

Heritability is simply the-- whoops. The genetic variance over the total variance, which, in this story, would be the environmental variance plus the genetic variance.

There are difficulties with thinking about-- with drawing conclusions from that that we will come to shortly, but the first thing I want to do before going on to that is to talk about the sort of data that are brought to bear to understand variability, because a lot of that-- a lot of this is so-called correlational data. And it is important to turn you into educated consumers of correlational data. So that's why you have this lovely second page of the handout.

Correlation is simply a way of describing the relationship between two variables measured on the same subject. So let's take the silly example in the upper-left there.

If I took everybody here and measured your height in inches and measured your height in centimeters, and for each person-- now each person generates a data point, those data points had better lie on a straight line. Those are two measures that are really seriously correlated one with the other. If I know inches, I know centimeters.

Correlation coefficients are calculated-- so you calculate the line that fits the data. And then you calculate how strong your correlation is by looking at the distances of data points away from that line. In this case, all the data points lie on the line, and that leads to a regression value, a regression coefficient usually written as little r of 1.

The maximum-- a correlation coefficient of 1 means, if I know this variable, then I know this variable perfectly. Now, those are really boring data. Nobody spends a lot of time working out correlation coefficients for that. You work out correlation coefficients for data where there's some variability. That's the whole point here.

So the second one is height and weight actually taken from a subset of a 900-class some years ago. If you measure height and weight, you now get data points that are clustered in a broken hunk of chalk around some line. If you calculate the regression coefficient, now it's going to be something less than 1, but still positive. So greater than 0, less than 1. What is it actually on the handout? Like 0.78 or something? The relationship between height and weight is pretty strong.

So if I know that you're 6-foot-5, I don't know your weight exactly, but I can make a non-random guess about that weight. On the other hand, if I know your height, the last-- and let's plot-- OK, we still have height there. So let's plot last two digits of Social Security Number against height.

It is my firm belief-- I don't know this to be the true not having collected the data, but it is my firm belief that those these data are just a random cloud of spots. I don't think there's anything about Social Security Number that's related to the height-- to your height. I hope not.

A correlation-- something-- so if I know your height, I know squat about your Social Security Number. That is a correlation of 0. Correlation can go below 0, but below 0 is not worse than 0. It just tells you the direction of the correlation. So let's go back to in inches-- OK, we'll stick with height.

So this time, I'm going to measure-- I'll get everybody here. I'm going to measure their height, and I'm going to measure the distance from the top of their head to the ceiling. Very exciting data collection. I'm going to get orderly-looking data. But this time it's going to look like this. I just changed the slope. That's going to give me a correlation, in this silly example, of minus 1. It's a perfect correlation, but the direction of relationship is the other way.

If I know distance from the floor, I absolutely know distance from the ceiling. It's just that as one goes up, the other one goes down. Again, that's a really boring example. A more interesting example is on the handout, which is-- if you come into my lab, and we do a reaction-time experiment, and I plot your average reaction time in whatever the task is, and I plot your error rate, what I will find across individuals is data that are noisy, but look like this. The faster you go, the more errors you make.

It's known as a speed-accuracy trade-off in the literature, which, you will notice, has an interesting set of initials. So the SAT gets written about in my trade all the time, but has nothing to do with standardized tests, it's a speed-accuracy trade-off. But it will produce a negative correlation. I think I put one of those on the handout, too. What's the correlation there?

STUDENT: Negative 0.52.

JEREMY WOLFE: Negative. OK, negative. So negative 0.52, meaning a pretty good relationship, but going in this negative direction. You will often see in papers r squared rather than r. r squared, of course, is always positive. So r squared here would be, what, about 0.26 or something.

The reason people use r squared is it turns out that gives you the percentage of the variance that you're explaining. So if you've got a correlation of 0.5, you're explaining-- you can explain a quarter of the variability. If you know one, you know about where a quarter of the variability would come from in the other variable in this case.

Now it should say on the handout-- oh, actually, I think I put the answer on the handout this time, too. The most-- I'm not sure it's really the most important thing to know about correlation, but the thing that gets lost in discussions in psychology all the time, certainly in discussions of intelligence, all the time about correlation is that correlation does not tell you about causality.

It is extremely tempting-- it's not extremely tempting in these examples. Does height-- does inches tell you about centimeters? Yeah, but not because inches cause centimeters. That's stupid. But it's really tempting to infer directly from nothing but correlational data to infer causality.

So, I put fertilizer on the field. The tomato plants grow bigger. So if I plot amount of fertilizer in yellow now, hmm. Cool. Against height of tomato plants I presumably get data that look like this, some nice, positive correlation, I may have a notion-- I may even have a correct notion that the fertilizer is the cause of this change in the height of the tomato plants.

But just these data don't tell me that I would need more because I'd get exactly the same data if I plotted-- if I flipped the axes. Height of tomato plants, fertilizer, get exactly the same data. The height of the tomato plant causes how much fertilizer I put on it. No, that would be stupid.

You have to impose a theory on your correlational data. Just the correlation-- the correlation's just math. It's not it's not by itself a theory. It can be used to support causal theories, but it is not by itself a causal theory. I'll try to point out later where this runs into trouble.

OK, so we can get correlational data. Correlational data are very important data in the study of variability in intelligence. So you might get data like the following. Let's plot parents' IQ against child's IQ. What you'll get is another one of these clouds-- I think it actually says on the handout that the r-value is about 0.5 for that. So it is the case that if you know the parents' IQ, you know something about the child's IQ.

And the goal is to figure out why. Where is that relationship coming from? The obvious temptation, of course, is to think that the answer is, well, the parents have good genes and/or bad genes, or they have some amount of intelligence coded into their genes. They pass it on to their kids.

To understand why it's not completely trivial, recognize that parental wealth is correlated with child's wealth, not because there's money coded into the genes. It is true that the richer your parents are, the richer you're likely to be, but the causes might-- well, you do inherit that, but in a different kind of non-genetic way.

As I say, the simple story has been to try to partition the variance into a genetic component and a environmental component. That leaves out-- the simple version of that leaves out an important piece of it, which is that when you do-- if you do an analysis of variance, you should--

Everybody should do an analysis of variance sometime because the computer will do it for you on your data now. Everybody should really do one by hand. Back when we were young, we had to do them by hand, which took a long time.

But anyway, when you do that, suppose you've got two variables like a genetic component and an environmental component. An analysis of variance will tell you, by this statistical testing, this much of the variance is due to this and this much is due to this. But it'll also give you an interaction term to say that the genetics and the environment might interact in some fashion.

Interestingly, that term never gets introduced into these calculations of-- that doesn't quite get introduced into the calculations of heritability, but let me try to give you a feeling for why that's important. Let's move off of intelligence and ask about a personality variable.

How anxious do tests make you? You've now taken a bunch of MIT tests. How anxious do you get? Well, let's develop a little variance partitioning theory here. Not very-- let's not develop that theory, let's develop this theory. So the-- whoops. Oh, this looks like a great theory. No, no, no, no, no, let's get rid of that theory, that's got too much fancy stuff in it. We will have a simpler theory.

So the simple theory might be that the variance-- the total variance-- the total anxiety is a function of the variance due to you, to your personality. Are you an anxious person or an anxious person? And the variance due to the class. If you're taking Introduction to Clay Ashtrays, I don't make you that anxious. And if you're taking Advanced Thermonuclear Chemical Integral Thermodynamical Bio-something or other, and you skipped all the prereqs, yeah, it makes you a little anxious.

And you could try partitioning your variance into these two components. But it turns out, that doesn't do-- that's not where the action is. The action in anxiety about tests is all in the interaction term, which we can call the "you" crossed with class interaction term. Because how anxious you are depends on how you are doing in this class.

You-- in short, it matters if you're basically nervous person or not. But you're going to be nervous in Intro Psych if the midterm's coming up and you never cracked the book. You might be less nervous in calculus because-- oh, you're good.

Your neighbor might have memorized Gleitman and forgotten to show up in calculus and have the flip anxiety. The anxiety is dependent on the interaction. And those interaction terms-- you will almost always get a nice nod to the notion that of course we know in something like intelligence that the environment and genetics interact. But we will typically not get much more than a nod at that. You then get simple-minded statements about just how heritable something is.

Let me give you an example from the intelligence literature from a new, and I gather, somewhat controversial study, controversial in the sense that there are other people who claim that the methodology is flawed and that they don't believe the result. But this is new enough that we don't know how it shakes out, but it makes the point about the importance of interaction terms here.

Suppose you calculate how heritable intelligence is, but we're going to do it separately-- as a function of, oh, here, let's introduce a little more jargon. SES stands for Socioeconomic Status. It's the fancy way of asking how much money and other resources you've got.

If you look at high-SES kids and ask how much of a genetic component is there to IQ, you get estimates, as I recall-- it's something like 0.6, 0.7, something like that-- a relatively high number for that H, that heritability number. If you look at low-SES kids in this particular study, it was dramatically lower, about 0.1.

What's going on there? Could it possibly be the case that these kids-- that the genetics are operating differently at the low end of the scale-- the economic scale and at the high end of the economic scale?

I mean, this implies that if you plot something like parents' IQ against kids' IQ, one of the ways of looking for a genetic contribution that at the low end of the economic scale, the data look like a cloud, and at the high end, they look like closer to the line kind of data. That's very odd.

What really seems to be going on is an interaction between environment and genetics influencing this heritability thing. What's going on? Well, here, you can look at this equation and ask yourself, what happens if you drive this-- the environmental variance to 0? Well, you're going to drive this up to towards 1. It's just going to be the genetic variance over the genetic variance.

It may be that for the point of view of intelligence, or what's measured on IQ tests, that by the time you get into the middle class, the environment is largely homogeneous. Everybody gets fed. Everybody goes to school. Everybody has books. Lots of-- everybody has access to medical care. Most people come from family situations that are at least not vastly problematic.

At the lowest end of the socioeconomic scale, that's not true. It's not true that everybody has the same access to resources, and this environmental factor may get much larger with the result that this measure of the apparent heritability-- the genetic component if you like, seems to get bigger. So you see how the interaction can end up being important.

All right, let's go back to this-- all right, let's go back to this example of parents and kids across the population as a whole that relationship gives you an r squared value of about 0.5. What does that mean?

Well, we don't know, really, because while you share some genetic material with your parents, assuming you're not an adopted child-- we'll come back to that in a minute. If you share genetic material with your biological parents, if you were raised with your biological parents, you also share a lot of environment with them. The two factors covary.

So in order to separate this out, what you want to do is you want to get the two factors to vary at least somewhat independently. Now the little table on page 3 of the handout gives you one effort to do that. Let's look at sibling pairs who vary systematically in the amount of genetic material they share.

So identical twins are genetically identical. And they have very high correlations between their IQs, around-- a correlation of around 0.9. Fraternal twins-- same-sex fraternal twins, I should have added, have a correlation that drops to about 0.6, which tells you that environment-- well, they are only as related as standard siblings. And so you reduce that genetic component, you reduce the correlation.

Siblings-- aged-different siblings-- standard brother-sister, brother-brother kind of pairs have a correlation of 0.5. And if you have unrelated children raised in the same family, that correlation drops to about 0.2.

So that certainly indicates a genetic contribution to IQ, but it's not entirely clear what's going on, because, again, environment and genetics are covarying one with the other. Identical twins get treated more similarly, they have a more similar environment than fraternal twins.

Fraternal twins, by virtue of being the same age, are treated more similarly than age-separated siblings. And typically, adopted children are treated somewhat differently-- children who have been adopted into a family have experiences that kids born within the same family don't have and vice versa. So again, there's more of a difference there. So environment and genetics are covarying, so it's not a clean experiment.

One way to do the clean experiment is to take a jumbo jet full of identical twins at birth, put little parachutes on them, fly around the world and push them out at random, come back 18 years later after fluid intelligence has reached its asymptotic level, collect all your twins, and see what the correlation is.

This is, for a variety of reasons, a difficult experiment to actually do, and so we don't have the data on that. But there is a literature on so-called-- well, on identical twins reared apart. It's not common, but it does happen. It happens when either both twins or one of a pair of twins gets put up for adoption.

One of a pair of twins thing may sound a little strange, but this happens, for instance, typically at the lower end of the socioeconomic scale when you're thinking, oh my goodness, I think we can just barely manage this kid when he or she is born, and [GASP] there's two of them. And so one of them gets put up for adoption. It's rare. These things these things are rare, but it does happen.

And a variety of efforts have been made over the years to collect data on such-- some of this having has less to do with IQ than with general personality variables.

There's a whole lot of amusing, though God knows what to make of it-- literature on identical twins who only meet their twin, didn't realize they had a twin until they're adults, and then they meet, and oh my God, they both married women named Gladys and they both have dogs named Gerald Ford or something like that. That's a little strange. It's a little hard to believe that Gladysness was wired into the genes, but weird coincidental things happen.

The identical twins reared apart stuff is, again, not perfect data. Because, for instance, twins that are separated at birth are sometimes separated by going off to live with aunt so-and-so who lives in the next valley or something like that. Is that really separated? Hard to know.

Oh, the place where you do these studies-- well, there's the one thing on the handout about the Minnesota twins study, because those guys are at Minnesota, but the place you want to do these studies is Scandinavia. Not because they take their twins apart a lot in Scandinavia, but because, boy, do those guys keep records.

You get yourself some idea that you want to know where all the twins who were separated at birth are in Denmark, and there's somebody in the Danish bureaucracy who can get that answer for you. I mean, in the US bureaucracy, you're lucky if they can figure out, oh, I don't know where your 300 tons of Iraqi implosives are or something like that. But in Denmark, they'll know where your stuff is.

The previous remark was should not be construed as being paid for by any particular political campaign. It's just what bubbled into my fevered brain here.

But in any case, when you do the identical twins reared apart study, what you find-- people yell and holler about these, but the best of these data look like a correlation of around 0.7 or so. Significantly lower than the 0.9 for identical twins reared in the same family, but clearly indicating a genetic component to what is being measured by IQ.

So I think that-- it's been a very hot topic for a variety of reasons, many of them not well-formed, to ask how much of a genetic contribution there is to IQ. And it's been an answer where-- the answer that you're looking for is heavily driven by your politics as much as by your science.

In part-- well, look on the handout. There are a bunch of pitfalls to this idea of heritability. Jump down to number 3. Number 3 is perhaps the reason that it's been most politically loaded. There are people and there are groups whose IQ, on average, are lower than other groups or other people.

If you believe that genetics-- that there's a strong genetic component to IQ, and you believe that this item 3 here, that things that have strong heritable components are largely unmodifiable, then what you're saying is that if you've got low IQ, that's your tough luck, there's nothing much that we as a society could do about it.

This was the thesis of a-- actually, it's been a thesis of a repeated series of books. The most famous recent one is a book called *The Bell Curve* by Murray and-- Herrnstein and Murray. And the basic argument ran like this. There's clear evidence for heritability of IQ. IQ is not very modifiable. IQ is related-- correlated positively with good stuff and correlated negatively with bad stuff.

And that this country is an IQ-stratified country. Another way of putting it, is a meritocracy. It's not that you get to be-- you get born the Duke of Cambridge or something like that. You get to rise to the top because you've got this great IQ that gets you to MIT, that gets you the good job, and then you become President of the United States or something like that. Whatever. Interesting.

[LAUGHTER]

You get this great IQ and you come to MIT and you hang around in the Infinite Corridor making boingy noises. That's different. Anyway. If you take, I don't know, that four points or something, you take those four points and you add them up, what you get to? Somebody over there, take a little walk down the hall and ask boingy to cool it. Thank you.

What you get is the notion that there are some people who are going to be at the bottom of the stack in America. And that's just the way it's going to be. They're going to be the criminals, they're going to get pregnant, they're not going to make any money, and that's just tough. There's nothing much to be done about it.

I'm oversimplifying the book. It ought to be fairly obvious that I disagree strongly with that thesis, but I should say, it's not a stupid book. If you're interested in these issues, it's worth reading the book in the way that--

If you're on the left politically, it's worth listening to right-wing talk radio to sharpen your brain, and if you're on the right politically, it's worth listening to left-wing talk radio to sharpen your brain as long as it lacks-- well actually, talk radio is probably a wrong example because it really is pretty stupid, most of it. Herrnstein and Murray aren't stupid. I think they're wrong, but they're not stupid.

In any case, why is-- let me give a non-intelligence example, for why this pitfall of thinking that these things are fixed and unalterable just because they're inherited. Did it work? Oh, were you the person? You weren't the person looking for-- it's not the same guy. Oh, this is a lovely change blindness thing. Right? It's perfect.

A guy went out, the boinging stopped, the guy came back, and-- unfortunately, I guess the boingy guys killed the guy who went out, this is really sad. We could send another one out, but-- where was I? OK. So things can be inherited, and things can be inherited and related to intelligence, and nevertheless, quite changeable.

PKU is a disorder where you are unable to metabolize one of the basic amino acids. And the result is it produces neurotoxins, it munches up your brain. Kids with this disorder-- it's a genetic birth defect type of disorder. Kids with this disorder, before it was understood, were condemned to severe mental retardation.

Once it was figured out what the problem was, you could prevent the severe mental retardation by controlling diet-- basically by controlling an environmental factor. You take the precursor out of the diet, you don't produce the neurotoxins, you don't produce the mental retardation. It doesn't mean that the disorder was any less heritable. It's a birth defect. Are you the guy? Is he the guy? Thank you. What was it?

STUDENT: It was just someone walking through the hall making noise. He left.

[LAUGHTER]

JEREMY WOLFE: OK. He's not going to need medical care or nothing, right? OK, good. No, I was worried that you might have worked him over or something. Thank you. Thank you for taking care of that in any case. So you can have something that's clearly genetic in origin where an environmental change might make a difference. PKU is simply a dramatic example of that. Let me just take a look--

OK, so I've already hit the pitfall to the notion that the interaction term might be important. The evidence for that might be this low socioeconomic status-- high socioeconomic status influence on the apparent heritability of it. And I really also already hit that first pitfall there. High heritability might just mean that there wasn't much variation in the environment in your particular experiment.

If you grow all the tomato plants in exactly the same field with the same water, the same sun, and the same fertilizer, they will still be some variability, of course. You'll get a heritability score that will be near 1, but that's because you've driven this term down to 0 or near 0, and that doesn't prove that the environment is unimportant.

So, the fact that there is a significant genetic component doesn't mean there is not a significant environmental component. OK, take a quick stretch. Make boingy noises. That's good. Thank you.

STUDENT: Hi. Do you actually decide how we were going to go over the midterms in class?

JEREMY WOLFE: Yes, of course. Go ahead.

STUDENT: All right. But my class is right after this.

JEREMY WOLFE: No, no, go ahead. No, no, no. Absolutely. No, this is in case there are-- all those-- the Society for Neuroscience TAs. No, no, by all means. I want to cover for them, but not to discourage you.

STUDENT: OK.

[INTERPOSING VOICES]

JEREMY WOLFE: Looking at the time and looking at my notes, I realize I'd better get cooking here. So let me cook here. What I want to do is to tell you a little bit-- let me frame this. Since I've already introduced the Herrnstein and Murray book.

The most controversial piece about of the Herrnstein and Murray story is when you start getting to group differences and you say, look, in America, at the present time, the average African-American IQ score is about 10 points lower than the average white American score. That's data. And what you care to make of those data is very important from a policy point of view.

Herrnstein and Murray were making the argument that since genetics has this big role and these are things that are unalterable, that the fact that Blacks in the US also, on average, make less money and so on, hey, man, that's just science and genetics and the fact that we're a meritocracy and good things like that. Live with it.

What I want to do first is to describe a couple of-- what are really amusing historical anecdotes about the history of intelligence testing drawn from Stephen Gould's book called *The Mismeasure of Man.* I will answer the question on the handout already. What's the point of these amusing stories?

The point is not to make fun of folks operating 100 or 150 years ago. The point is to make us take with caution our understanding of similar answers that we're getting today. So for example, who has higher average IQ, men or women? How many vote that it's men? How many vote that it's women? How many vote that it's equal? How many vote that I ain't touching this because I smell a political question when I can--

[LAUGHTER]

How many vote I don't vote? That's the wrong answer, at least next Tuesday. This ad paid for you by the League of Women Voters.

[LAUGHTER]

Yeah. I mean, just stepping aside here, it's a pain often to vote if you're an undergraduate because you're way away from whatever district you're supposed to vote in, but go and vote, if for no other reason than nobody polled you, and you can screw up all those polls that claimed that they knew the answer, which they don't know, to the election one way or the other by voting because when they called your parents, you weren't home. So anyway, but you should vote.

What was I-- oh yeah. So men and women-- the answer is that men and women have the same average IQ. But the interesting question is why that's the case. Why is it the case? Well, back at the beginning of the 20th century when IQ tests came from France to America, how do you build an IQ test?

What you do is you make up some questions that you think might be reasonable measures of intelligence. You give them to a bunch of kids because this was originally a school testing kind of thing. And then you ask, are these sensible questions like, do the kids who the teacher thinks is smart do well on them and stuff? And you work from that.

And so they're working on standardizing the original test. And on the original drafts of the test, women-- girls-- were scoring about 10 points higher than men. The guys who-- the guys, literally, who made up the test knew that this was wrong.

Now, it is to their credit in the early 20th century that they knew a priori that the correct answer was that men and women were equal. It would have been no big surprise at that point to have them figure out that men should have been scoring higher. But they knew that the answer was that men and women were equal.

And here's what they did. You do what's known as an item analysis on your test. You look at all the questions. You say, oh, look, guys did much better on this question than women did. Oh look, women did much better on this question than guys did. You know what we're going to do with this question? We're going to throw it off the exam. We're making up the exam as we go along.

And so they tooled the exam to get rid of that 10-point difference, and subsequence tests are standardized against the older tests. That's why men and women have the same IQ. Yes?

STUDENT: How do you factor motivation into this? Aren't little girls who more focused in general?

JEREMY WOLFE: Oh, there's a whole lot of-- I don't know when it is that guys finally get focused.

[LAUGHTER]

But yeah, yeah, yeah. I mean-- and I don't have much direct experience with this having merely had three unfocused guys myself in my family. I always wanted one of those focused girls who just-- anyway. Yeah, yeah, yeah, yeah, there's all sorts of stuff like that. But, yeah, that's a whole other course. But what they did was they made the difference go away by manipulating the test.

Now these tests were hardly the first efforts to study intelligence. Actually, in an interesting circular movement, these days, there's great interest, again, in looking at the brain and saying, is there something about smart brains that's different from less smart brains? We can do that-- the renewed interest comes from the fact that you can now go and look at brains in walk and talking people.

The previous boom in looking at brains was in the 19th century. The difficulty-- the reason Binet developed his test was that looking at brains was only good at autopsy. You're not going to figure out if your kid needs help in school by cutting his head open and looking at his brains any good in the 19th century, it's just not a really practical solution.

But people like Paul Broca of Broca's area, famous French neurologist, spent a lot of time looking at the brains of their deceased colleagues and others to see what made people talented. Broca's doctrine, translated from the French, but quoting, is that, "All other things being equal, there's a remarkable relationship between the development of intelligence and the volume of the brain." He was interested in the size of the brain.

To a first approximation, he's gotta be right. One of the reasons, there are no chickens enrolled as MIT undergraduates. Because little chicken brains just don't cut it when it comes to surviving at MIT. So having quantity of brain really does make some difference.

So what he did was to look at the sizes of brains. And his conclusion was that in general, the brain is larger and mature adults than in the elderly, in men than in women, in eminent men than in men of mediocre talent, and in superior races than in inferior races. This reflects very much the biases of certain-- 19th century European. In fact, that's the point.

It's not to say, ooh, Broca was an evil, nasty man, but you should be a little suspicious when your science places you at the pinnacle of creation. That should be a little warning bell that goes, oh, these inferior races, by the way, were, for Broca, were the Chinese, the Hindus-- that's subcontinental India, and the Blacks-- I can't remember if Jews made it onto his list or not. But in any case, it was the 19th century collection of not-white males.

But how did Broca get to this conclusion? Well, he weighed a lot of brains. And what he discovered was, in fact, it's true that female brains are on average a little lighter than male brains on average. All right, so? No? Chicken brains are lighter than your brain. Chickens don't go to MIT. Female brains are lighter than male brains. But he also found that French brains were lighter than German brains.

[LAUGHTER]

Broca was French. So he wrote, "Germans ingest a quantity of solid food and drink far greater than that which satisfies us. This, joined with his consumption of beer, makes the Germans so much more fleshy than the Frenchmen. So much more so that the relation of brain size to total mass far from being superior to ours seems, to me, on the contrary to be inferior."

So-- well, what he's doing is not stupid. He's correcting for body size. And there's a very interesting graph that you may have seen someplace or other, that if you plot body size-- weight against brain, weight-- I can't remember if it works just for mammals or for everybody, but anyway. Let's claim it's mammals. You get a very tight correlation all the way up from mouse to whale. Except that humans are up here somewhere. They're off the curve.

And so the argument is-- people always think-- a lot of people think, whales, they must be these philosophers of the deep. They got a huge brain. But there-- nobody quite understands what they're doing with that great, big brain, but they do lie on this function. And humans have a very big brain relative to their body size. So this is the point at which some-- typically a woman in the class is supposed to raise their hand and say--

STUDENT: Females are smaller.

JEREMY WOLFE: Yeah. Females are smaller than males. So if we correct for body weight-- well, Broca wasn't stupid. He knew that. And he wrote, "We might ask if the small size of the female brain depends exclusively on the small size of her body. We must not forget," says Broca, "that women are, on average, a little less intelligent than men. We are therefore permitted to suppose that the relatively small size of the female brain depends in part on her physical inferiority and in part on her intellectual inferiority."

Now, those two quotes, those two quotes from Broca are taken from completely different publications. Even Broca might have noticed if you put them right next to each other, that there's a certain conflict there. Again, the point isn't to say Broca was a mean, nasty, stupid man. There's no evidence for any of that, but there's clear evidence that what he thought he knew ahead of time was influencing how he was reading his data.

The brain-weighing endeavor fell apart because it didn't work all that well. People like Gauss, the scientist who gives his name to that unit of magnetic whatever it is and Gaussian curves and stuff like that, turned out to have a small brain. Had a lot of wrinkles in it, though.

Lenin-- the communists were always big on carving up the brains of their ex-leaders. Lenin was reputed to have a cortex-- we all have a cortex. It's got six cell layers in it. Lenin's allegedly had seven.

Again, the point of these stories is not to say that we're smart and they were all stupid and silly people. The point is to say that people tend to impose their ideas on their data as well as imposing their data on their ideas and you gotta keep an eye open for that.

In the remaining time, let's ask a bit about this question about, suppose we really do think that more IQ is better. Is there any evidence that we can get more? Is there a way to get more IQ? The answer appears to be yes, though we're not-- well, some it's kind of mysterious.

The mysterious bit is on the handout on the back page I see-- well, on page 4, at least-- as the Flynn effect. Flynn is a political scientist-- James Flynn is a political scientist sitting down at the University of Otago at the bottom of New Zealand, which nobody had ever heard of until the *Lord of the Rings* movies, but you don't get further away unless you go to Antarctica.

But what he did was he took a look just at raw IQ statistics, initially in the Pacific Rim countries, in the period-- before-- shortly before and since World War II-- a couple of generations' worth.

And what he found-- well, it's summed up in the title of his paper. Massive IQ gains in these countries. So for example, back a decade or two ago when the Japanese economy was booming, people liked to point out, people given to these group IQ arguments, like to point out that the average Japanese IQ is about 10 points higher than the average American IQ.

And the reason they're eating our lunch is because they are just a-- they've been breeding with each other for years, and they're just smarter people than we are, and we're all doomed to serve the Japanese forever. Well, that's argument has gone away since they went into a 10-year recession or something.

But the more interesting point from our point of view is that apparently, they got smart really fast because before World War II, the average Japanese IQ was about 10 points lower than the US IQ. There is no genetic story that makes that work. And this happens in Pacific Rim country after Pacific Rim country, that after World War II, IQs just go way up.

And then subsequently, it turns out, what's happening all over the world, in fact-- it had been mapped in the US because IQ tests keep getting re-normed, the average IQ in the US keeps drifting higher, and then because IQ-- average IQ is defined as 100, you re-norm the test so that the average is 100 again.

Flynn wrote a wonderful paper, which I didn't cite on here, but if anybody wants it, send me the email, where he was having fun with these statistics proving that if you use these statistics, literally you would conclude that our Founding Fathers were all congenital idiots and were probably too dumb to walk across the street if you just extrapolate back.

Something very odd is going on. It's not clear what it is. One of the thoughts had been that it was simply nutrition. Pacific Rim nutrition got a lot better after World War II, and maybe better food makes better brains. That seems to be true. But there's counter-evidence.

For example, there's no dip in the Dutch average IQ for the cohort that was in the vulnerable part of early childhood during World War II when the Germans systematically starved the Netherlands. There's no dip in the IQ. So it's not clear that the food story works.

There are other stories that say that what's going on is something about a change in the culture, that the world culture has become this much more information-intensive culture that supports and nourishes the sorts of things that are measured by IQ.

That the sorts of talents that you needed when you were a subsistence farmer, you needed some smarts to make yourself survive, but they weren't the thing that were getting picked up on IQ tests, and that now the whole-- your life builds IQ points-- it's not clear what's going on.

What is clear is it's not genetic. It's just too fast to be a genetic change. Now that's at the level of groups. Can you change individual IQs? And the evidence there is, yeah, you can do that, too. And the classic experiments come from the '60s-- oh, what is he today? He's a rat.

All right. So we're going to take rats, a homogeneous population of rats, and we're going to randomized them into three populations. Population 1 goes into-- well, let's stick with socioeconomic status because that's what they were trying to model. This is the low-SES group which meant, in rat case, that they lived looking like ducks or something. They lived all alone in an isolated cage with nothing to play with.

The medium group lived in what was the standard lab cage of a couple of cockroaches-- a couple of rats, not much action. And then there was the high-SES rat group or the enriched group who lived in a big group rat daycare center with lots of cool toys to play with and the habitrail thingy and stuff-- a lot of good cool stuff there.

Let them grow up in these environments, test them on little rat IQ tests, cognitive tests for rats, these guys do not do as well as these guys. Look at them at the end of the experiment-- I mean the real end of the experiment when the rat is now dead, and you discover, these guys have brains that, on all sorts of measures, looked better than these brains. Thicker cortex, more synapses, bigger brain. Clearly, the enriched environment was having some effect.

These data, back in the '60s, were part of what motivated Head Start, the notion that kids in low socioeconomic environments could be-- had lower IQs than kids in high socioeconomic environments. They could be brought along to the same higher level by putting them in school earlier, putting them in a preschool enrichment situation.

And it worked. That if you went-- ooh, I need to stop. If you took kids-- took low-SES kids who plateaued out at this level and you took them and put them in Head Start, they went up to this higher level that was the same level as the high-SES kids.

Well, what are Herrnstein and Murray talking about, then, when they say you can't change it? Well, Herrnstein and Murray said, yeah, that was very nice. Look what happened when these kids hit middle school and high school. And the answer is, they went right back down while the high-SES kids stayed up.

Herrnstein and Murray concluded that what this is like a rubber band. Yeah, you can stretch it a bit, but when you let go, it just snaps back to where it was. The alternative view is, yes, exactly like a rubber band, but why did you let go? When you let go, you dropped these kids back into a lousy inner city school rather than this enriched state, and they fell back to where they were, the effects were transient.

You want a silly example, think about diabetes. So diabetes has a similar graph except it's a little more stark. No insulin, you're dead by your 20s. With insulin, you're not dead. OK, so here, we're in the not-dead state. Let's say, OK, well, you're done with that insulin stuff now, we'll stop giving you insulin. Oh, look, they're dead now. There wasn't any point to giving insulin. Well, that's a stupid conclusion.

The conclusion-- well, in diabetes, obviously it's that that's the conclusion, is you'd better keep giving insulin. And you could argue that the same thing is going on here. That we know that if you want more IQ points, putting people in better environments works, but you gotta keep them there.

I could try-- I will tell you one more factoid and leave it at that. If you take-- in adoption studies, if you adopt kids into-- typically, adoption moves you from a lower to a higher socioeconomic status because that's just-- it's just the typical reason why people would be put up for kids would be put up for adoption. It doesn't go the other direction, typically.

So, most kids are moving from low to high when they're adopted. Who does their IQ correlate with? The answer is it correlates with their biological relatives because there is a genetic component to IQ. What is their average IQ, however? Their average IQ is the IQ of the environment that they are now in. So their IQ is, on average, indistinguishable from the biological kids in the same family.

How can that be? That doesn't sound like it ought to work in-- with-- but let me just draw you a quick picture and then you can go off and think about it.

So, here's this-- here are these pairs of siblings. And their IQs-- let's take pairs of siblings. Their IQs are correlated with each other. Now we're going to take one of each of those pairs, and that kid's going to get adopted out. And that kid is going to move as a result to a higher socioeconomic status. That doesn't change the kid's genetics any. And so the kid is still has a IQ that's related to his brother or sister.

But it shifts all of-- so this is the kid who's in a low socioeconomic state and stays there. This is a kid going from low to high. What happens is that the low-to-high move pushes everybody up. So the cloud of spots just moves up. The correlation is the same. The average IQ here is higher because going from a low to a high socioeconomic status gives you IQ points.

If you really thought that what you wanted to do as a society, if you really believed more IQ points mean more good stuff, there's a clear enough way to do it. The question becomes a social policy issue about how you end up doing this, but it seems perfectly clear that it is possible to do that. I'm covered in chalk.