

Last week's article began the topic of scientism and ended with the question of: shouldn't scientism be accepted? Science, after all, can't be wrong, can it? It's science. This article will begin with that question. Throughout this discussion on "scientific method" remember that the point is not to "teach science" but rather to address the question of: **is "science" infallible?** Many people seem to believe it is, that there is some sort of almost mystical method that yields answers that are absolutely clear and unquestionable. Is that true? To see the answer to that question, there's no getting around talking a little bit about "scientific method." Bear in mind that ultimately we are questioning scientism, but part of the reason that belief in scientism is so easy to propagate is because of this belief that "science" provides unmistakable answers to questions about the physical world. A little consideration of scientific methods will show that belief to be untrue, and it will bring out the absurdity of the statement: trust the science – which carries the connotation of unmistakable methods.

So: how are questions about the material world answered by "science?" What is the "scientific method?" It depends a little on what discipline you're in. Questions of physics, for example, rely heavily on mathematics and exact mathematical equations. Biological disciplines, on the other hand, rely heavily on statistical methods – methods that make statements about probability, not certitude. Let's begin with the statistical methods commonly used in research in biological as well as other disciplines.

It is always helpful to have an example in mind. Suppose a beef nutritionist (a scientist), based on what he knows about beef biology, has developed a feed additive and now he wants to know if the additive increases rate of gain in steers. What he will do is something like place (say) 10 steers in one group and 10 in another group. He will do everything the same for both groups except one will get the additive and the other won't. After, say, 6 months, he'll compare the average rate of gain of the 2 groups.

Let's say the rate of gain in the group with the additive was a half a pound per week greater than the other group. The problem is that he knows if he repeats the experiment, the next result might be:

- more than 0.5 lb greater gain per week – maybe it would be 0.7 lb, for example, or
- there might be no difference at all between the 2 groups, or
- he might even find that the group *without* the additive had a higher rate of gain.

This is just the well-known nature of experiments in any biological field. Biological systems are generally so intricate that you can't control (or even know, for that matter) every factor affecting your measurements – in this case, rate of gain. So the scientist (beef nutritionist in this case) resorts to the use of statistical methods to decide whether or not, based on the results he's found, the additive really does have an effect – or did it just happen to turn out this way this time because of various other factors affecting rate of gain.

When facing these kinds of questions, statisticians (or statistical methods) are concerned with two main types of wrong conclusions that can occur:

1. Concluding that there *is* an effect (of the additive) when in fact there's not (so I say: yes, the additive does increase rate of gain, when in fact it doesn't)
2. Concluding that there is *no* effect when in fact there is one (so I say: no, the additive does not increase rate of gain, when in fact it does)

Now statisticians are true masters of language – they call the first type of error a Type I error and the second a Type II error! Of course, these are just arbitrary names but it might be helpful to use those names. So Type I = concluding yes when the true answer is no; Type II = concluding no when the true answer is yes.

So the beef nutritionist will now do a statistical analysis on the results of his experiment. One of the things the analysis will tell him is how likely it is that you would get these results (.5 lb greater rate of gain for the group who got the additive) IF in fact the additive does not have an effect – i.e., it will tell him the probability of a Type I error, of concluding there is an effect when in fact there's no effect.

Suppose the results come out and say: there's only a 5% chance of getting these results if there is no effect of the additive: if your hypothesis about the additive increasing the rate of gain is NOT true, you would get this

result, the difference you've found, only 5% of the time. Now the scientist looks at that and says: well those are pretty good odds so I will conclude that the additive does increase rate of gain.

That, in a very small nutshell, is the "scientific method" used in biological experiments.

Now there's several things to draw out of this. First, we see immediately that scientific research that uses statistical methods (which all biological research necessarily does because of the complexity of biological systems) does not supply definitive, irrefutable answers. Conclusions of yes, there is an effect (of say the feed additive) is well-based but it is not certain, it's likely; i.e., it is not infallible. But there is more to it than that.

Notice also that statistical methods are necessarily going to entail a sort of philosophical decision as well – a nonscientific judgement about how much chance I'm willing to take before making a conclusion. Am I willing to conclude that there is an effect if there's a 5% chance it's wrong? Should I tell people: yes it does increase rate of gain if there's a 10% chance of it being wrong or a 50% chance? Should I wait to conclude until there's only a 1% chance of being wrong, rather than 5%? In practice, what happens is that there's a generally agreed upon (amongst scientists) acceptable error rate for concluding there is an effect and it's often 5%, maybe 10% at the most. But notice that science does not answer that question; the question of "what error rate I should accept before concluding there is a real difference," is a non-scientific choice. It depends on what level of certitude I, or others, are willing to accept. This is not something intrinsically bad or wrong; it's the best anybody knows how to do, at this point, with questions in the area of biology. The point is: that judgement is not science.

The extent of usage of statistical methods to make "scientific conclusions" should not be underestimated. It's not limited to just areas that you might think of as "biological." Economics, for example, uses statistical methods extensively, in fact so much that they kind of have their own branch of statistics called econometrics. As I understand it, a good part of the reason economics uses statistical methods is because what happens in economics is dependent on human choices. Psychology, then, is another area that makes use of these methods. Statistical methods have a long reach in scientific research.

There are 2 main things to draw out of this so far. One is that when using statistical methods conclusions are not stated with certainty – i.e., they are not only not infallible but are also only probable. The second thing is that "science" alone is not used to make scientific conclusions! The claim of scientism – that it alone can determine truth – is at best confusing since scientific conclusions involve human judgement, e.g., what error rate am I willing to accept? Finally notice that the whole approach has another "philosophical" element or dimension or question, namely: am I willing to accept this approach for answering questions at all, is it reasonable? I think it is but my answer of yes is not a "scientific" answer, it's a human judgement.

But there is still another difficulty, namely Type II errors – concluding no when the true answer is yes. Let's say the beef nutritionist runs his experiment, gets the same result (a half pound greater rate of gain per week) but the statistical analysis says: you could get this result, this difference, 40% of the time even if there's no real effect of the additive. Now the scientist stops and scratches his head and says: well those are not such good odds, I can't really ("safely") conclude that the additive works. Sounds ok but the question is: can he conclude, with any known degree of certainty, that it doesn't work? In fact, he cannot because that statement, as it turns out, depends on the true effect of the additive, which he doesn't know! Indeed, that's what he's trying to figure out. The most he can say "scientifically" – which means with a known error rate – is that there's no conclusion, the results are inconclusive. This can create problems if the scientist is not careful and rigorous; it creates a problem when the scientist concludes there is no difference when in fact all he should say is: it's inconclusive. This overstepping has happened in the past; conclusions of no difference have been widely publicized in popular press journals, everybody jumped onboard with it, and it turned out to be false. "Science" is not infallible. (Good) Science yes, Scientism no.

God bless you, Fr Kuhn.