The Death of Science
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When I was a kid. No, I can't start that way. But really, back when I was a child, computers were not found in every home. In fact, they were unheard of. Literally, unheard of. The adding machine had been around for a hundred years but the computer, the first real computer, ENIAC, was built during the Second World War just before I was born. From the first grade all the way through the end of high school, we did our mathematics using a pencil. I was usually the one with a big eraser. Graphs were done by hand. This did not make the mathematics any harder. It only made the process take longer. And we had no reason to think it would ever change.

In high school I learned that there were computers in the biggest and best universities. My brother did a Science Fair project on binary numbering and how it worked. By the time I was a senior in college, desktop calculators were available that were capable of working problems using basic mathematics and logarithms. I bought one for a hundred dollars but, at the time, I was not allowed to use it in class. I finally successfully argued that it was nothing more than an electric slide rule, and it was allowed.

I take you through these memories because things changed so much so quickly and because science could become an innocent, but no less dead, bystander, run over by progress.

Consider for a moment the evolution of written language. Thousands of years ago the Egyptians, Mayans, and a few lesser known cultures began to record their thoughts in pictographs or hieroglyphics. The written words were pictures of real life activities. In the orient, these evolved into the characters still in use today. A complex system to say the least. In Arabia, the pictographs became 'pictures' of phonetic sounds, called syllables, and then, eventually, individual sounds. The Arabic alphabet, not Farci, became a way of constructing all of our complicated words with combinations of simple pictures (letters) indicating each particular sound. The alphabet was nearly universal in that it was not language specific. French could be spelled using the same letters that the Germans used.

Progress then gave us computers. Computers are basically stupid. They think in binary. Actually, they don't think at all. They perform in binary. In order to translate, from human thought and language, to binary, the engineers built keyboards and monitors. Essentially, these two pieces of equipment are nothing more than sophisticated mechanical and electrical translation devices. Then software engineers decided that it was too difficult to teach people the stilted command-line language needed to run computers and windows-based, client-server operating systems became

available. To ease the interface, icons were developed. Icons are now in widespread use for many things. Icons are nothing more than pictographs and hieroglyphs. Individual icons cannot be spelled. They have no phonetics. They, as were their predecessors, imprecise in their meaning. Have we come full circle? Are we back to communicating with modern day hieroglyphs?

Let us go back to the pencil we used in our childhood mathematics. Using a pencil to do simple addition, had great value in the effect of the use of time. In this case, the most effective use was and still is the length of time used. While the common wisdom of today says that speed is more efficient, in grade school, being efficient meant taking longer. Time gives the mind a chance to absorb and learn the lessons of mathematics. Today, the lessons are largely limited to which buttons to push. Even the user's manual is in digital form, making it difficult to trouble shoot your calculator or computer when it won't turn on.

The mathematics in the university setting are much more complex than addition and subtraction. In college, I used to do complex calculations of quantitative chemical analyses. A pencil was used to hand calculate analysis of variance routines. To hand calculate a simple standard deviation of a hand calculated fitted line is an exercise in boredom interwoven with the excitement of gaining new knowledge at a pace that allows one to appreciate it. Those same calculations that took weeks before, are now done in the computer at the push of a few buttons. Time is saved, but is it at the cost of understanding?

I present this argument to you because I have seen otherwise respectable scientists rely on packaged statistical software to think for them. As a child, I was exposed to statistics through the need to conduct tests on data that were intermingled such that the mind alone had difficulty separating single statistics to the point of significance. I was also taught that you only needed to use a statistic if you had an uncertainty. No one needs a mathematical test to tell them that an elephant is different from a blue crab. But is a Texas Cougar different from a Florida panther? How exact are public opinion polls? Are Viceroy butterflies really less subject to predation because they look like Monarchs? Simple logic would say yes, or certainly, probably. But if the scientist, the one with the mind, knows that certain insects and small predators don't see light the way that we do and that some 'see' light in a different spectrum, the logic no longer has a common precept and statistics are needed.

To answer questions such as these, statistics may become valuable.

What has become common, however, is to reject any thought unless it is supported by a statistical test for significance. Because we have computers to conduct this exercise, we simply feed in the data and get the result. The error in this process arises from the juxtaposition of hierarchy between the computer's thought processes and those of the scientists. We are becoming computer dependent. The statistic is supposed

to help the scientist make the correct conclusion. Instead, what is happening is that the scientist is accepting the statistical answer as the conclusion with no further thought or understanding.

The exchange of relative positions between man and computer leads to quicker results but a total loss of the meaning of the results: the 'how' of the results. Where is the interpretation? Statistical significance is meant only to be a sign post for the human brain. It is a suggestion; perhaps a well-founded suggestion, but a suggestion nonetheless. The brain must accept the output by determining what the implications are. What does it mean? Does it account for all of the observations or only some? What, in the biology of what is being assessed, drives the data to reflect a significant difference or similarity?

Unfortunately, most of the answers would be inaccurate under today's modus operandi because, in a good portion of the cases, the assumptions of the statistic have been violated. If you don't know what a basic assumption of a particular statistic is, stop reading now, be very afraid for your science, and go to a library until you can answer the question.

Today's normal procedure is to collect data, put it into a spreadsheet, and then run a linear regression, or some other test, primarily because the test is in the software package. Is the data normal? Is the data biased? Is the data multivariate? Has the data been collected throughout the population being tested? Has the population to be tested even been defined? Have enough samples been taken? Have the data been collected correctly so that you can answer these questions? In a classically controlled experiment, the statistics needed should be discerned prior to actual sampling design. Preliminary testing should be conducted to determine the extent and complexity of the sampling effort. Will three cores give you enough benthic data? Or did you really need four, but now it's too late.

The summary of this reflection on the changes made in the conduct and pursuit of science is simple and short.

We, as a people, and in particular as scientists, are becoming more and more dependent on machinery and computer programs to do our work and our thinking for us. There are those of us who have joined the resistance, but are we too few and too late?

Almost on a daily basis, I observe various stages of the advancing atrophy of mental acuity.

Be the resistance. Pull the plug. Pick up a pencil. Disable spell-check.