CARGO CULT SCIENCE by Richard Feynman

Adapted from the Caltech commencement address given in 1974.

During the Middle Ages there were all kinds of crazy ideas, such as that a piece of rhinoceros horn would increase potency. Then a method was discovered for separating the ideas--which was-- to try and see -- if one worked, and if one didn't work, so eliminate the one which didn't work. This method became organized, of course, into science. And it developed very well, so that we are now in the scientific age. It is such a scientific age, in fact that we have difficulty in understanding how witch doctors could ever have existed, when nothing that they proposed ever really worked--or very little of it did. But even today I meet lots of people who sooner or later get me into a conversation about UFOs, or astrology, or some form of mysticism, expanded consciousness, new types of awareness, ESP, and so forth. And I've concluded that a large part of our humanity is not very scientific. So we really ought to look into theories that don't work, and science that isn't science.

In the South Seas there is a cargo cult of people. During the war they saw airplanes land with lots of good materials, and they want the same thing to happen now. So they've arranged to imitate things like runways, to put fires along the sides of the runways, to make a wooden hut for a man to sit in, with two wooden pieces on his head like headphones and bars of bamboo sticking out like antennas--he's the controller--and they wait for the airplanes to land. They're doing everything right. The form is perfect. It looks exactly the way it looked before. But it doesn't work. No airplanes land. So I call these kind of situations - "cargo cult science", because they follow all the apparent precepts and forms of scientific investigation, but they're missing something essential, because the planes don't land. Now it behooves me, of course, to tell you what they're missing. But it would be just about as difficult to explain to the South Sea Islanders how they have to arrange things so that they get some wealth in their system. It is not something simple like telling them how to improve the shapes of the earphones. But there is one feature I notice that is generally missing in cargo cult science. That is the idea that we all hope you have learned in studying science in school--we never explicitly say what this is, but just hope that you catch on by all the examples of scientific investigation. It is interesting, therefore, to bring it out now and speak of it explicitly. It's a kind of scientific integrity, a principle of scientific thought that corresponds to a kind of utter honesty--a kind of leaning over backwards. For example, if you're doing an experiment, you should report everything that you think might make it invalid--not only what you think is right about it: other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked--to make sure the other fellow can tell they have been eliminated. Details that could throw doubt on your interpretation must be given, if you know them. You must do the best you can--if you know anything at all is wrong, or possibly wrong—you have to explain it. If you make a theory, for example, and advertise it, or put it out, then you must also put down all the facts that disagree with it, as well as those that agree with it. There is also a more subtle problem. When you have put a lot of ideas together to make an elaborate theory, you want to make sure, when explaining what it fits, that those things it fits are not just the things that gave you the idea for the theory; but that the finished theory makes something else come out right, in addition. In summary, the idea is to try to give all of the information to help others to judge the value of your contribution; not just the

information that leads to judgment in one particular direction or another. The easiest way to explain this idea is to contrast it, for example, with advertising. Last night I heard that Wesson oil doesn't soak through food. Well, that's true. It's not dishonest; but the thing I'm talking about is not just a matter of not being dishonest, it's a matter of scientific integrity, which is another level. The fact that should be added to that advertising statement is that no oils soak through food, if operated at a certain temperature. If operated at another temperature, they all will-- including Wesson oil. So it's the implication which has been conveyed, not the fact, which is true, and the difference is what we have to deal with. ***We've learned from experience that the truth will come out***. Other experimenters will repeat your experiment and find out whether you were wrong or right. Nature's phenomena will agree or they'll disagree with your theory. And, although you may gain some temporary fame and excitement, you will not gain a good reputation as a scientist if you haven't tried to be very careful in this kind of work. And it's this type of integrity, this kind of care ***not to fool yourself***, that is missing to a large extent in much of the research in cargo cult science. A great deal of their difficulty is, of course, the difficulty of the subject and the inapplicability of the scientific method to the subject. Nevertheless it should be remarked that this is not the only difficulty. That's why the planes didn't land--and they don't land. We have learned a lot from experience about how to handle some of the ways we fool ourselves. One example: Millikan measured the charge on an electron by an experiment with falling oil drops, and got an answer which we now know not to be quite right. It's a little bit off, because he had the incorrect value for the viscosity of air. It's interesting to look at the history of measurements of the charge of the electron, after Millikan. If you plot them as a function of time, you find that one is a little bigger than Millikan's, and the next one's a little bit bigger than that, and the next one's a little bit bigger than that, until finally they settle down to a number which is higher. Why didn't they discover that the new number was higher right away? It's a thing that scientists are always prone to. When they got a number that was too high above Millikan's, they thought something must be wrong--and they would look for and find a reason why something might be wrong. When they got a number closer to Millikan's value they didn't look so hard. And so they eliminated the numbers that were too far off. We've learned those tricks nowadays, and now we don't have that kind of a disease. But this long history of learning ***how not to fool ourselves***, of having utter scientific integrity is, I'm sorry to say, something that we ***haven't specifically included in any particular course*** that I know of. We just hope you've caught on by osmosis. The first principle is that you must not fool yourself and ***you*** are the easiest person to fool. So you have to be very careful about that. After you've not fooled yourself, it's easy not to fool other scientists. You just have to be honest in a conventional way after that. …. I would like to add something that's not essential to the science, but something I kind of believe, which is that you should not fool the layman when you're talking as a scientist. I'm talking about a specific, extra type of integrity that is not lying, but bending over backwards to show how you are maybe wrong, that you ought to have when acting as a scientist. And this is our responsibility as scientists, certainly to other scientists, and ***I think to laymen also***. For example, I was a little surprised when I was talking to a friend who was going to go on the radio. He does work on cosmology and astronomy, and he wondered how he would explain what the

applications of this work were. "Well," I said, "there aren't any." He said, "Yes, but then we won't get support for more research of this kind." I think that's kind of dishonest. If you're representing yourself as a scientist, then you should explain to the layman what you're doing--and if they don't want to support you under those circumstances, then that's their decision. One example of the principle is this: If you've made up your mind to test a theory, or you want to explain some idea, you should always decide to publish it whichever way it comes out. If we only publish results of a certain kind, we can make the argument look good. We must publish both kinds of results. I say that's also important in giving certain types of government advice. Supposing a senator asked you for advice about whether drilling a hole should be done in his state; and you decide it would be better in some other state. If you don't publish such a result, it seems to me you're not giving scientific advice. You're being used. If your answer happens to come out in the direction the government or the politicians like, they can use it as an argument in their favor; if it comes out the other way, they don't publish it at all. That's not giving scientific advice. …. So I have just one wish for you--the good luck to be somewhere where you are free to maintain the kind of integrity I have described, and where you do not feel forced by a need to maintain your position in the organization, or financial support, or so on …..

(***one personal note*** about "odd" results. After fitting a straight line, say, to a group of points there may be a misfit – a point far from the straight line. Please take a careful look at this point!
Science is littered with oddities. The stars in the sky make nocturnal journeys but just a few "stars" didn't obey the rules. Perhaps the Gods were playing tricks ???
We know these "stars" as planets and studying planetary motion culminated in Newton's Gravitational theory. Researchers must always be beset with doubts. Could Rutherford have discounted his strange scattering results or Jocelyn Bell Burnell ignored erratic movements on her chart recorder? Professor Web could have admitted that his gravitational wave detection was a fake but look at the amount of experimental activity that has followed from his initial work; we now have LIGO, (Laser Interferometer Gravitational-Wave Observatory) and gravity waves have now been detected.

Some would say that Science is more of an "art" than a "science" but whichever way you think there is one unassailable truth that--

--- ***SCIENCE IS VERY PRECIOUS TO THE HUMAN RACE***)

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