LECTURE 26

EXPERTS

As remarked in an earlier Lecture, as our knowledge grows exponentially we cope with the growth mainly by specialization. It is increasingly true:

An expert is one who knows everything about nothing;
A generalist knows nothing about everything.

In an argument between a specialist and a generalist the expert usually wins by simply: (1) using unintelligible jargon, and (2) citing their specialist results that are often completely irrelevant to the discussion. The expert is, therefore, a potent factor to be reckoned with in our society. Since experts are both necessary, and also at times do great harm in blocking significant progress, they need to be examined closely. All too often the expert misunderstands the problem at hand, but the generalist cannot carry though their side to completion. The person who thinks they understand the problem and does not is usually more of a curse (blockage) than the person who knows they do not understand the problem.

Kuhn, in his book Scientific Revolutions examined the structure of scientific progress and introduced the concept of paradigm, (pattern, example), as a description of the normal state of Science. He observed that most of the time any particular science has an accepted set of assumptions, often not mentioned or discussed, whose results are taught to the students, and which the students in turn accept without being aware of how extensive these assumptions are. There is also an accepted set of problems and methods of attacking them. The workers in the field proceed in this fashion, extending and elaborating the field endlessly, and simply ignoring any contradictions that may come up.

Occasionally, usually because of the contradictions that most of the people in the field choose to ignore or simply forget, there will arise a sudden change in the paradigm, and as a result a new pattern of beliefs comes into dominance, along with the ability to ask new kinds of questions and get new kinds of answers to older problems. These changes in the dominant paradigm of a science usually represent the great steps forward. For example, both special relativity and QM represent such changes in the field of physics.

At first the change is resisted by the establishment, which has so much of their past effort invested in the old approach, but usually, so Kuhn and others like to believe, the new triumphs over the old. I suppose if you allow enough time, then that is right, but the number of years may be more than the initiator's

lifetime! For example, I earlier mentioned that continental drift was discussed by Thomas Dick in 1838, and later in a book by Alfred Wegener written in the early 1900's. As children both my wife and I, (independently, as we did not know each other at that time), read Wegener's book and noted that yes, the shapes of Africa and South America fit very well, but we were not convinced until Wegener also observed that along certain corresponding parts of the two coasts the sequence of rock formations agreed in detail! Never mind that it was obvious to even the untrained eye of a child, the experts would have no part of it, and it was ridiculed regularly by the experts in geology.

There is another source for continental drift, namely the distribution of forms of life over the aeons of history. The mutually common forms of life found in widely separated places necessitated the creation of "land bridges" that were supposed to have risen and sunk again - and the number of these, plus their various placements, seemed unbelievable to me as a child, particularly as there were no observations of their traces in the depths of the oceans to justify them. The biologists studying the past, in trying to account for what they saw, had also postulated both a Pangaea and Gonwanaland as successive arrangements of the continents, not apparently caring for the "land bridges" that seemed necessary otherwise, yet the geologists still resisted. The concept of continental drift was accepted by the oceanographers only after WWII when by studying the ocean bottom they found, by magnetic methods, the actual cracks and the spreading of the land on the ocean floor.

Of course geologists now claim that they had always sort of believed in it (the textbooks they used to the contrary) and it was only necessary to exhibit the actual mechanism in detail before they would accept the continental drift theory, which is now "the truth". This is the typical pattern of a change in the paradigm of a field. It is resisted for a shorter or longer time, (and I do not know how many theories were permanently lost - how could I?), before being accepted as being right, and those concerned then saying that they had not actively opposed the change. You have probably heard many past examples such as the aviation expert saying, just before the Wright brothers flew, that heavier than air flying was impossible, the old claim that if you went too fast in an automobile or train that you would lose your breath and die, that faster than sound flight (supersonic flight) was impossible, etc. The record of the experts saying that something is impossible just before it is done is amazing. One of my favorite ones was that you cannot lift water more than 33 feet. But when the patent office rejected a patent that claimed his method could, the man demonstrated it by lifting water to the roof of their building, which was much more than 33 ft. How? He used, Figure 26-1, a method of standing waves which they had not thought about. When a low pressure of the standing wave appeared at the bottom then water was admitted into the column, and when a high pressure appeared at the top water exited due to the valves that were installed. All the Patent Office experts knew was that the text books said it could not be done, and they never looked to see on what basis this was

stated.

All impossibility proofs must rest on a number of assumptions which may or may not apply in the particular situation.

Experts in looking at something new always bring their expertise with them as well as their particular way of looking at things. Whatever does not fit into their frame of reference is dismissed, not seen, or forced to fit into their beliefs. Thus really new ideas seldom arise from the experts in the field. You can't blame them too much since it is more economical to try the old, successful ways before trying to find new ways of looking and thinking.

All things that are proved to be impossible must obviously rest on some assumptions, and when one or more of these assumptions are not true then the impossibility proof fails - but the expert seldom remembers to carefully inspect the assumptions before making their "impossible" statements. There is an old statement that covers this aspect of the expert. It goes as follows:

"If an expert says that something can be done he is probably correct, but if he says that it is impossible then consider getting another opinion."

Kuhn, and the historians of Science, have concentrated on the large changes in the paradigms of Science; it seems to me that much the same applies to smaller changes. For example, working for Bell Telephone Laboratories it was fairly natural that I should meet the frequency approach to numerical analysis, and hence apply it to the numerical methods I used on the various problems I was asked to solve. Using the kinds of functions that the clients are familiar with means that insight can arise from the solution details that suggest other things to do than what they had originally thought. I found the frequency approach very useful, but some of my close friends, not at Bell Telephone Laboratories, regularly twitted me about the frequency approach every time they met me for all the years we have been meeting at various places. They simply kept the polynomial approach, though under questioning they could give no real reason for doing so - simply that that was the way things had been done, hence that was the right way to do things.

It is not just for the pleasure of poking fun at the experts that I bring this up. There are at least four other reasons for doing so.

First, as you go on you will have to deal with experts many times, and you should understand their characteristics.

Second, in time many of you will be experts, and I am hoping to at least modify the behavior of some of you so that you will, in your turn, not be such a block on progress as many experts have been in the past.

Third, it appears to me that the rate of progress, the rate of innovation and change of the dominant paradigm, is increasing, and hence you will have to endure more changes than I did.

Fourth, if only I knew the right things to say to you then when a paradigm change occurs fewer of you would be left behind in your careers than usually happens to the experts.

In discussing the expert let me introduce another aspect that has barely been mentioned so far. It appears that most of the great innovations come from outside the field, and not from the insiders. I cited above continental drift. Consider archaeology. A central problem is the dating of the remains found. In the past this was done by elaborate, unreliable stratigraphy, by estimating the time needed to bury the material where it was found. Now carbon dating is used as the main tool. Where did it come from? Physics! None of the archaeology experts would have ever thought of it. So far as I can make out, the first automatic telephone came from an undertaker who thought that he was not getting fair treatment from the telephone company and designed a machine that would be fair. Similar examples occur in most fields of work, but the text books seldom, if ever, discuss this aspect. At the time of Einstein's famous "five papers in one year" he was working in the Swiss patent office! He had not been able to find an official position within the circle of University physics. In fairness to the system, in a few years he was recognized and offered various prestigious positions, ending up in Berlin. The Nazis later drove him out of Berlin to the Institute of Advanced Study, Princeton.

Thus the expert faces the following dilemma. Outside the field there are a large number of genuine crackpots with their crazy ideas, but among them may also be the crackpot with the new, innovative idea that is going to triumph. What is a rational strategy for the expert to adopt? Most decide that they will ignore, as best they can, all crackpots, thus ensuring that they will not be part of the new paradigm, if and when it comes.

Those experts who do look for the possible innovative crackpot are likely to spend their lives in the futile pursuit of the elusive, rare crackpot with the right idea, the only idea that really matters in the long run. Obviously the strategy for you to adopt depends on how much you are willing to be merely one of those who served to advance things, vs. the desire to be one of the few who in the long run really matter. I cannot tell you which you should choose - that is your choice. But I do say that you should be conscious of making the choice as you pursue your career. Don't just drift along; think of what you want to be and how to get there. Don't automatically reject every crazy idea, the moment you hear of it, especially when it comes from outside the official circle of the insiders - it may be the great new approach that will change the paradigm of the field! But also you cannot afford to pursue every "crackpot" idea you hear about. I have been talking about paradigms of Science, but so far as I know the same applies to most fields of human thought, though I

have not investigated them closely. And it probably happens for about the same reasons; the insiders are too sure of themselves, have too much invested in the accepted approaches, and are plain mentally lazy. Think of the history of modern technology that you know!

I have covered the two main problems of dealing with the experts. They are: (1) the expert is certain that they are right, and (2) they do not consider the basis for their beliefs and the extent to which they apply to new situations. I told you about the FFT and why it is not the Tukey-Hamming algorithm. That was not the only time I made a mistake like that, forgetting that there had been a technological change which invalidated my earlier reasoning, as well as the many other cases where I have observed it happen. To my embarrassment I told the story in order to get the point vividly across to you. I made the mistake; how are you going to avoid it when your turn comes? No one ever told me about the problem, while I have told you about it, so maybe you will not be as foolish as I have been at times.

With the rapid increase in the use of technology this type of error is going to occur more often, so far as I can see. The experts live in their closed world of theory, certain that they are right and are intolerant of other opinions. In some respects the expert is the curse of our society with their assurance that they know everything, and without the decent humility to consider that they might be wrong. That is where the question looms so important that I suggested to you long ago to use in an argument, "What would you accept as evidence that you are wrong?" Ask yourself regularly, "Why do I believe whatever I do" Especially in the areas where you are so sure you know; the area of the paradigms of your field.

The opposition of the expert is often not as direct as indicated above. Consider my experience at Bell Telephone Laboratories during the earliest years of the coming of digital computers. My immediate bosses all had succeeded in the mathematical areas by using analytical methods, and during their heyday computing had been relegated to some high school graduate girls with desk calculators. The bosses <u>knew</u> the right way to do mathematics. It was useless to argue their basic assumptions with them - they might even have denied that they held them - since they, based on their own experiences knew they were right! They saw, every one of them, the computer as being inferior, beneath the consideration of a real mathematician, and in the final analysis possibly in direct competition with them - this later giving rise to fear and hatred. It was not a discussible topic with them. I had to do computing in spite of all their (usually unstated) opposition, in spite of all the times they said that they had done something that I could not do with the machines that I had available at the time, and in spite of all my polite replies that I was not concerned with direct competition, rather I was solely interested in doing what they could not do, that I was concerned with what the team of man and machine could do together. I hesitate to guess the number of times I had to give that kind of a reply to a not direct but a covert attack on

computers in the early days. And this in a highly enlightened place like Bell Telephone Laboratories.

The second point I want to make is that many of you, in your turn, will become experts, and I am hoping to modify in you the worst aspects of the know-it-all expert. About all I can do is to beg you to watch and see for yourself how often the above descriptions occur in your career, and hope thereby that you will not be the drag on progress that the expert so often is. In my own case, I vowed that when I rose to near the top I would be careful, and as a result I have refused to take part in any decision processes involving current choices of computers. I will give my opinion when asked, but I do not want to be the kind of drag on the next generation that I had to put up with from the past generation. Modesty? No, pride!

To put the situation in the form of a picture we draw a line in n-dimensional space to represent, symbolically, the path of progress in time, Figure 26-2, which is drawn, of course, in 2-dimensions. At the start of the picture, say 1935 and earlier, the direction was as indicated by the tangent arrow, and those who sensed what to do and how to do it (then) were the successful people, and were, therefore, my bosses. Then computers came in and at the later date the curve is now pointed in another direction, almost perpendicular to the past one. It is asking a lot of them to admit that the very methods that they earlier used to succeed are not appropriate present! But it is true, if this picture is at all like reality (remember it is in n-dimensional space). If my claim that progress has not stopped miraculously at present, but rather there is probably an accelerating rate of progress, then it will be even more true when you are in charge that:

What you did to become successful is likely to be counterproductive when applied at a later date.

Please remember this when you have risen to the top and are in charge; do as I have tried to do and let the next generation have a cleaner chance at success than you were granted by your management while you were rising to the top. I observed to you some lectures ago, that a friend behind my back remarked that he doubted that Hamming understood error correcting codes - and I admitted that probably he was right! I do believe in what I am telling you; the old expert is all too often wrong and a block to progress. Consider the case of Einstein, who gave QM such a start with his photoelectric paper, and was in his turn a plain drag on QM when he so aggressively opposed the theory of QM as it developed. Physicists are polite about this point as they hate to admit that their tin god Einstein could be so definitely wrong; they excuse him this way and that, but under pressure they have to admit that once again the person who opened up the field did not understand what he had done, and is best ignored at a later date!

There is the final, and overwhelming, reason for telling you these things. I have observed again and again that most experts

are left behind as their field progresses and new paradigms come in. Taking only the history of computing as I observed it, I have told you in Lecture 4 of the great opposition of the programmers to: (1) symbolic languages (what you call machine language but is not absolute binary coding), (2) higher level software, and (3) FORTRAN when it first came in. What happened to many of them? Most of them gradually dropped out of the field and disappeared! They could not keep up.

A very good friend of mine was a great analog enthusiast and it was from him that I learned a lot about analog computers when I acquired the management of the one at Bell Telephone Laboratories. When digital methods came in, he constantly emphasized the advantages, at that time, of the analog computers. Well, he was gradually squeezed out by his own behavior and fell back on other skills he had. But when I retired early to go to teaching, as I had long planned to do (since I felt that old research people mainly get in the way of the young), he also found it convenient to retire early (because of a company offering at that time for early retirement). But I left with pleasant memories of Bell Telephone Laboratories and later, in talking with him, I found that his memories are not so pleasant!

If you do not keep up in your field that is almost certainly what will happen to you. While living in California I have met and talked with a number of ex-Navy officers of the rank Captain, and the stories they tell often reveal a degree of distaste in their careers. How could it be otherwise? If you are passed over for an important (to you) promotion in an organization, then it will tend to affect all the relevant memories of a great career and taint them darker. It is this social, as well as the economic, consequence that I care about and why I am preaching this lesson - you must keep up or else things will overtake you and may spoil the memories of your career.

I have used isolated stories many times in these Lectures. They are illustrative of situations, and I know many other stories that would illustrate the same points. I began to formulate many of these "theories" long ago, and as time went on experience illustrated their truth many times over, though some turned out to be false and had to be abandoned. These are not absolute truths, they are summaries of many observations which tend to "prove" the points made. Of course, you can say that I looked for confirmations, but being a scientist I tried also to look for falsifications and in the face of counter evidence had to abandon some theories. When you think over many of the stories, they often have an element of "truth" based more on human traits than anything else. We are all human, but that does not prevent us from trying to modify our instincts that were evolved over the long span of history. Civilization is merely a thin veneer that we have put on top of our anciently derived instincts, but the veneer is what makes it possible for modern society to operate. Being civilized means, among other things, stopping your immediate response to a situation, and thinking whether it is or is not the appropriate thing to do. I am merely trying to make you more self-aware so that you will be more

"civilized" in your responses and hence probably, but not certainly, more successful in attaining the things you want.

In summary, I began by warning you about dealing with experts; but towards the end I am warning you about yourself when in your turn you are the expert. Please do not make the same foolish mistakes I did!

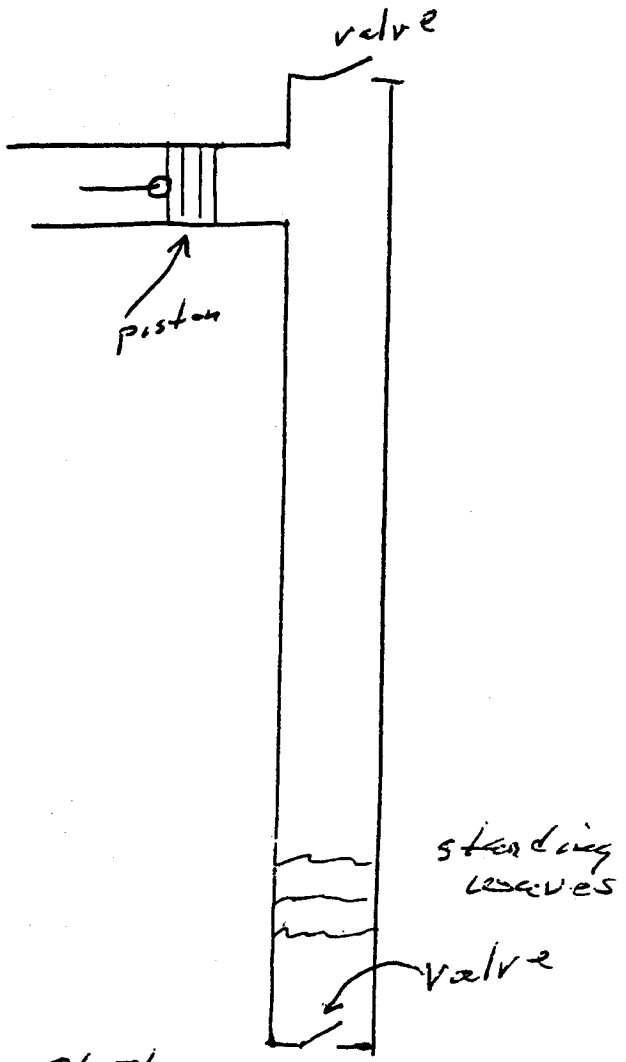
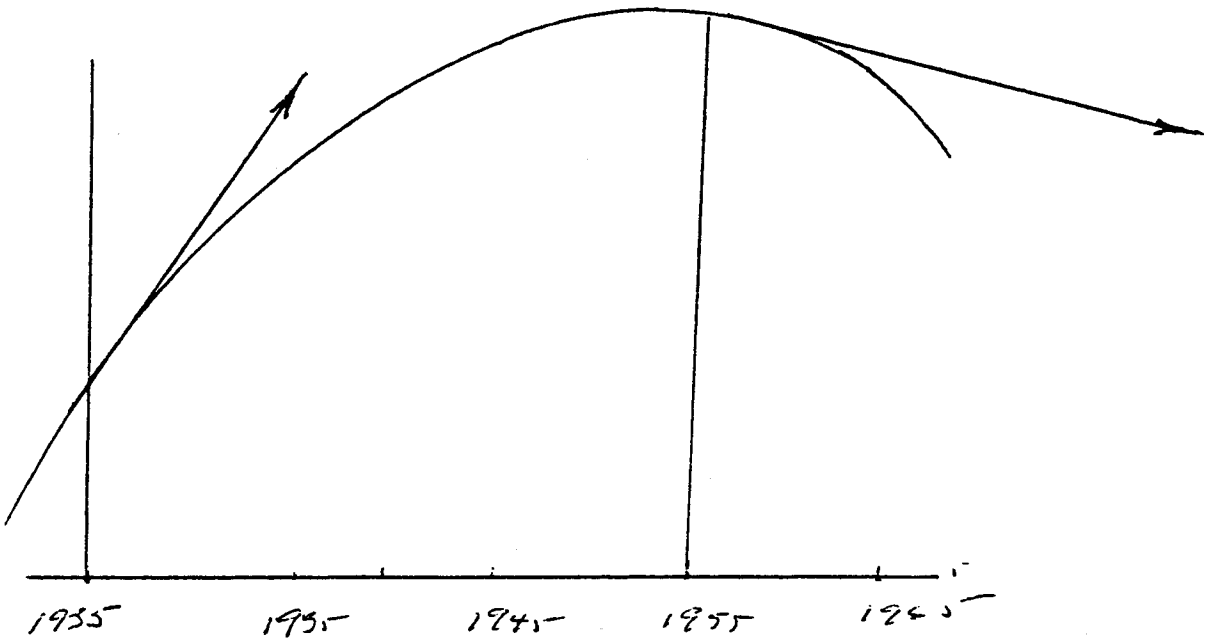


Figure 24-1



Local progress

Figure 26-2