LECTURE 25

CREATIVITY

Creativity, originality, novelty, and such words are regarded as "good things", and we often fail to distinguish between them - indeed we find them hard to define. Surely we do not need three words with exactly the same meaning, hence we should try to differentiate somewhat between them as we try to define them. The importance of definitions has been stressed before, and we will use this occasion to illustrate an approach to defining things, not that we will succeed perfectly or even well.

It should be remarked that in primitive societies creativity, originality, and novelty are not appreciated, rather doing as one's ancestors did is the proper thing to do. This is also true in many large organizations today; the elders are sure they know how the future should be handled and the younger members of the tribe when they do things differently are not appreciated.

Long ago a friend of mine in computing once remarked that he would like to do something original with a computer, something that no one else had ever done. I promptly replied, "Take a random 10 decimal digit number and multiply it by another random 10 digit number and it will almost certainly be something that no one else has ever done." There are, using back of the envelop computing, about $(81/2)\times10^{18}$ such products, and with only around 3×10^{16} nanoseconds in a year you can estimate the odds of it being an original product. Naturally he was not pleased with the suggestion, but he would have gladly settled for computing the largest known prime number up to that time! Why the difference? Why would one number go into a record book, at least temporarily, and not the other? For one thing, records require either a great deal of effort to accomplish or else a remarkable coincidence, and the random multiplication had neither so far as the average person can see. Evidently "not done before" is hardly enough to make anything important or original. "Originality" seems to be more than not having been done before.

The Art world, especially painting, has had a great deal of trouble with the distinction between <u>creativity</u> and <u>originality</u> for most of this century. Modern artists, and Museum Directors, offer to the public things that are certainly novel and new, but which many of the potential paying public often does not like. For many people the shock value of various forms of art has finally worn off, and the average person no longer responds to the current "modern art". After all, I could paint a picture and it would be new and novel, but I would hardly consider it as a "creative work of Art" - whatever that means.

Evidently we want the word "creative" to include the concept of value - but value to whom? A new theorem in some branch of mathematics may be a creative act, but the number of people who can appreciate it may be very few indeed, so we must be careful not to insist that the created thing be widely appreciated. We also have the fact that many of the current highly valued works of Art were not appreciated during the artist's lifetime - indeed the phenomenon is so common as to be discouraging. By a kind of inverted logic it does allow many people to believe that because they are unappreciated therefore they must be a great artist!

I hope that the above has disentangled some of the confusion between creativity, novelty, and originality, but I am not able to say just what this word "creativity", that we value so much in our society, actually means. In women's fashions it seems to mean "different", but not "too different"!

I must continue for now using your intuitive feelings as to what the creative act is and how to recognize it. In 1838 Thomas Dick published a book in which what is now called "continental drift" was clearly mentioned, and in the early 1900's Wegener published a book devoted to the topic of continental drift but it was only after WWII that continental drift was accepted in official circles. So Art is not the only field in which creativity is not recognized when it happens - Science has its failings too. One can also cite Mendel (1822-1884) and his experiments with peas, which were ignored until three people in 1900 simultaneously rediscovered genetics, and then still later found Mendel's paper! In genetics Mendel now generally gets the public credit, but with continental drift it is often credited to the post WWII creators.

In a discussion about creativity some one observed to me that if he took parts of three extensively developed fields and combined them simply then that it would be a large creative act, that the degree of creativity does not depend on how hard the actual act is to do - so far as it appears to later generations. I once applied the well known method of least squares to a problem in magnetics. The other person wrote it up, with me as joint author, and sent it to me for my signature (for release for publication). I went to a shrewd physicist friend and said that I could not publish a paper which merely applied least squares. He observed to me that his most requested reprint was for a paper in solid state physics which applied standard circuit analysis to the problem; and that since the paper awaiting my signature was new in the area I should sign and let it be published.

Creativity seems, among other things, to be "usefully" putting together things that were not perceived to be related before, and it may be the initial psychological distance between the things that counts most. How difficult was it for me to discard L_2 and use L_1 when considering the distance between two strings of bits? All that can be said was that it had apparently not been done before and that doing so advanced the field significantly, (at the same time maximum likelihood occurred in

Shannon's Information Theory papers, and it is equivalent to L_1).

It appears to be the "set of the mind" at the creative moment that enables creativity to be done. Can we do anything to increase creativity? There are training courses, and books, as well as "brain storming sessions" that are supposed to do this. Taking the "brain storming sessions" first, while they were very fashionable at one time, they have generally been found to be not much good when formally done, when a brain storming session is carefully scheduled. But we all have had the experience of "tossing an idea around" with a friend, or a few friends (but not a large group, generally) from which insight, creativity, or whatever you care to call it, arises and we make progress. As for the many other approaches to creativity, again the record does not show any one approach has been so successful as to produce a great number of dominant figures in Science or any other field.

It should be evident, from the fact I am using a whole Lecture on the topic, that I think creativity in an individual can probably be improved. Indeed, it has been a topic in much of the course, though I have often called it "style". I believe that the future will have even greater need for new, creative, ideas than had the past, hence I must do what I can to increase the probability that you will form your own effective style and have "great ideas". But except for discussing the topic, making you aware of it, and indicating what we think we know about it, I have no real suggestions (that I can put into concrete words) on how to make you, magically, more creative in your careers. The topic is too important to ignore, even if I do not understand the creative act very well. Better I should try to do it, a person you know who has experienced it many times, than you get it from some people who themselves have never done a significant creative act. I often suspect that creativity is like sex; a young lad can read all the books you have on the topic, but without direct experience he will have little chance of understanding what sex is - but even with experience he may still not understand what is going on! So we must continue, even if we are not at all sure that we know what we are talking about.

Introspection, and an examination of history and of reports of those who have done great work, all seem to show that typically the pattern of creativity is as follows. There is first the recognition of the problem in some dim sense. This is followed by a longer or shorter period of refinement of the problem. Don't be too hasty at this stage, as you are likely to put the problem in the conventional form and find only the conventional solution. This stage, more over, requires your <u>emotional involvement</u>, your commitment to finding a solution since without a deep emotional involvement you are not likely to find a really fundamental, novel solution.

A long gestation period of intense thinking about the problem may result in a solution, or else the temporary abandonment of the problem. This temporary abandonment is a common feature of many great creative acts. The monomaniacal pursuit often

does not work; the temporary dropping of the idea sometimes seems to be essential to let the subconscious find a new approach.

Then comes the moment of "insight", creativity, or what ever you want to call it - you see the solution. Of course it often happens that you are wrong, that a closer examination of the problem shows that the solution is faulty, but might be saved by some suitable revision. But maybe the problem needs to be altered to fit the solution! That has happened! More usually it is back to the drawing board, as they say, more mulling things over.

The false starts and false solutions often sharpen the next approach you try. You now know how not to do it! You have a smaller number of approaches left to explore. You have a better idea of what will not work and possibly why it will not work.

When stuck I often ask myself, "If I had a solution, what would it look like?" This tends to sharpen up the approach, and may reveal new ways of looking at the problem that you had subconsciously ignored but you now see should not be excluded. What must the solution involve? Are there conservation laws that must apply? Is there some symmetry? How does each assumption enter into the solution, and is each one really necessary? Have you recognized all the relevant factors?

Out of it all, sometimes, comes the solution. So far as anyone understands the process it arises from the subconscious, it is suddenly there! There is often a lot of further work to be done on the idea, the logical cleaning up, the organizing so that others can see it, the public presentation to others which may require new ways of looking at the problem and your solution, not just your idiosyncratic way that gave you the first solution. This revision of the solution often brings clarity to you in the long run!

If the solution does come from the subconscious, what can we do to manage our subconscious? My method, and it is implied above, is to saturate the subconscious with the problem, try to not think seriously about anything else for hours, days, or even weeks, and thus the subconscious which, so far as we know, depends heavily upon live experiences to form its dreams, etc. is then left with only the problem to mull over. We simply deprive it of all else as best we can! Hence, one day, we have the solution, either as we awake, or it pops into our mind without any preparation on our part, or as we pick up the problem again there the solution is! In a way, I am repeating Pasteur, "Luck favors the prepared mind." You prepare your mind for success "by thinking on it constantly" (Newton), and occasionally you are lucky.

Probably the most important tool in creativity is the use of an <u>analogy</u>. Something seems like something else which we knew in the past. Wide acquaintance with various fields of knowledge is thus a help - <u>provided</u> you have the knowledge filed away so that it is available when needed, rather than to be found only when

led directly to it. This flexible access to pieces of knowledge seems to come from looking at knowledge while you are acquiring it from many different angles, turning over any new idea to see its many sides before filing it away. This implies effort on your part not to take the easy, immediately useful "memorizing the material" path, but prepare your mind for the future. It is for this reason that I have urged you in many of the Lectures to get down to the fundamentals of a field, since it implies that you must examine things many ways before you can decide what is fundamental and what is frills. In fact, for one person they may be in one order, and for another in the opposite order. What is fundamental partly depends on the individual and their mental make-up. It is obvious that you need many "hooks" on the knowledge if you are to use it in new situations.

We reason mainly by analogy. But it is curious that a valuable analogy need not be close - it need only be suggestive of what to do next. A dream by Kekule about snakes biting their own tails suggested to him, when he awoke, the ring structure of carbon compounds! Many a poor analogy has proved useful in the hands of experts. This implies that the analogy you use is only partial and you need to be able to abandon it when it is pressed too far; analogies are seldom so perfect that every detail in one situation exactly matches those of the other. We find the analogies when something reminds us of something else - is it only a matter of the "hooks" we have in our minds?

Over the years of watching and working with John Tukey I found many times that he recalled the relevant information and I did not, until he pointed it out to me. Clearly his information retrieval system had many more "hooks" than mine did. At least more useful ones! How could this be? Probably because he was more in the habit than I was of turning over new information again and again so that his "hooks" for retrieval were more numerous and significantly better than mine were. Hence wishing that I could similarly do what he did, I started to mull over new ideas, trying to make significant "hooks" to relevant information so that when later I went fishing for an idea I had a better chance of finding an analogy. I can only advise you to do what I tried to do - when you learn something new think of other applications of it - ones that have not arisen in your past but which might in your future. How easy to say, but how hard to do! Yet, what else can I say about how to organize your mind so that useful things will be recalled readily at the right time?

Many books are written these days on the topic of creativity; we often talk about it, and we even have whole conferences devoted to it, yet we can say so little! There is much talk about having the right surrounding atmosphere - as if that mattered much! I have seen the creative act done under the most trying circumstances. Indeed, I often suspect, as I will later discuss more fully, that what the individual regards as ideal conditions for creativity is not what is needed, but rather the constant impinging of reality is often a great help.

In the past I have deliberately managed myself in this mat-

ter by promising a result by a given date, and then, like a cornered rat, having at the last minute to find something! I have been surprised at how often this simple trick of managing myself has worked for me. Of course it depends on having a great deal of pride and self-confidence. Without self-confidence you are not likely to create great, new things. There is a thin line between having enough self-confidence and being over-confident. I suppose that the difference is whether you succeed or fail; when you win you are strong willed, and when you lose you are stubborn!

Back to the topic of whether we can teach creativity or not. From the above you should get the idea that I believe it can be taught. It cannot be done with simple tricks and easy methods; what must be done is that <u>you must change yourself</u> to be more creative. As I have thought about it in the past I realize how often I have tried to change myself so that I was more as I wished I were and less as I had been. (Often I did not succeed!) Changing oneself is not easy, as anyone who has gone on a diet to lose weight can testify; but that you can indeed change yourself is also evident from the few who do succeed in dieting, quitting smoking, and other changes in habits. We are, in a very real sense, the sum total of our habits, and nothing more; hence by changing our habits, once we understand which ones we should change and in what directions and understand our limitations in changing ourselves, then we are on the path along which we want to go.

In planning to change yourself clearly the old Greek saying applies, "Know thyself." and do not try heroic reformations that are almost certain to fail. Practice on small ones until you gradually build up your ability to change yourself in the larger things. You must learn to walk before you run in this matter of being creative, but I believe that it can be done. Furthermore, if you are to succeed, (to the extent you secretly wish to), you must become creative in the face of the rapidly changing technology which will dominate your career. Society will not stand still for you, it will evolve more and more rapidly as technology plays an increasing role at all level of the organization. My job is to make you one of the leaders in this changing world, not a follower, and I am trying my best to alter you, especially in getting you <u>to take charge of yourself</u> and not to depend on others, such as me, to help. The many small stories I have told you about myself are partly to convince you that you can be creative when your turn comes for guiding our society to its possible future. The stories have also been included to show you some possible models of how to do things.

I have not yet discussed the delicate topic of dropping a problem. If you cannot drop a wrong problem then the first time you meet one you will be stuck with it for the rest of your career. Einstein was tremendously creative in his early years, but once he began, in mid-life, the search for a unified theory then he spent the rest of his life on it and had about nothing to show for all the effort. I have seen this many times while watching how Science is done. It is most likely to happen to the

very creative people; their previous successes convince them that they can solve any problem; but there are other reasons besides over-confidence why, in many fields, sterility sets in with advancing age. Managing a creative career is not an easy task, or else it would often be done. In mathematics, theoretical physics and astrophysics, age seems to be a handicap (all characterized by high, raw creativity) while in music composition, literature, and statesmanship, age and experience seem to an asset. As valued by Bell Telephone Laboratories in the late 70's, the first 15 years of my career included all that they listed, and for my second 15 years they listed nothing I was very closely associated with! Yes, in my areas the really great things are generally done while the person is young, much as in athletics, and in old age you can turn to coaching (teaching) as I have done. Of course I do not know your field of expertise to say what effect age will have, but I suspect that really great things will be realized fairly young, though it may take years to get them into practice. My advice is that if you want to do significant things, now is the time to start thinking (if you have not already done so) and not wait until it is the proper moment - which may never arrive!

In closing I want to remind you yet again of Pasteur's remark, "Luck favors the prepared mind." Yes it is a matter of luck just what you do, it is much less luck that you will do something if you prepare yourself to succeed. "Creativity" is just another name for the great successes that make a difference in history.