euresis journal

euresis
Association for the Promotion of the Scientific Endeavour

Volume 2
Winter 2012

journal homepage
www.euresisjournal.org

The Dimensions and Dialectics of Creativity

Alan Macfarlane
King's College, Cambridge, CB2 1ST, UK
am12@cam.ac.uk

Abstract

Human creativity is a mystery. In the first part I will outline some of the theoretical issues and ways of approaching creativity that have interested me. These are the questions and conjectures that lie behind the particular project described in the second half. This describes a set of film interviews with scientists and others about their life and work undertaken in order to see how creativity works in the intersection between lives and structures. The first part describes the construction of a theoretical net. The second describes some of the methods of using the net, and a few of the fish who have been landed.

1. The levels of creativity

It is possible to approach the analysis of the conditions for intellectual creativity from many angles. Each of them is fruitful and they complement each other. It is helpful to think of these as levels or dimensions, all inter-acting but analytically separable.[1]

There is the macro level of the society or civilization. Thus we might compare the conditions for creativity in Tokugawa Japan and Renaissance Italy, with such factors as economic wealth, political freedom, and religious tolerance being considered at the level of the whole civilization.

Then there is the dimension of institutional conditions. Here we might compare the conditions at the level of an enduring institution, for example the University of Cambridge and a Buddhist monastery in Nepal, or compare the same institution at different times in its history, for example the University of Bologna in the fourteenth and nineteenth centuries.

1 My approach has been influenced by the work of Mihaly Csikszentmihalyi, for instance in 'The domain of creativity' in [1], though his levels and mine are somewhat different.

Then there is the dimension of the networks of knowledge that surround all creative thinkers. Much work in the recent history of science has shown that the idea of the lone genius is a myth. Even Newton or Einstein were deeply embedded in exchanges with others. Modern science is heavily dependent on collaborative work undertaken by teams of scientists.

Then there is the level of the individual, their personality, intellectual abilities and the events through their whole life. Much of the attention of past investigators has concentrated on this level, namely what happens within a single mind. Through texts and interviews this is in some ways the easiest to begin to approach, though in the end the details remain a mystery.

These four levels provide the necessary conditions – but none of them are sufficient. The final dimension is a mechanism so complex and unpredictable that we usually put it into the black box of 'chance' or 'luck', a kind of dark energy or matter. Again and again in the interviews with major thinkers that I shall presently describe, the individual explains a moment that altered his or her life in words such as 'then I was incredibly lucky and met X' or 'went to Y' or 'read Z'. It is somehow akin to Campbell's famous definition of the Darwinian mechanism of 'random variation and selective retention' [2]. Certain individuals with a particular personality, set of intellectual interests and life experience find themselves in situations where 'nature' favours them – and they selectively retain, or rather exploit and expand, the opportunity.

In my own work I have tried to work on all of these five dimensions simultaneously. At the level of civilizations and societies I have examined the contrasted conditions for achievements in England (and selected European countries), Japan, China and Nepal. I have learnt something about their general histories, politics, economies and social structures and how these might encourage or inhibit creativity.

With Gerry Martin, I have specifically examined the role of one technology – glass manufacture – in allowing and encouraging rapid scientific and artistic progress in Western Europe while its virtual absence in later Islamic civilization and China and Japan made both the Renaissance and the Scientific Revolution impossibility [3]. This is one answer to the so-called 'Needham Question' of the absence of a scientific revolution in China, though glass again is a necessary but not sufficient explanation.

At the level of institutional structures I am currently writing a book on the way in which one of the great institutions for scientific discovery, the University of Cambridge in its eight hundred year history, provides propitious conditions for creative discovery. I am examining how the architecture and aesthetics of the city influences those who work there; how a certain culture of openness and trust encourages collaboration; the customs of conversation and argument make exchanges possible; the organization of the Colleges and the notions of fellowship bind people together and diminishes disciplinary boundaries; the teaching system

encourages questioning, argument and the pursuit of new reliable knowledge; the micro-politics and administrative system gives a sense of participation and control over one's life. All of these conditions have provided the context over the centuries for the work of some of the great scientists – Gilbert, Harvey, Newton, Darwin, Babbage, Maxwell, Thomson, Dirac, Crick and Watson amongst them.

At the level of networks I have long been intrigued by the way in which strands of knowledge and emotion encompass the individual, how an individual's life experiences from childhood upwards have shaped their work. I have written two books that analyse the personalities, working methods and experiences of four thinkers who have made major paradigmatic shifts in our understanding. These are the Baron de Montesquieu, Adam Smith, Alexis de Tocqueville, Fukuzawa Yukichi and F. W. Maitland [4]. I have also investigated the networks of knowledge in many of the interviews described below, most of which reveal clearly the interconnected nature of intellectual research, not just in the sciences, where one might expect it, but also in the arts and social sciences.

At the level of individual creativity, I have studied this through observing it in action and in the reflections of living people who are creative and innovative. I have approached the matter in three ways. One is to observe and film children learning to be creative in play, art, language and problem solving. In the Himalayas I have worked with a family whose daughter I have recorded on film as she grew from the age of two onwards. In Australia and England I have worked with my own step granddaughters since their birth (to their present age of 11 and 9). I have engaged in participant-observation fieldwork, playing with them, talking to them, filming them and thinking about the imaginative growth, logical abilities and creativity they display.

A second way is to observe myself. In writing over twenty books and organizing a number of collaborative research projects, I have always been intrigued by how we discover things and the ways in which it might be possible to break through the conventional wisdom and make one of those paradigmatic shifts in understanding of which Thomas Kuhn talks. So I have kept detailed records – drafts of work, diaries, a book of plans and analyses of my work, films, photographs and letters.

Using some of these I have written 'An Autobiography of a Book'.[2] This is one of the few accounts of how a book is written which relies on thoughts during the process. There are many accounts of scientific discovery, as compiled in Koestler and other books, or in such famous works as those of Crick and Watson. But reading them against my own experience makes me aware of how different the actual process of discovery is from the 'after the event' accounts that are usually presented. Such accounts tend to iron out most of the accidents,

2 Please see http://www.alanmacfarlane.com/savage/auto.html

chances, surprises, frustrations and give a teleological and smoothed out account.[3]

Thirdly, I have approached the problem through a number of in-depth interviews of creative people whom I have encouraged to talk about how their life has shaped their ideas, their networks of knowledge, what has inspired them, their 'eureka' moments and the nature of their major achievements. This is the project described in the third part of this paper.

1.2.- Dialectics[4]: Tendencies towards the increase of reliable knowledge

The natural creativity of human beings

Humans, like a number of higher animals, have a great deal of curiosity, love of pattern making, ingenuity and playfulness. If this is encouraged, or just allowed to flourish over time, it will lead to experiments, creative solutions to problems, the avoiding of obstacles and probably lead to successful attempts to overcome difficulties.

The processes of wonder, surprise and admiration are obvious in the case of a young child. Filming my grandchildren and children in Nepal as they grew up - as they tried out foods, fitted shapes together and explored their worlds, I could see a very powerful survival instinct at work in their desire, from a few days old, to understand how things work and are connected. Just to look is to start asking those 'why' questions for which children are famous. In order to answer these questions, the child uses all sorts of methods; comparison, deduction, induction and experimental testing. Every child has to be a pretty good scientist in order to survive.

A child, a painter, a poet, a scientist, all are filled with wonder and surprise and try to explore and solve puzzles. The only difference between a child and a modern scientist is that as science becomes more effective it develops other tools and methods for this purpose. The child uses its natural intelligence; the musician the accumulated heritage of music in his or her own society; and the natural scientist uses mathematical and other methods in pursuit of understanding. Science also tends to be cumulative, knowledge can be tested, and questions are open and never finally settled. These three characteristics combine to give the potential for the development of reliable knowledge.

As Einstein commented, not only does great science arise from the ability to go on asking child-like questions, but all science is ultimately based on an extension of every-day, normal, reasoning. So we can take it as an axiom that homo sapiens is an inquisitive and knowledge-generating species.

3 This is a point well made in the fascinating older study [5].

4 Much of what is discussed here is expressed in a similar form in Ref. [6] from which I have quoted extensively. That book is unlikely to come to the attention of specialists in creativity theory or the history of science. These sections encapsulate almost fifteen years of intense discussion between Gerry Martin and myself on the themes of creativity, as well as the input of many others who took part in Gerry Martin's 'Achievement Project'.

Not only have I observed all this in young children, but also in my students at Cambridge, in my own life since childhood, and in many of the in-depth interviews of scientists and others. Wonder and curiosity are the driving force in almost all great thinkers and hence the root of discovery, as Adam Smith, amongst others, pointed out long ago.

The triangle and the meccano: the externalization and accumulation of knowledge

What is special about human beings is that, more than other animals, they can transfer what they learn from their individual brains to the external world. They can store and transmit ideas through an elaborate cultural system. This makes knowledge grow quickly. This essential skill of human beings, their 'culture', can be either immaterial (language, rituals, songs, myths, traditions and skills) or material (writing, physical tools). Part of this vast realm, which is most dramatically changing life on earth, is the effect of technology.

One way in which technology alters our world is through the storage and expansion of ideas. New ideas become embedded in tools, which then, in turn, help us to think better. It is a triangular movement, which is well illustrated in the comments of many of the interviewees, for example the astronomers Hewish, Rees, Turok and the astronomers. They show how the development of our understanding of the universe was made possible, and spurred on, by the development of computers, radio telescopes, space probes and other technologies. Even in certain branches of mathematics, as Peter Swinnerton-Dyer points out, advances would have been impossible without computers.

There is an increase in theoretical understanding and reliable knowledge about the world. This first point of the triangle is vital. The repeatable and dependable information about how the world works is almost always obtained through disinterested research. This is then sometimes embedded in improved or new physical artefacts or tools, the second point on the triangle. These artefacts, if they are useful and in demand and relatively easy to produce are disseminated in huge quantities. This multiplication of objects and their mass dissemination is the third point of the triangle. This then changes the conditions of life and may well feed back into the possibilities of further theoretical exploration.

For instance, this is the triangle now reaching its final phase with Richard Friend's discovery of a new high-quality plastic which may lead to the 'plastic book', replacing many contemporary forms of paper and again making information more widely available. Or again, the theoretical work on 'zinc fingers' by Aaron Klug may well revolutionize both plant breeding and medicine by allowing us to manipulate genetic sequences with far greater accuracy, and hence provide a new set of conditions within which science can develop further.

This triangular movement has occurred in many spheres of life. The speed of moving round this triangle and its repetition lie behind much of what we describe as human development.[5]

5 This idea comes largely from Gerry Martin. It has been expanded and documented in [7].

Furthermore it is a general principle that as each piece of reliable knowledge is added it leads to the possibility of doing dozens of new things. Just as adding a wheel to a 'meccano' or other construction set transforms the potentials of all the previous pieces, so it is with many technologies, including wheels, printing, clocks, glass, photography and computing.

In terms of the 'meccano' effect, the exponential growth of computing power, obeying 'Moore's law' of a doubling each eighteen months or so, is largely a consequence of the fact that each new development in hardware or software does not merely add to the speed and efficiency of computers, but multiplies the power of all the previous features.

'Bounded but leaky' – the ecology of productive collaboration and external stimulation

The rapid development of knowledge and artefacts needs an exact balance between what we can call 'boundedness' and 'leakiness'. At the extreme, if a system has no bounds, then nothing will have time to grow before it is swept away by the next thought or invention.

Yet at the other extreme, if the boundaries turn into impassable barriers, there is the opposite difficulty, of involution or stasis. Change and improvement have many foes and there are always more reasons for not doing things than for doing them. If almost complete control can be maintained within a bounded unit, as happened in China or Japan for long periods, then few things can change radically.

New ideas, coupled with the threat of being outflanked and outmoded, make people inventive. However, ideas must come in at a controlled, rate. This happened in Japan over the century from 1868. It is happening in rather different ways in China today. If they pour in too fast, as with market capitalism in Russia at the end of the twentieth century, they can overwhelm a civilization. From the ninth to the nineteenth century Europe combined bounded political and cultural entities within a highly inter-connected land mass. So ideas and artefacts could rapidly drift from place to place.

The interconnections between a number of independent centres of innovation are very important. Because of the difficulties of achieving major break-throughs, it is unlikely that they will often occur within a bounded unit all by themselves. There is too little data available, very highly trained and able thinkers are few, and people are blinkered. Thus major break-throughs tend to occur when scientists communicate with each other at a distance.

Many of the film interviews document this process of international collaboration, which has, in certain ways, been made easier with the communications revolution. Although physically located in Cambridge, most of the scientists I have interviewed work with colleagues all over the world. Though they stress that an initial physical contact may be essential, thereafter a virtual collaboration is often very productive.

The major scientific discoveries from the twelfth century to the present were the results of wide European contacts. The ease of such networking in Europe was made much greater by a common religion (Christianity), common language (Latin) and many common traditions. There was a fraternity of scholars and inventors. Good ideas travelled very fast. The impact of printing as a way of moving ideas rapidly across Europe is obviously also crucial.

A major motive in the search for increasingly reliable knowledge is curiosity, as we have seen, and curiosity arises from the unexpected contrasts between what we expect and what we find. The European experience increased the number of puzzles which faced people. Huge amounts of new information poured into Europe from the fifteenth century from long distance travel, the discovery of America and voyages to India, the Pacific and East Asia. The new knowledge challenged current ideas. For a long time the bracing effects of the mixing of cultural traditions in the relatively small area of the Mediterranean, in particular between Islamic societies and the Christian civilization which borrowed from it, also clearly stimulated new thought.

My own experience of spending time in a remote part of Nepal, and also in Japan and China, has led me to question many of my deepest assumptions and to be curious about the nature of my own world. Many of the interviews of anthropologists in particular, but also of scientists and others show the same shock of wonder at alternatives to what we would expect.

The cumulative expectation: exponential growth

The process of discovery is potentially an exponential one. This can be shown to be the case through the logic of the processes and we can also point to periods when knowledge has, for a while, grown at a faster than linear rate; the Greek golden age, the Tang-Sung period in China, the ninth to twelfth centuries in certain Islamic societies, the Renaissance and the Scientific Revolution are famous examples.

Yet, as we know, these bursts are rather unusual and in all of them (except the last - so far) the rapid rate slowed down and levelled off. So there are clear difficulties, obstacles, blocks, which impede the process from continuing.

1.3. Antithesis: tendencies which block the growth of reliable knowledge

I can only summarize a few of the pressures which act to encourage or suppress the natural tendencies to the rapid accumulation of reliable knowledge. Given the four levels I have suggested, the national, institutional, network and individual, we can look at one example of each, and then one case which crosses between them.

The national: some political and religious pressures

Human beings are not just knowledge-seeking and sociable animals. They are also deeply imbued with a desire to find a moral meaning in their lives and moral laws in their world. They seek to understand the purpose of life, the meaning of pain, the rules of ethical behaviour. This leads us into a huge field of religion and ethics which could absorb many books, but which cannot be ignored when considering the pressures which increase or inhibit the chances of gaining reliable knowledge about the world.

As well as being knowledge-seeking, social and moral creatures, humans desire power. Indeed, knowledge is power. Living in liberal democracies, people often have little sense of the 'weight of ideas' (as an analogy to Boyle's discovery of the weight of air might put it). Ideas kill and maim, or heal and console. Who owns them, who passes them on, what is allowed and what disallowed is very much a political concern. Much of the history of the expansion and contraction of reliable knowledge can only be explained by looking at the political (in the wider sense which covers things like 'the politics of the family', 'the politics of religion') dimension. Just as great thinkers realized that politics and economics cannot be separated, hence political economy, so thought and power are inseparable, hence political-mentality or ideology.

The moment one notices this, that Genghis Khan or Stalin or McCarthy and their politics had a sizable influence on the world of knowledge, the subject again becomes a vast one. Here I shall look at just one example. The intersection between power and the individual is very often found most openly displayed in the legal system. This is explicitly the area where State and citizen meet in their frequent confrontations. The legal system not only encompasses secular, but also religious law. The way in which law works therefore both reflects and shapes ideological systems.

In essence, because ideas have political weight, those in positions of power, whether educational, religious or political, will try to control thought. At the extreme we call this censorship, but there are many degrees of semi-censorship or 'gentle guidance'.

I have spent a good deal of time over the years investigating this growing tendency towards what one might call inquisitorial thought systems. As political power and centralization grow, so the State and other authorities increasingly have the power (and usually feel they also have the duty) to prevent people expressing, or even thinking, certain thoughts. This tendency is re-enforced by the usual agreement between the Church and the State which turns the law into the enforcer of both the secular and the moral order. Intentions, motives, ethics, commitments are all of concern. The extreme forms, which we see in communism or fascism, are foreshadowed.

Nearly always there is a tendency to try to bring the individual's body and his (or her) mind into line with the current orthodoxy. Galileo is only the most famous example. There are

countless others whose ideas have been inhibited or crushed by the inquisitorial process. Once such a system is instituted it is very difficult to see how humans can escape. All power tends to corrupt, and the corruption enters the human mind at all levels. People of the most honourable kind find themselves abandoning or suppressing their ideas through 'collective responsibility', 'protecting one's family', 'thinking in the long run'.

This climate of fear, or at least heightened anxiety, is something which few practising academics in western liberal democracies have personally experienced. As far as I can recall, none of the two dozen interviewees in my sample mention it in their interviews. Freedom is part of the air they breathe, though some note the situation in South Africa in the era of apartheid or in the Soviet Union in the 1960s. Yet any short acquaintance with the world today, or over the last thousand years, will quickly make us aware of how far forms of institutional religion or politics, or the mixture of the two, can enable or shatter creativity.

Institutional: the tendency towards emphasizing the old and discouraging the new
Many people assume that the purpose of education is to make us think. We live in historically unusual societies where this is indeed often the case. Yet education can just as well be seen as a device to constrain thought. It is often used to direct people to think acceptable ideas, so that the only thoughts which are thinkable are those which one's teachers (and the society as a whole) consider appropriate.

Knowledge has been passed on through most of history by word of mouth. This does not allow much criticism. Nothing is written down, so different versions cannot easily be compared. There is no external truth or way which provides an orthodoxy against which there can be deviations. Formally recognized differences came later with the development of writing. The rulers again usually monopolized such writing in order to preserve the status quo. It was not an instrument for questioning the system.

The tendency thereafter was for those who developed writing systems to use them to instil traditional and accepted wisdom. The educators concentrated on the classics, whether religious – Buddhist sutras, Sanskritic texts, the Koran, the Bible, the Torah – or secular texts - the writings of Confucius or Aristotle. The assumption was that the truth had all been revealed long ago. The task of education was to instil this truth in young minds through repetition. There was no questioning, just some explanation, elaboration, teasing out obscure meanings.

This tendency is re-enforced as wealth increases. There are more priests and teachers, the ability to pass the examinations on the texts becomes ever more important as the key to power and status, the period of education becomes ever longer.

In this expansion and formalization of education there is often little pressure towards independent, questioning thought in the sense of encouraging originality, doubt and difference of opinion. Mental worlds are, if anything, increasingly closed. Truth is asserted and given sanction by being written down. Knowledge of the world is unquestioned and what is read is self-evidently true.

This tendency, as we see it developing in many great traditions of scholarship, often ended up after some centuries in an almost total lack of change. There is nothing new to be said or thought. The aim is not to lose any of the accumulated wisdom. The charismatic founder's thought (Confucius, the Buddha, Jesus, Mohammed) is distributed to his followers who earn a reasonable living by interpreting it and passing it on to their pupils.

The tendency shows itself in the appeal to authority and the learning of things by heart without really understanding them. Persuading, intriguing, encouraging young minds is strenuous work; much easier to assert and dominate using authority and telling students merely to copy down the wisdom.

If changes are to be made, they must be so small that they are invisible to the teachers. Tinkering on the edges of knowledge, 'shifting the mental furniture around', is all that is allowed. Since these minor adjustments require less mental effort and often bring prizes and even serious wealth, it is often preferable to work on small-scale modifications to a paradigm rather than to try to make advances in deeper understanding.

Having made a preliminary study of the University of Cambridge over the last eight hundred years, I have been amazed that the creativity of the people who worked within it, or were deeply influenced by being taught there, has never dried up. There were high points, for instance in the period between about 1560 and 1720 with Gilbert, Harvey, Newton and others, or after 1860 with Maxwell, Thomson, Rutherford, Dirac, Crick and Watson, Hawking and others. But in every century since its founding there have been some people who have made a considerable mark by questioning the current state of knowledge and suggesting new ways to look at the world.

I have not made a detailed study of other universities older or almost as old as Cambridge, but I suspect that the same could not be said of them all. Some special conditions are obviously needed to protect and encourage this kind of institutional creativity.

Networks: 'Limited good' and secrecy

Another widespread tendency is towards a situation where, for every really creative thinker, there are dozens of less talented critics. It is often easier to live by destroying other people's ideas than by generating many of one's own. The 'frogs in a well' syndrome, where humans, like frogs, pull down anyone escaping from the well is widespread (the misery of all is better

than the escape of a few, according to an Indian proverb). It is combined with the growing ethic of 'limited good' as anthropologists call it, or a 'zero sum game' in economist's speech, where it comes to be believed that another's success does one down, another's failure pushes one up.

These are insidious pressures working against the increase of knowledge. Many have experienced this in schools when peer pressure will soon create an anti-work, anti-achievement ethic where a 'swot' is picked on. Again, my experience in Cambridge and the interviews with leading scientists shows that while this is occasionally evident, it is not the norm. This is surprising, yet something which many of my informants take for granted, and which I have experienced over the thirty-seven years of teaching within Cambridge University. It is a sign of a great institution – but what enables it?

Another feature of advanced or specialist knowledge is that it tends to become private. Yet over-privatization, over concentration on intellectual property rights, sets individual against individual, organization against organization in a world of secrecy and excessive competition. Good science usually operates best in an open market for ideas and through co-operation

There are periods when an individual or institution may be forced into secrecy for a while, as in the famous case of Charles Darwin's concealing of his theory of the evolution of species for over twenty years partly because of fear of upsetting the religious hierarchy. But the ultimate aim is to publish the results and earn praise and gratitude by providing a rung upon which others can climb.

In contrast, in many societies all deep knowledge is by definition esoteric (specialist and secret). A particular family, sect or organization develops it and the widespread feeling is that it should never be made generally known. The intellectual or priest in many societies lives off his monopoly of secret knowledge.

All this works against the rapid expansion of reliable knowledge. In a world of falsehood and deception, of secrecy and privatization, where is the 'reliable' to come from? For most people nothing can be relied on, least of all information from non-related strangers. Why should others tell us the 'truth'?

Knowledge is usually costly to acquire. Once gained, like other capital it should pay dividends. Those who have worked themselves up to the top of the knowledge tree are hardly likely to favour radical thinkers who are hacking away at the trunk. As Thomas Kuhn has argued, established systems of knowledge are not dislodged by rational argument but because the older generation die off or their theories just feel stale and out of fashion. In many societies the senior generation ensures that its successors are so indoctrinated that they never threaten the system. Yet all of this is the opposite of modern science. Here findings are, in theory,

published and open so that the hypothesis can be fully tested by colleagues. The scientists and philosophers of Europe lived off their ability to spread their knowledge.

In relation to this difficulty I have been immensely impressed in the interviews with leading scientists as to their openness, trust, general lack of secrecy and inhibitions in sharing knowledge. This cannot be taken for granted at all, but Cambridge, and within it Cambridge scientists are remarkable. Here am I, someone who knows nothing about the issues involved, probing into private and professional lives of highly distinguished individuals who are aware that what they say may be seen by a host of their students, peers and competitors. Yet they talk with directness, honesty and candour and reveal what they are currently working on and their feelings about their life and career. I am constantly astonished by the circle of trust which is, no doubt, partly created by my own membership of the 'Academy'.

Individual: the 'oasis' trap and the roundabout route to new reliable knowledge

One well-known difficulty in finding new things has been termed the 'oasis trap' by David Perkins [8]. Knowledge becomes centred in an 'oasis' of rich findings and it is just too risky and expensive to leave that still productive and well-watered zone. So people stick to what they know. This is what happened to a certain extent in China and Japan over many centuries. The huge physical distances between centres of knowledge in China, and the fact that even if one made the effort to travel to another it usually turned out to be little different to that which one had left, discouraged exploration.

In Europe in the last eight hundred years there were numerous oases, separate national cultures a few hundred miles apart, yet each with a very different intellectual flora and fauna. This network of 'oases', each independently developing thoughts and then communicating with other oases is perhaps the ideal one for the development of new ideas. Another way of putting this is that in order to advance one often has to go backward, go down hill before one can go up. It is not possible to proceed steadily up the slope of increased knowledge for it becomes necessary to make a costly detour.

To do so requires great faith, self-confidence and ample patronage. These are assets which many Europeans seem to have had at certain points in history. Yet they are pretty unusual in general. In order for an entirely new technology to come up and replace an old one, such as a new weapon or ship, there may be quite a long period when the new is less efficient than the old, even though its potential is greater. There is a long, loss-making, period when the older views can outpace the new, untried and inexperienced ones. Who is going to bear the long development costs?

This difficulty also applies to scholarly progress. Often the older, experienced intellectuals can effectively destroy the half-baked, if ultimately more powerful and 'true' new ideas. Very often, the innovators give up, discouraged. Or they are left hanging from some literal

or metaphorical cross. As Oscar Wilde noted, 'An idea that is not dangerous is unworthy of being called an idea at all'. Yet, if it is dangerous, we have to be careful. Sometimes the risk is not worth taking.

Yet the interviews show again and again the taking of intellectual risks, working on boundaries, putting forward implausible hypotheses, going against the received wisdom, possibly ending up with nothing. I have experienced the same sense of feeling of mixed exhilaration, terror and hopelessness when embarking on impossible journeys. But being in a place like Cambridge has made it that much easier.

Multi-level: The tendency to diminishing returns: the effects of increasing complexity
Most of the pressures outlined above work simultaneously at several levels, affecting institutions, networks and individuals, but can be principally located in one dimension. There are others which are intrinsic to knowledge itself and hence operate at all levels. One example is the knowledge equivalent of the economic law of diminishing marginal returns.

As knowledge increases through the rapid accumulation of a mass of details, it becomes more and more difficult to see the overall pattern. This is why, for example, a number of enormously learned people have produced so little and tend to produce less and less as they grow older.

Each new piece of information, when added to a complex, inter-acting system, alters all the existing information. Thus to add a new piece becomes more and more difficult. To find an item amongst ten thousand objects is much more than ten times as difficult as finding it amongst one thousand. These laws explain why the 'advancement of learning', the increase of knowledge, is so very difficult and seems to become increasingly so.

In the early days of an intellectual career or when starting a new discipline, it is easier to be radical, to make considerable advances; everything is open and fluid, the returns on a little labour are great. The easiest advances are made first and difficult terrain can be avoided. But after a time the best mental land is occupied and one has to move to marginal areas. Furthermore each new piece of information has to be fitted into an increasingly complex pre-existing set of information. Even minor changes come up against daunting entrenched obstacles. It seems only possible to tinker at the boundaries.

Radical innovation also becomes more difficult because the time and energy it takes to master all the professional expertise needed to understand and then change a system starts to exceed any human being's normal capacity. At the start of a new discipline, an amateur can make huge advances by pursuing what is really a part-time hobby. By the late nineteenth century, it required highly organized and disciplined teams to carry out major research.

This tendency is evident in a number of the interviews, where scientists when asked to give advice to young scholars frequently say that it is now more difficult to make a real mark. To discover plate tectonics at 25 or sequence the first virus by hand is not now open to all.

This increasing complexity is one reason why we often see a growth of conservatism, routinization and ritualization in academic life or techniques. This happens when processes become more complex, yet the understanding of the way in which they work, that is the reliable knowledge content, does not increase proportionately. This is the trap shown for example by the history of the making of Japanese swords. This technique reached a peak by about 1200 and was scarcely improved over the next five hundred years.[6] In a situation such as this, the only way to make sure such complex processes continue to work is not to change them.

This 'lock-in' occurs in all forms of knowledge. It occurs in secular processes (making things, education) and also in most religions (ritualization and formalism) and politics. Thus the knowledge component levels off or even decreases; the almost exclusive task is to remember how to repeat the words and actions which were passed on by the ancestors and seemed to work. This is the opposite of innovation and invention which deliberately force us to forget, superseding previous knowledge, making it 'out of date' and irrelevant. Very few civilizations have avoided this tendency towards conservatism for more than a few hundred years.

1.4.- Synthesis: the first and second laws of intellectual dynamics

While the first set of tendencies in intellectual dynamics suggest that knowledge can expand exponentially, the second set suggest that the rate of discovery of new knowledge will tend, after a period, to slow down, level off, and in the end decline. This pattern is one we see again and again in history.

Since knowledge-generation is a social activity, the specific nature of the society and the institutions within which the discovery of new reliable understanding occurs will deeply affect which knowledge is pursued and to what effect. Over time there is a tendency for thought and social power to become aligned so that as social structures become more rigid (which they tend to do) so knowledge systems also become more rigid.

There seems, in fact, to be a three-fold cycle. This is due to the fact that too much chaos, competition and disorganization is as undermining of knowledge generation as too much rigidity, conformity and over-organization. Systems tend to move from chaos to conformity over time, in an equivalent to the Second Law of Thermodynamics. When they are in the mid-point, as in the famous examples cited above, they are at their most creative. Then all

6 The Japanese case is described by Gerry Martin in [9].

these hidden obstacles and traps start to freeze out major innovation.

These social pressures and contexts could also be seen to operate as a filter or screen that operates at different levels on the individual. In many cultures they prevent a person even thinking about new things. The old wisdom is best, do not question accepted authority, be obedient, stick to the tradition. This is perhaps the most common pressure.

If the situation moves beyond this so that some thought is encouraged, again it may be channelled by the society into activities which are gainful and status and/or wealth-enhancing for the individual. Yet in terms of knowledge increase they are relatively sterile: the law, stock exchange dealing, civil service, theology, art. In many societies, certainly after a while, many of the best minds go into what one might call the intellectual service industry. All these industries have their function and small numbers of lawyers, brokers, civil servants, and artists are of great value. But when this becomes the only goal and hugely inflated, it acts as a diversion.

At a third level, even those who have escaped the first two obstacles and who have been enabled to pursue knowledge (say in history, mathematics, chemistry) often meet other social blocks, status hierarchies, over-division of labour, increasing complexity, intellectual dead ends.

This three-stage set of filters can be summarized colloquially. The first tells the individual 'Don't even think about it'. The second says 'Think about this, but not that'. The third says, 'think as hard as you like, but either we, or the nature of the problem, will block your thought'.

2. Connecting the levels: personal materials on creativity

There have been many autobiographical accounts of the creative process in science.[7] These tend to concentrate on one level, and within that one aspect, the cerebral, intellectual working of a single scientist's mind. If we are to investigate further the connections between the levels of civilization, institution, network and individual, and the fifth dimension of chance or random variation, we need to supplement these accounts, in particular by letting scientists and others talk in a relaxed way about what they think has been important in their lives and works. Over the years I have been collecting such data and here I would like to describe how this happened and what opportunities it opens up for further understanding of the springs of creativity. I will start by describing how this project has developed.

7 A good recent collection of some of the best of these is contained in [10].

2.1 A brief history of the project[8]

In 1983 I started to experiment with the newly available lightweight film equipment (low band u-matic) that allowed an in-depth interview in a non-studio setting, often lasting more than two hours. If possible I would ask a colleague and friend of the interviewee to ask the questions, but most of them were conducted by me. In this way I accumulated about 40 or so interviews by about the year 2000.

Those interviewed until 2000 were almost all in my own field – social anthropology. The field was small and highly inter-connected, so it formed a fascinating interwoven network of mutual influences, of moments of encounter with other worlds, of humour and discovery. Since anthropologists, like all thinkers, learn by apprenticeship, I believed that recording in depth the wisdom of the 'ancestors', the younger generation, including myself, would learn what had been found to be the most productive methods and life styles for generating new reliable knowledge.

There was one difficulty. It was almost impossible for anyone but myself (or with a large effort, a small audience of students at Cambridge) to see what I was collecting. So the u-matic tapes sat gathering dust as an archive for a day not yet born.

Then, around the millenium, three things happened to transform the situation. The Internet and then decent bandwidth broadband emerged as a way of making the materials available to people around the world. Many of the thinkers were of more interest to someone in Italy or Australia than they were to a set of undergraduates at Cambridge. Now people around the world could find and watch the interviews.

Secondly, the technology for editing and compressing the materials and holding the results on external hard discs suddenly emerged. One could make films relatively easily and improve the quality of what had been gathered. This was the era of new editing programs, large storage devices and new codecs.

Thirdly, in a joint initiative, Cambridge University set up a digital library, Digital Space or Dspace. This was a permanent archive, a virtual repository managed by the University Library and Computing Service, which would maintain what was submitted – migrating the materials as new standards became available and making global access easier. The 'Film interviews of academics and others' project was the first large film collection on this new archive and remains by far the largest project of its kind in Cambridge.

8 After writing an earlier draft of this piece, I read the paper by Rogers Hollingsworth presented at the San Marino Conference. I also had the pleasure of conversations with Professor Hollingsworth. It appears that we have been working in parallel for some years and we hope, in the future, to integrate our projects more closely.

The effect of having a permanent depository, the chance to show the films around the world, and to edit and compress them fairly simply, encouraged me to expand the interviewing of anthropologists. By the end of 2006 there were about seventy interviews and lectures in the fields of the social sciences.

I described what I was doing to two friends in King's College, Sir Patrick Bateson a zoologist and Herbert Huppert, Professor of Astrophysics. They urged me to broaden my interviews to include scientists and mathematicians. I replied that I knew nothing about science in any detail. That will be an advantage, they answered, since you will not be a threat and your subjects will have to explain things simply. This turned out to be true.

I also answered that if I was doing this for a small subject like anthropology, surely there must be many similar projects for the far larger worlds of science and mathematics. They replied that no one was engaged in anything of this kind, and that many of the major figures of twentieth-century science, now retired, would be beyond interview within twenty years.

To my surprise they appear to be roughly right. I have made some investigations on the Internet by looking for film interviews of those I have now covered, and all I can find is the Vega site started by Sir Harry Kroto.[9] This is supported by over twenty-five organizations and foundations, and has some useful material on it. But it has scarcely scratched the surface. Of the two dozen interviews I have undertaken, only two of the subjects have been interviewed by the Vega project and my interviews of each of these (Sanger and Friend) are longer and in more depth. The Vega interviews tend to be in a formal setting, with specialist questioners and concentrate on the work more than the life.

There are no doubt other sites and I would be interested to hear of initiatives since it would be good to collaborate. For instance there is a Berkeley site called 'Conversations with History', where there are over 100 interviews. Nearly all those who figure are in the political field, though there are some important people and some scientists are included.[10]

So, some eighteen months ago, in considerable trepidation, I started on the interviews. The first set, two interviews each of two hours, was relatively easy since it consisted of Patrick Bateson interviewing his friend and long-term co-worker Sir Gabriel Horn, also a zoologist. This is a fascinating four hours, made richer by the fact that I later interviewed Bateson for two hours and then filmed Bateson and Horn talking about their collaboration for two hours. I have also interviewed their close colleague and friend Robert Hinde for another two hours. So there is a unique ten hours about the great period of biology, zoology and ethology in Cambridge, the world that overlapped with DNA and with such students as Diane Fossey

9 See http://vega.org.uk/about/internal/1
10 See http://globetrotter.berkeley.edu/conversations/

and Jane Goodall.

My first solo interview of a scientist was with someone I had known a little for thirty-five years, and with whom I share a set of rooms in King's College, the geo-physicist Dan McKenzie. Dan was one of the two co-discoverers of plate tectonics and continental drift and one of the youngest ever Fellows of the Royal Society. Fortunately, the interview went excellently thanks to his articulate enthusiasm and his ability not to make me feel completely ignorant. So I arranged further interviews, advised by my scientific friends in King's who told me who I should approach.

One particularly rich week was when on the Wednesday I interviewed the astronomer-royal, President of the Royal Society and Master of Trinity College, Lord Martin Rees. The next day I interviewed Sydney Brenner, Nobel laureate and long-time co-worker with Francis Crick and the day after that Fred Sanger, the only living double Nobel laureate. Later I interviewed the great grandson of Charles Darwin, Richard Keynes, and then a week or so later the grandson of Darwin's great defender, T.H.Huxley, the Nobel Prize winner Sir Andrew Huxley (step-brother of Aldous and Julian Huxley).

So far, I have interviewed some 34 major scientists (including mathematicians and computing science), among them the winners of seven Nobel prizes. They are mainly in the fields of chemistry, biochemistry, astronomy, physics, biology and mathematics (see the list at end). They range in age from 55 to 92, and all have been associated with Cambridge University for a major part of their life.

Since creativity in the sciences, engineering and mathematics is not, in its inner essence, different from creativity in the social sciences (including economics, sociology and anthropology), or even in the arts (including history, literature, music), I have also expanded the interviews in the last 18 months to cover these fields and have interviewed many distinguished thinkers.

2.2 The framework and methods of the interviews

On the surface, the interviews are almost unstructured and I avoid referring to a written questionnaire as this can distract from the spontaneity of the occasion. I encourage the interviewee to talk about whatever they would like. My role is similar to a psychiatrist, that is to say to let the subject narrate their life, in particular in relation to the obstacles and encouragements to creativity and discovery. We tend to cover the following.

- When and where born
- Ancestry: going back as far as they like, including occupation and temperament and possible effects of grand-parents, parents and siblings

- First memories and hobbies as a child
- First and subsequent schools, with important teachers, hobbies, subjects which gripped them, sports and games, music, special books
- University and those who taught and studied with them and interests there
- First research, supervisors, mentors, influences
- Jobs and career and travels through life, work abroad
- Colleagues, friends and network of workers, partners and children
- Methods of working and thinking
- Major achievements and problem-solving during life, and how they occurred, including especially important bursts of activity
- Administrative tasks
- Teaching and supervising of students
- Effects of their work environment (laboratories, departments, colleges etc)
- Philosophy and religion
- Political views and activities
- Advice for a young person starting out in their field
- Specifically ask if there is anything which they would like to have talked about and I have omitted to ask about

Yet if the subject does not want to follow this order, or to answer all of these, or to add further subjects, that is fine. What I want the viewer to see is the inside of a life, told in a conversational and personal way.

The interviews are an intimate probing of personal experience, usually by a complete stranger who is holding a potentially threatening video camera. The subjects know that this may be seen by almost anyone in the world - friends, students, competitors, and enemies, now and in the future. This could be intimidating, especially to older subjects and for those who share a widespread reserve and distaste for talking about themselves.

I have therefore developed a number of techniques for putting the subjects at their ease. These have contributed, I believe, to the rather startlingly honest and trusting conversations that I have managed to have with a wide range of near strangers. It is worth briefly summarizing these since they could be helpful for others who help to extend this project.

1. It is important to have a fairly small and unostentatious camera that does not dominate or frighten the subject. The less intrusive the microphone the better – which is one reason why I have given up using lapel microphones. I place the camera on my knees and do not use a tripod, which can again be intimidating.

2. The room in which the interview is done is important. I avoid formal settings

if possible– lecture theatres, 'offices', and seminar rooms. A room with gentle furnishings, an easy chair for both interviewee and interviewer, books and pictures and objects in the background, a pleasant view all helps. And of course absolute silence and absence of telephones, mobiles, computers and interruptions is essential. I do not sit too close, or too far away. I sit at the same level, as I would do in any normal relaxed conversation between friends.

3. I try to develop the sheep-dog technique. When gently moving a flock of sheep to its destination, a good sheep dog is mostly silent and still. Each time the sheep move in a satisfactory direction, the dog creeps forward. And then sinks onto the grass and waits attentively. It does not bark, just guides. So, if possible, I try to help the interviewee along, but only interrupt when they need encouragement or direction. I never shut them off (though I occasionally warn them if the conversation is getting into the realms of damaging speech and check that they are aware of this), but try to bring them to subjects as they are needed.

4. I always try to show interest, however little I know, or even care about the subject being discussed. What is being said is often important to the subject and has a depth that I, or others, may only realize later. They deserve serious attention and respect for what is often a summary of a life. Of course I may verbally disagree a little, or query things, but I try always to do so in the pursuit of a common goal of understanding. Curiosity is the most important attribute.

5. It is important for there to be no sense of rush. If I want an hour of film, I allow ninety minutes, which gives time for general conversation, a cup of tea etc.

6. I used to prepare carefully for the interviews. With people in my own subjects, this was possible. With scientists, beyond reading a brief life in an encyclopaedia, I cannot really prepare. It seems to work as well without preparation.

7. I used to think that it would be good if the subject prepared her or himself in some detail, and when they asked me I would advise this. In fact, I have found that spontaneity, even if it leads to some confusion, forgetting of names etc., is better and I advise people not to think about the interview – just that it will be chronological and they can say what they like (though they can look at one or two of the earlier interviews on the web if they would like to do so).

8. The fact that there is no commercial side to the endeavour has an effect. That I am doing it without specific pay for the job and not as part of a well-funded project, is usually obvious and helps. That all the materials are freely available

on the web, can be downloaded for free anywhere in the world and used in teaching and research, all adds to the trust and spirit of altruistic collaboration.

9. The absence of any bureaucracy is important. We enter into an implicit contract. I have no paper for them to sign, assigning copyright, intellectual property rights etc. It is all agreed verbally and informally in the act itself. And hence the bond of friendship is not broken.

10. One of the things that has developed over the years and has greatly increased the interest and usability of the interviews is the possibility of putting up a summary[11] with some time codes to help viewers navigate to an area that particularly interests them. The summaries are often very detailed and the development of the web has again made them more interesting and reliable since one can check names, theories, and connections. This avoids the repetitions and roughness of ordinary speech (and time it takes to make) of a full transcript – and one has the film after all for the actual words. But they summarize much of the essence and flow of the interview. It is an art form in itself, combining considerable synthetic skills, a jigsaw ability and great concentration. It is not easy, but the website gives many examplars of highly professional examples which have won high praise from the interview subjects who are often amazed at how accurate and complete they are. The obvious comprehension shown in the summary further adds to the sense of trust.

11. Before the interview it is important to explain that anything that is said can be retracted or glossed later. People should not censor themselves too much. Candour and a relaxed flow of ideas are important and trying to avoid things detracts from this. I explain that while filming – before or after saying something – the interviewee can easily say 'this is not for public dissemination', 'this is confidential' or whatever. Any such passage is then excised from the version that becomes publicly available – but the original tapes are kept for posterity. I also explain that we will send them the full summary that needs to be checked for accuracy (especially names and technical terms), interpretations of statements, and also gives the person a chance to withdraw any section or passage if they wish. They may, as has sometimes happened, feel that they want to add something – some more autobiography, a clearer exposition of something technical. It is not difficult to put this into the summary either in square brackets or as an appendix.

11 The summaries are done by Sarah Harrison, who also devised this method and acts as the web-mistress for the site.

12. The duration of time people can concentrate varies. Most people can manage an hour, and then, with a break, another hour. When the tape ends I allow a few minutes for revival – but it is important not to lose the momentum. Some people prefer to do an hour, go away and come back some days later. This is all right, but can lead to repetition. But for older subjects (and many of mine are in their later eighties and older) it may be necessary. The older subjects also often feel more comfortable in their own homes amongst their books and belongings. This often gives an added dimension to the interviews.

3. Preliminary impressions from the current science interviews

As for drawing out the riches contained in the interviews, I am only just starting to analyse the contents and to incorporate the findings into my broader investigation into creativity. A few very preliminary impressions can be given.

In relation to the country of origin, about two thirds come from the U.K., three from South Africa and the other from Southern Ireland, Poland, Australia, Malaysia, etc. In terms of parental backgrounds, if we make a simple differentiation between professional classes and others, so far about half have been from the professions; the non-professional include a shoe repairer, cattle-dealer, restaurateur, tailor, steel worker, stonemason and coal miner. Only two, so far, had a parent who had been an academic.

In terms of schooling and early life, most of those interviewed showed some interest in science – particularly hobbies like botany, bird-watching, making things with construction kits. The effect of particular named teachers is often mentioned and some of the interviewers have kept up contact with the person (often a female teacher early in life) until the present. Most mention a special book that suddenly sparked an interest in science. At University there was often a role model or inspiring teacher.

Most of the interviewees remember the moment, often away from the laboratory or office, when a break-through occurred, at a party, on a walk or in conversation with colleagues.

It is interesting that many of the interviewees were thought to be of only average ability at school. They were good enough to get into University, but so far only a few seem to have been outstanding before the age of about eighteen. Yet quite a few found their special ability in their first degrees at University.

Most of the subjects frequently mention their 'luck' or 'good fortune'. 'Then I was lucky to meet a certain person …', 'get a research fellowship…' 'go to America…', 'find a wonderful problem to try to solve'. The mind may be well prepared and honed, but the unforeseen chances are always at the forefront of breakthroughs. Intelligence, curiosity, hard work,

concentration and the right national and institutional environment may be necessary conditions. But almost all those I have talked to were aware that something extra was needing, which could not be planned or predicted.

So what are the extra things that turn promise into a paradigm-shifting contribution? Here we have to listen to the accounts themselves, preferably in full, to start to understand the interwoven texture of the life and personality as they develop. For a great deal more is there to be explored. The exciting thing is that is not locked away in my personal notebooks or films, but rather available to anyone in the world with broadband. It can be downloaded and used in teaching and research. As the generations go by, people can hear and watch people talk in depth about lives which have led to some significant achievements in arts, humanities, social sciences, science, mathematics and technology.

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Appendix: Science interviews , to end of October 2008[12]

The interviews are characteristically 90 to 120 minutes long.

Biology, zoology and ethology:
Sir Patrick Bateson, Sir Gabriel Horn, Professor Robert Hinde, Professor Michael Bate, Dr Alison Richard, Sir John Gurdon

Physiology and medicine:
Sir Andrew Huxley, Professor Richard Keynes, Professor Yung Wai (Charlie) Loke

Chemistry and biochemistry:
Professor Sydney Brenner, Dr Dan Brown, Dr Hal Dixon, Sir Aaron Klug, Dr Frederick Sanger, Sir John Sulston, Sir John Meurig Thomas, Sir John Walker

Astronomy and cosmology:
Sir Antony Hewish, Lord Martin Rees, Professor Neil Turok, Professor Owen Gingrich

Physics and geo-physics:
Sir Richard Friend, Professor Dan McKenzie, Sir Brian Pippard, Dr John Polkinghorne

Mathematics:
Professor John Coates, Sir Peter Swinnerton-Dyer

Computing and technology:
Professor Andy Hopper, Dr Ken Moody, Professor Jean Bacon, Hermann Hauser

History and philosophy of science:
Professor Simon Schaffer

12 The interviews can be watched on www.alanmacfarlane.com A selection of them is also being put up on 'Youtube' on the 'Ayabaya' channel. There are also nearly 100 interviews in non-science fields. There have been a number of further science interviews since October 2008. All the interviews, numbering 190, can also be seen in various formats on the University of Cambridge Streaming Media Service (http://www.sms.cam.ac.uk/collection/1092396)