oil-contaminated areas, areas receiving industrial waste discharge, effluents of acid mines, corroded materials, etc.), presents great opportunities for the investigations of extremophiles. Because unusual habitats occur across the length and breadth of the country, research on extremophiles may well be one of the best ways to reach out and encourage scientists in the remote and less endowed institutions. Moreover, extremophile research is an area in which, because of the paucity of information, these scientists can contribute to the generation of knowledge, accomplish something and not feel frustrated. The pioneering studies of Thomas Brock on thermophilic microorganisms were done in remote places with simple facilities[26]. Could any one have predicted that the bacterium *Thermus aquaticus*, isolated in 1969 by Brock and Freeze from a hot spring in the Yellowstone National Park, USA, would in less than 20 years be exploited as a source of thermostable DNA-copying enzyme (*Taq* polymerase) and make the PCR technology an enormously successful technique? This enzyme and many restriction enzymes discovered from screening of thousands of bacteria and archaea are now churning millions of dollars annually in the developed countries. Witness the *Taq* polymerase controversy[27]. There was a time when people fought for the possession of women or for a piece of land. Now people are fighting for the rights to a bacterial gene product!

An understanding of life cannot be complete without a knowledge of the variations of biochemical design that evolved over many millions of years. Microbes offer unique experimental material for understanding the diversity of adjustments that they make to get adapted to their environment. Let us hope that the traditional areas of microbiology concerned with the study of the diversity of microbes and of their biochemical activities will be pursued vigorously.

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Finding *patterns* in nature's maze: An endless quest

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I am writing in response to 'Are patterns a rule in nature?'[1] by K. N. Ganeshaiah (KNG). Without doubt, reading it was quite a stimulating experience. However, I feel compelled to respond to a few issues raised in the paper; as the saying goes, it is better to debate an issue and not settle it rather than settle an issue without debating it.

Patterns: a question of scale

Are patterns a rule in nature? I find the question rather incomplete and bordering on the philosophical. What sort of pattern does the author have in mind? At what level of organization? At what temporal and spatial scales? To a physicist, chemist or for that matter any scientist, the answer to the question will be an assertive 'yes', given the fact that all matter in nature, animate or inanimate, diamonds or DNA, represents a highly ordered arrangement of atoms. A historian sees a pattern in the evolution of civilization, an economist in share market fluctuations and a Coorg planter in coffee prices in the London market! They may, however, fail to see any pattern in short-range local events such as changing consumer tastes over a period of a few weeks or the variation in the onset of summer showers in April. Clearly, it is important to specify exactly what sort of pattern and scale one is dealing with before asking if patterns are ubiquitous.

What is a pattern: toward a definition

What is a pattern? As pointed out in the article, it is difficult to define what a pattern is. It is further argued that there may be disagreement among scientists on the signal component or specific feature of the system that is considered to reflect the pattern[1]. For this reason, the author says, it is difficult to define a pattern and that this constitutes a major difficulty in pattern finding in science. Perhaps not. Pattern is 'an arrangement or order discernible in objects, actions, ideas or situations' (*New Shorter Oxford English Dictionary*). Many of my colleagues when asked what the term pattern meant to them opined that the term pattern could be used to describe any phenomenon which is predictable. Unlike argued by KNG, it hardly matters what parameters are chosen to identify a pattern, because scientists from varied fields do recognize patterns in each other's fields though they may not fully understand the approach adopted in identifying the pattern.

In my opinion, what we probably have to split hairs about are the scientific merits and the criteria in classifying patterns as 'yes' or 'no' patterns. Taking the help of information theory, we can perhaps classify patterns. Many systems, be they organization of ideas or objects, carry information which has predictive value. Systems with '0' information content can be labelled 'no' patterns and those with information content of '1' as 'yes' patterns. Clearly, the information content will also influence the degree of predictability. Therefore, as pointed out by KNG, the patterns need not be discrete and there could be a continuum, at least in principle.

Patterns: good vs poor?

It is pointed out by KNG that there is a general agreement among scientists that patterns are an all or none phenomenon, notwithstanding his earlier argument that it is difficult to define what a pattern is and that it poses a major problem in pattern finding in science. He then expresses surprise that science immediately recognizes and appreciates '. . . demonstration of *absolute* "yes" patterns, more easily than that of "poor" or "no" patterns (italics mine)'. That is setting up a strawman and shooting him down! As pointed out earlier, the crux of the matter is predictability and it is this feature which enables scientists to label something as a pattern. The reason why scientists do not appreciate a 'poor' pattern is because it is not explicitly labelled so. If a phenomenon concerning subatomic particles or stars has an information content which is greater than '0' (however small) and, therefore, has a certain level of predictability, it is labelled as a pattern.

Scientists are always aware of the inadequacy of a 'model' that explains patterns and it is unfair to say that no distinction is made between good, poor and no patterns. It is also true that as our knowledge about a phenomenon increases, the information content of the phenomenon may be revealed in greater detail and the predictability may also improve. This would result in a phenomenon being explicitly labelled as poor with hindsight, but for a given amount of knowledge and at any given moment there is merely a pattern or no pattern. Conversely, with increasing knowledge a 'yes' pattern may turn out to be a 'no' pattern. As an extreme example we can remind ourselves of Ptolemy's geocentric view of the universe, which was replaced by the heliocentric view – the well-known Copernican revolution.

A search for the 'ultimate particle' led Dalton to formulate the notion of indestructible atom; this he is known to have derived from the laws of visible heavenly bodies. But Humphry Davy was not convinced; he argued that 'there is no reason to suppose that any real indestructible principle has yet been discovered'. It took 50 years for science to prove Humphry right. However, by then, the concept of indestructible atom was used and elaborated by Gay-Lussac, Avogadro and Mendeleyev. The blow to indestructibility of atom came from two sources, the study of light and the discovery of electricity, the latter being totally unexpected[2]. The early history of physics and chemistry is peppered with many similar events that tell us three things; (i) that patterns when discovered are questioned; (ii) that even if the pattern is 'poor', considerable progress can be made in understanding nature and (iii) that the poor pattern may turn out to be a good pattern as we acquire more knowledge.

It is, therefore, not quite correct to say that science does not distinguish between good and bad patterns. When subjects in a psychological test are given a choice between various visual patterns and asked to sift the good from the bad, it is understandable, because they have a choice of 'alternatives'. Now how am I to say that the return of the Haley's comet once every 75 years, or the life-cycle of 13-year cicada is a good pattern or a bad pattern? If a good pattern is 'invariant' or has fewer or no 'alternative states', it again boils down to predictability or regularity, fewer the alternatives or alternative states, greater is the predictability. Which means we can now define a pattern in terms of predictability. If the predictability is greater than 0, we can claim to have discerned a pattern, however poor it may be. Once that is done, the scientists would like to take the predictability as close as possible to 1. This represents the range of patterns exemplified by Ganeshaiah's ink blot to a square or a circle. I argue that science has not instinctively picked the good patterns but has only so far described what is obvious; squares and circles – one of the two ends of the continuum. It would take more effort and time for science to traverse the entire range from both ends. Towards this the scientists are justified in using all the tools that are at their disposal and such attempts need not be dubbed 'frustrating search for patterns'.

Patterns and perception

KNG's major criticism is that our ability to detect patterns is limited by our perceptual abilities. This may indeed be so as philosophers right from Plato have emphasized. Given this handicap, how are we ever going to decide what is a 'good' pattern? A martian with better perceptual ability may throw out all our 'good' patterns as 'no' patterns! Our visual sense of a stick held in water deceives us to believe that the stick is bent at the water surface. How can we demonstrate that the stick is straight? Simple, by running our hand down the stick. Herein lies our folly and by extension the general tentativeness of all our discoveries. Because in our eagerness to prove an error in our sense of vision, we have trusted our sense of touch. In other words, how can 'deceptive tools' prove their own deception? However much we dislike it, we have to contend with our limited array of senses, suspect or not, to go about the job of discovering patterns in nature. Though we cannot assert that patterns abound everywhere in nature, we have to tap them using our limited tools. It is likely that as we polish nuggets of information and discover more and more of the hidden treasures, we will carve even more patterns from nature. If all this is the construct of the language and grammar of science, so be it. Roger Boscovich, a mathematician and physicist of the eighteenth century has gone beyond this and argued[3] that exploiting determinism to obtain complete knowledge is not possible because '... our human intellect is not equal to this task...'.

It has been rightly argued that randomness is in the eye of the beholder and is a function of the power of our models to analyse the phenomena. Most of us have the experience of fitting our observed data points into one or more models In the process, if we have been successful, it only shows that we have been able to explain the observed phenomena in some predictable way. I see no harm in such an exercise. Data fitting to wrench a pattern is a routine exercise through accepted rules of the game of science. Transformation of data is a legitimate practice. If log-transformation enables me to gather a greater comprehension of my observations (more patterned or less patterned), what is the harm? But for noise filters in radio and television, we would not be enjoying music, a pattern of sound.

Sure, as KNG points out, some amount of data or chips of information may be lost as noise in the process, but is it important? For instance, if a certain method of short-range forecasting of the possibility of rain in a particular week of the year is going to be predicted at some assured level of probability, even if it is not very close to 1, I am willing to lose any amount of information as noise through all the 'frustrating' jugglery!.

It required the mental acumen of great men to unravel patterns in nature about us where none was realized earlier. As Alexander Pope wrote, 'Nature and nature's law hid by night; God said, let Newton be and all was light'. To see woods from forest requires some skill and time. And seen it would be, definitely. So, if a hundred Newtons with their powers of senses identify patterns all around us, why complain. Certainly, it is our naivety to chide them that they are squeezing nature dry of 'no' patterns. Even in arts we need artists who see appealing patterns around them. I would welcome a hundred Michelangelos or Jakanacharis, who imposed *their* patterns onto stone – without their patterns the world would have been such a dull place.

Patterns: stochastic or deterministic?

I do not think that it is a general attitude of science to attribute an order-generating process to any pattern[1]. Science does not underplay or has disregard for the role of randomness in generating order. Stochastic processes are invoked as often, if not more, as are deterministic processes in describing patterns. Indeed, before the notion of chaos became an established concept, scientists addressed a complicated process as a statistical problem – a random process[3]. It is true that it took a long time for science to shed the blinkers of deterministic clockwork of the Newtonian world view – 'laws that never shall be broken'[3]. We now know that in a large number of physical systems, from heart beat to weather, the slightest uncertainty in the knowledge of the system at one moment will result in complete loss of information about the state of the system in a very short time and where randomness appears to prevail.

It is true that only recently have we begun to realize the power of randomness more explicitly in generating order, especially in biological sciences. Even here, for example, the so-called order we see in the evolution of organic diversity is a result of random or chance process. Evolutionary biologists agree that if the tape of evolution were to be rewound and run again, we cannot be certain that we will see an amoeba-like organism again; leave alone *Homo sapiens* or a *Tyrannosaurus rex*! Natural selection is not an order-generating process, it merely represents the success or failure of individuals of a species to respond to randomly changing local conditions.

The ability to find patterns has had a long evolutionary history. It was perhaps the ability of our australopithecine ancestors to find patterns in the movement of animals which helped them hunt, escape predators, and avoid other groups of competing individuals; later on, the same ability must have even enabled them to light fires. The success of australopithecines was due perhaps more to this than their erect posture or the ability to make tools! Human beings are known to make sense of their surroundings by making a 'mental representation' of what they see – an important feature of cognition. Given this it is not surprising that we try to find pattern in everything that impinges on our senses. I would even argue that this constant search for patterns contributed in no small measure toward the enlargement of the forebrain to which *Homo sapiens*, as a species, owes its success today.

I have deliberately not attempted to respond to the philosophical aspects of the question raised by KNG: simply because when I see a brick or a chair, I see *it*. I find it difficult to subscribe to the kind of philosophy which argues that a brick or a chair does not exist – it is only an interpretation of the human mind. It has to be. Even in Ganeshaiah's imaginary planet 'Binearth' we *need* a biologist from earth to study and interpret life on the planet. It is difficult to comprehend how the universe can be visualized without the existence of cognitive beings (for whom and by whom anyway?). The world is, what the mind sees. There is, in my opinion, no question of imposing anything.

Lastly, I do not think that science looks for patterns for its own survival. A very interesting pattern relating to the sounds produced by humans has been discovered recently. It concerns the case of two individuals with mild brain damage who were otherwise normal. It seems these two individuals were unable to pronounce vowels while being perfectly capable of pronouncing consonants. This provides yet another example of the 'pattern' of modular construction of human mind and also suggests that categorization of sounds into vowels and consonants is a pattern. It may be *imposed* by human mind, so what? It could not be otherwise! Now if such pattern finding is going to ensure the 'survival' of neurologists and the growth of neuroscience, the 'last frontier in biology' we should only be too happy.

With surprises such as the one mentioned above being sprung on us from time to time, it may not yet be time to suspect that patterns are not a rule in nature. As Einstein said, 'the eternal mystery of the world is its comprehensibility', and toward this we should continue our search for patterns.

I am not sure if I have 'not settled' the issue by 'debate', but as Popper said, 'I may be wrong and you may be right and, by an effort, we may get nearer to the truth'.

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MEETINGS/SYMPOSIA/SEMINARS

National Workshop on Biodiversity Conservation in Managed Forests and Protected Areas

Date: 29 November –1 December 1995
Place: Bhopal

Topics include: Biodiversity conservation in managed forests; Biodiversity in protected areas; Ethical and ecological considerations; Socio-economic issues; Institutional, policy and planning issues.

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Xth National Carbohydrate Conference

Date: 8–9 November 1995
Place: Vallabh Vidyanagar

Topics include: Plant and microbial polysaccharides; Isolation, characterization and their biological activity; Carbohydrate synthesis; Industrial polysaccharides; Production and utilization; Carbohydrate fermentation/Biotransformation.

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National Seminar on Trends in Chemical Education and Research

Date: 16–18 November 1995
Place: Madras

Topics include: Innovation in creative chemical education; Recent advances in certain areas of analytical and general chemistry; Current trends and progress in biological, industrial and environmental chemistry

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