This essay discusses the ‘boundary problem’ in science – how the demarcation of ‘science’ from ‘non-science’, and ‘rational’ from ‘irrational’, is determined and maintained in modern science. Or, to put it differently, how do the boundaries of science, being determined at a point of time, purge all the ‘impurities’ from science and maintain a coherent internal content? Boundaries purportedly demarcate a pristine, transparent and coherently unified ‘internal’ against an impure ‘external’. Such a process of boundary-making is central to the project of modern science.

The pre-Kuhnian philosophers and historians of science were self-appointed watchdogs of modern science; by looking at science normatively, and by presenting knowledge production as a social cognitive enterprise, they successfully maintained an essentialist picture of science. They were thus engaged in delineating the boundaries of science by treating scientific disciplines as homogenous and coherent (Gieryn, 1995). Kuhn himself radically extended the analysis of scientific perception and methodologies. However, the post-Kuhnian turn in social studies of science was a constructivist twist that looked at the actual sites of knowledge production and the everyday practices of science from an anthropological point of view, to understand how social factors actually shape science in the making. This sociological turn, and a philosophy and history informed by it, thus presented a new image of science, developing fresh insights into the internal ambivalences and fluidity of scientific knowledge production.

The boundary-making impulse in science helps us to understand the hidden power relations and sociological processes involved in knowledge production. Borders are always maintained between disciplines and subcultures in science. There are borders between science and non-science too, as mentioned above. However these frontiers are not permanently fixed, but are constantly being challenged and remapped (Nader, 1996). It can be seen that beyond all positivist assumptions of science as a monolithic and homogeneous truth-seeking enterprise, a close look at the frontiers of science reveals the ambiguities immanent in knowledge production and the internal ‘disunity of science’ (Galison and Stump, 1996). As asserted by Gieryn (1995, p. 440), the “examination of how and why people do boundary-work – how they define ‘science’ by attributing characteristics that spatially
segregate it from other territories in the culturescape – could be the first step toward a cultural interpretation of historically changing allocations of power, authority, control, credibility, expertise, prestige and material resources among groups and occupations”. The frontiers of science are sites of power struggles and negotiations, ambivalences and equivocations, as well as impurity, hybridity and contagion.

The complex ways in which the notion of science has been fixed and subverted when scientists do science will be demonstrated in this essay through a case study: scientific analyses of the unusual phenomenon of ‘coloured rain’ that occurred in Kerala, India’s southernmost state, from July to September 2001. This ‘rain’ invited much attention nationally and internationally, because scientists were not able to satisfactorily interpret the phenomenon for a long time. They are yet to reach a consensus in this regard, though one group of scientists offered a credible explanation at a later stage of the investigation.

**Coloured Rain in Kerala**

The phenomenon of coloured rain was the last episode of a long trail of events in Kerala. A chain of unusual geological events occurred in the region in the wake of a series of low-intensity tremors, the first of these occurring on 12 December 2000. Many tremors of lower intensity continued striking the region from then on; and as a possible aftermath of the Gujarat earthquake on 26 January 2001, several extraordinary geophysical events started to manifest in the region, including well collapses, oscillation and rise in water levels, well water changing colour, cracks in buildings, appearance of ground fissures, and unseasonal leaf fall. Scientists from different institutional associations and disciplinary backgrounds attempted to explain the phenomena, and this led to a situation where several scientific explanations were proposed and contested.

The rain was first reported from Changanacherry, a small town in Kottayam district. The inhabitants of the locality of Morkulangar witnessed a peculiar ‘red rain’ on the morning of 25 July 2001. Two scientists from CESS, Dr V. Sasi Kumar and Dr S. Sampath, arrived at Changanacherry the next day and made preliminary investigations. Following the Changanacherry incident, ‘red’ and later ‘yellow’, ‘green’, ‘blue’ and ‘black’ rain was reported from all over Kerala, raising hue and cry among the public. On 30 July 2001, CESS published its preliminary report on the red rain phenomenon in Changanacherry, declaring a meteor explosion above the town as causative. According to the report, about 1000 kilograms of ash from the burnt-out meteor dispersed through the atmosphere and were washed down by the rain that followed. Thus, the rain was red because it contained a large amount of meteor ash. The scientists contended that the unusually dramatic thunder and lightning witnessed by locals was provoked by the meteor explosion.

The ‘meteor hypothesis’ was challenged after a few days: a group of scientists with another institutional and disciplinary affiliation came up with a new theory. Dr K.C. John, director of the School of Applied Life Sciences (SALS) of Mahatma Gandhi University, Kottayam, declared that certain biological cells in the rainwater added colour to it, as
observed in samples studied under an electron microscope. Three different types of cells were identified: translucent, yellow, and brick-coloured. There was also evidence of rudimentary cell division. It was suggested that the cells were of either algal or fungal origin, or deriving from pollen grains.

The controversy escalated the next day, with more scientists and scientific institutions showing interest in the phenomenon. The biological cell theory has been substantiated by scientists from the Central Plantation Crop Research Institute (CPCRI). Scientists supporting the meteor theory proposed that the colour was caused by the Delta Aquarids meteor shower that passed close over the earth. Challenging the two major explanations of the coloured rain phenomenon offered by CESS and SALS scientists, many alternative theories were also offered at this juncture, from scientists of different disciplinary backgrounds and expertise. Dr Sainudeen Pattazhy, president of the Kerala Environment Researchers’ Association, suggested that coloured rain was linked to well collapses and landslides. Another interpretation was that water molecules clustered together around the minute crystals of micro-pollutants in the air, and thereby formed coloured raindrops. Another scientist suggested the presence of either chemicals such as metal oxides, nitrates and chlorides, or biological materials from algae, fungi and lichens, as initiating coloured rain (Pillai, 2001). Dr K.J. Joseph, former director of the Meteorological Centre, Thiruvananthapuram, argued that the phenomenon was the aftermath of industrial pollution (Joseph, 2001). Scientists at the Vikram Sarabhai Space Centre, Thiruvananthapuram, linked the phenomenon to the fine particles of dust that reached Kerala from the Arabian desert (Jacob, 2006).

Such an outburst of alternative explanations, along with criticism of the meteor theory from a wider circle of scientists, however, urged the CESS scientists to conduct a fresh investigation on the matter, taking into consideration new cases of coloured rain. Since their earlier explanation was not satisfactory, scientists from the institute therefore visited various places where coloured rain had occurred; water samples were collected and further observations made. After a few days, CESS researchers declared that their preliminary inference was wrong, as no meteor components could be identified in the samples during chemical analysis. Biological tests were conducted in the microbiology laboratory of the Tropical Botanical Garden and Research Institute (TBGRI) at Palode, and CESS in its final report refuted the meteoric origin of the phenomenon. “The colour was found to be due to the presence of a large amount of spores of a lichen-forming alga belonging to the genus Trentepohlia” (Sampath et al., 2001, p. 5). However, CESS also declared that further research would be carried out in association with TBGRI to identify the reasons behind the presence of spores en masse in the atmosphere, as well as its possible connections with other unusual geological phenomena (ibid.). The reasons behind the sustained appearance of coloured rain all over Kerala also continued as a public mystery. There were also several unresolved problems regarding the red rain in Changanacherry. Thus, competing theories were deadlocked, with no theory proving satisfactory enough to resolve the issue.
It's Raining Aliens!

However, Dr L. Godfrey Louis and his student Dr Santhosh Kumar of the School of Pure and Applied Research (SPAL) of Mahatma Gandhi University, Kottayam, continued with their analysis in 2001. Louis was specialising in experimental solid-state physics, electronic instrumentation and computer-based instrumentation, while Kumar was completing his doctoral research in solid-state physics. Louis had actively participated in the debate on the phenomena since the beginning, supporting the meteor theory and explaining the characteristics of the meteor that allegedly caused red rain. Right from the start he had hinted towards the possibly extraterrestrial origin of the cells present in the water samples. Louis and Kumar faced silence from CESS in this regard, as well as ridicule from the scientific community.

Although they were being totally lampooned by fellow scientists, Louis and Kumar continued their research along this track, and with great difficulty were able to publish their findings in an online archive of astrophysics in October 2003. They proposed that the red cells found in the coloured rain samples collected from various localities were of extraterrestrial origin. Their study indicated that the red colour of the rain was not due to fungal or algal spores. They pointed out that coloured rain occurred all of a sudden at a specific locality, while the rain in neighbouring localities was normal (Louis and Kumar, 2003a). Their study revealed that most of the coloured rain concentrated in central Kerala, and a sum total of 124 incidents occurred in the region (ibid.). They also suggested that the sound of the explosion heard by many people just before the first incident of red rain in Changanacherry was the ‘sonic boom’, a loud explosive noise caused by the shock wave from an aircraft or object travelling faster than the speed of sound. According to the researchers, the red cells of the meteor spread all over the atmosphere after the explosion and eventually reached the rain clouds. As the blazing meteor moved southeast, it fragmented; shattered chunks separated from the main body, causing coloured rain in various places as meteor particles slowly disintegrated in the earth's atmosphere. Data also confirmed that 85% of the coloured rain in Kerala occurred within 10 days of the Changanacherry incident.

Louis and Kumar analysed rainwater samples using the laboratory facilities at their university and the Sree Chithira Tirunal Institute for Medical Sciences and Technology at Thiruvananthapuram. With the help of laboratory studies they proved that the biological cells in the samples were devoid of DNA or any other known genetic material, although cell division was observed. They also found that these cells could withstand high temperatures, and observed germination at even 300°C (Louis and Kumar, 2003b). The cells survived for over two-and-a-half years at room temperature. Chemical analysis of the cells revealed the presence of carbon, hydrogen, oxygen and nitrogen – all elements found in abundance in comets and interstellar clouds – but found that elements such as phosphorous, critical for terrestrial life, were not essential for the survival of these cells (ibid.). Based on this evidence, the scientists argued that the red cells could be a strange
form of life from outer space, and that further research would prove that these biological
cells with unknown genetic material were in fact extraterrestrial.

When Louis and Kumar’s research paper appeared in the online archive, it attracted a
small international community of astrobiologists who had been working on theories of the
extraterrestrial origin of life. The researchers were invited to present their findings at a
cconference on the theme of ‘Astrobiological Problems for Physicists’, conducted by
NORDITA (Nordic Institute for Theoretical Physics) in Copenhagen from 8-10 January
2004. The researchers have thus been introduced to internationally acclaimed scientists
who work on the theory of ‘Panspermia’ (in Greek, lit. “seeds everywhere”), a hypothesis
proposed by astronomers Fred Hoyle and Chandra Wickramasinghe in the 1970s. Modern Panspermia theory (which is not accepted by mainstream science) suggests that
life began on earth when ‘seeds of life’ reached the earth from elsewhere via the vehicles
of comets or meteors.

By careful spectroscopic observation and analysis of light from distant stars, Hoyle and
Wickramasinghe found new evidence, traces of life, in the intervening dust. They also
proposed that comets, which are largely made of water-ice, carry bacterial life across
galaxies and protect it from radiation damage along the way. Hoyle and Wickramasinghe
also broadened or generalised Panspermia to include a new understanding of evolution.
While accepting the fact that life on Earth evolved over the course of about four billion
years, they say that the genetic programmes for higher evolution cannot be explained by
random mutation and recombination among genes for single-celled organisms, even in that
long a time: the programmes must come from somewhere beyond earth. This expanded
theory, which incorporates the original panspermia theory the way General Relativity
incorporates Special Relativity, is also termed ‘strong’ panspermia.

The international community of scientists who work on the Panspermia theory
considered the researchers’ findings about coloured rains as strong evidence of the extra-
terrestrial origin of life.

Louis and Kumar have consequently been absorbed into the research network of
astrobiology. Dr Wickramasinghe also got in touch with the researchers, and his host
institution in the UK, the Cardiff Centre of Astrobiology, offered them research facilities.
Consequently, the international scientific press also found their findings interesting.
Eventually their study appeared as cover stories in reputed scientific journals published in
the West, including New Scientist and Popular Science. This further legitimised and
facilitated their work. Such a warm reception at the international level brought Louis and
Kumar to affirmative public notice in India as well. Many national dailies and magazines
featured their research thereafter.

Dr Wickramasinghe visited Kerala at the end of May 2006, and delivered a lecture at the
Mahatma Gandhi University at Kottayam on the phenomenon of coloured rain and its
connection with the Panspermia theory; his presentation was followed by a press conference
(Jacob, 2006). A BBC crew visited the researchers at that time and made a television
documentary on them. A scientific paper by Louis and Kumar has recently been published in the international journal *Astrophysics and Space Science*, which gave them further validity and increased confidence to continue with their research. By the year 2006, their findings emerged as a ‘potential’, if not legitimate, scientific theory, well accepted and discussed. Notably, there was not much opposition to this novel proposition in Kerala from fellow scientists with different disciplinary backgrounds, who were working towards a better explanation of the phenomena of coloured rain. There were disagreements among the regional scientific community, but apparently most of them maintained a stoic silence.

This unanimous victory achieved by Godfrey and Santhosh was an accomplishment gained with great difficulty, through a careful manoeuvering of the ambiguities and hybridity at the frontier of science. In spite of the plenitude of scientific opinion, each struggling to achieve legitimacy as the most authentic and convincing account of the phenomenon, none of the proponents could actually explain it satisfactorily. Even after the proposition of major hypotheses such as the meteor theory and algal spores theory, most of the basic questions raised about the phenomena remained unanswered. At this juncture, Louis and Kumar successfully elucidated the cause and mechanisms of coloured rain; they also explained coloured rain as a future possibility, since meteors and cometary fragments enter earth’s atmosphere quite often. The researchers successfully drew elements from mutually contending accounts and adeptly incorporated fragments of these into their own explanation. Both the meteor theory and the biological cells theory proposed by two different groups of scientists thus neatly fit into the extraterrestrial cell ‘seeds’ theory. Even the novel component, i.e., the non-earthly matrix of the cells, was de facto not new. The researchers inoculated their argument by neatly situating it as strong evidence for the Panspermia theory, in which the concept of ‘alien’ cells had already been developed.

**Frontiers Revisited**

The equivocal narrative of coloured rain in Kerala is an exemplary instance of the boundary-making process in science. It demonstrates how an explanation, once lacking scientific legitimacy and discarded as non-scientific and farcical, slowly achieved legitimacy among the scientific community and emerged as a valid scientific theory. This inward percolation of ‘things’ and ‘ideas’ into the precincts of science from the ‘non-scientific’ and ‘chaotic’ outside clearly indicates the porous nature of the frontiers of science. It also shows that the inner core of science, considered to be of ‘pure’ essence by the gatekeepers of science, is actually an admixture of ideas from different terrains – other civilisations, knowledge systems, or subcultures of modern science itself. Such a process reconfigures disciplinary boundaries as well. However, although the border allows infiltration, it is only semi-permeable. The frontier necessarily repels certain ideas and things, and as a result there is always tension along its contentious verges.

The CESS scientists who posited the meteor explosion theory failed in their endeavour to convince the scientific community and the public because they did not manage their
resources skillfully. Their strict association with an institution devoted to earth science studies, and their attempt to understand the phenomenon from the narrow purview of this discipline, contributed to the delegitimisation of their theory from the very outset. The SALS scientists who proposed the biological cell theory were able to provide a more satisfactory explanation using the strong theoretical support of biology as a scientific discipline. They could also gather empirical evidence in support of their argument through the use of a powerful scientific apparatus such as the electron microscope; but their perspective was
also limited to the approaches offered by their field. In this context Louis and Kumar, two scientists without any prior expertise in the field of astrobiology and related areas, started from the point where the other scientists gave up. They developed fresh expertise in disciplines such as biology, genetics and astrobiology. They also collaborated with a wide range of scientific institutions and laboratories. By straddling different methodologies and thereby dissolving the disciplinary borders, they audaciously approached the inexplicable phenomenon from a fresh angle.

The case study of coloured rain thus illustrates how even while there is a strongly existent boundary-making practice in science, the frontiers remain contingent and fuzzy. They may appear as distinctly marked and permanently fixed, but a close examination reveals their often unexpected vulnerability and violability. Frontiers are contact zones where the inside of science meets its outside, where the ‘rational’ engages with the ‘irrational’ – and through this fraught engagement between science and non-science, the contours of science are remapped, and the content of science itself is redefined.

**Author’s Note**

In 1962, the American physicist/philosopher-historian of science Thomas Kuhn (1922-1996) published his *The Structure of Scientific Revolutions*. The main thesis of this remarkably influential – and controversial – book is that the development of science is driven, in normal periods of science, by adherence to what Kuhn called a ‘paradigm’. The function of a paradigm is to supply puzzles for scientists to solve, and to provide the tools for their solution. A crisis in science arises when confidence is lost in the ability of the paradigm to solve particularly worrying puzzles called ‘anomalies’. Crisis is followed by a scientific revolution, should the existing paradigm be displaced by a rival theory.

Kuhn claimed that science guided by one paradigm would be ‘incommensurable’ with science developed under a different paradigm, by which is meant that there is no common measure of the different scientific theories. Thus, Kuhn asserts that a Galilean and an Aristotelian, when both looking at a pendulum, will see different things: "In a sense I am unable to explicate further, the proponents of competing paradigms practice their trades in different worlds. One contains constrained bodies that fall slowly, the other pendulums that repeat their motions again and again. In one, solutions are compounds; in the other, mixtures. One is embedded in a flat, the other in a curved, matrix of space. Practicing in different worlds, the two groups of scientists see different things when they look from the same point in the same direction…"

Methodological incommensurability denies there are universal methods for making inferences from the data. Moreover, the theory-dependence of observation (i.e., rejecting the role of observation as a theory-neutral arbiter among theories) means that even if there were agreed methods of inference and interpretation, incommensurability could still arise since scientists might disagree on the nature of the observational data themselves...

Thus, we may distinguish between the world-in-itself and the ‘world’ of our perceptual and related experiences (the phenomenal world). This corresponds to the Kantian distinction between the *noumena* and the *phenomena*; but the important difference between Kant and Kuhn is that the latter regards the general form of the
phenomena to be not fixed, but changeable. A shift in paradigm can lead, via the theory-dependence of observation, to a difference in one’s experiences of things, and thus to a change in one’s phenomenal world. http://plato.stanford.edu/entries/thomas-kuhn/

Notes


2. Laboratory studies are crucial part of the sociology of scientific knowledge. The works of Bruno Latour and Karin Knorr Cetina have greatly influenced the discipline. The researchers used theoretical insights from anthropology to investigate the daily behaviour of scientists in their laboratories, in the manner that anthropologists study the behaviour of members of a tribe within their specific context.

3. They are affiliated with the Department of Physics and Meteorology at the Centre for Earth Science Studies (CESS). This autonomous research centre in Akkulam, Thrivananthapuram, was instituted by the Kerala government in 1978. The centre carries out research in different areas of earth systems studies from a multidisciplinary perspective, including studies on paleomagnetism, natural hazards, coastal zone management and use of resource studies for local planning.


5. Dr A. Chandran also assisted Dr K.C. John in the investigation.

6. See Mathrubhumi, 31 July 2001, p. 1. However, their sample was collected from another incident of red rain in Valanchuzhi, near Pathanamthitta where the institute is located.


8. Op. cit., 4 August 2001, p. 1. This argument was raised by S. R. Prabhakaran Nair, Professor of Astrophysics, Kerala University, Thrivananthapuram.

9. Propounded by Dr N. G. K. Nair, the former head of the Resource Analysis Wing of CESS. See Malayala Manorama, 2 August 2001, p. 8.

10. Dr Suresh C. Pillai, Department of Chemistry, University of Dublin.

11. If the red rain in Changanacherry was due to algal spores, how it appeared en masse, and the origin of the ‘explosion’ people heard just before the red rain, etc., remained some of the unanswered questions.

12. Dr Godfrey Louis is currently a faculty member at the Cochin University of Science and Technology (CUSAT).

13. See Dr Godfrey’s personal website for more information: http://www.education.vsnl.com/godfrey/.

14. My personal interviews with a wider range of scientists working on the unusual geophysical phenomena substantiate this. All the scientists I interviewed discarded the ‘extraterrestrial origin of cells’ hypothesis as non-scientific.

15. See list of references.

16. From the biological point of view, cell division (both mitosis and meiosis) is possible only if genetic material (DNA or RNA) is present in the cell.
17. For details of conference, see http://www.nordita.dk/conference/AstroBio2004/
18. For details of their pathbreaking study, see http://www.astrobiology.cf.ac.uk/aimsA.html; see also http://www.astrobiology.cf.ac.uk/fredhoyle.html
9. Dr Chandra Wickramasinghe was Director of the Centre as well as Professor of Applied Mathematics and Astronomy at Cardiff University (http://www.astrobiology.cf.ac.uk/staff.html). The Cardiff Centre for Astrobiology is a comparatively new institute started in November 2000 by Cardiff University in collaboration with University of Wales College of Medicine (http://www.astrobiology.cf.ac.uk/aimsA.html).
22. Dr Sainudeen Pattazhy consistently opposed the findings, but could not gain much public attention. Dr K. C. John openly criticised the findings and alleged that the researchers had ulterior motives. See Mathrubhumi, 7 June 2006, p. 10. Many scientists I interviewed were of the same opinion. However all of them either were silent earlier, or never got a chance to speak out in public.
23. Even the yellow rain that has occurred of late in some places was well explained. The researchers opined that the colour could have been formed when burnt organic material from the meteor dissolved in rainwater. However, they also stressed the need for further investigation. Personal interview with Godfrey and Santhosh, 23 June 2006.
24. Ibid. They also pointed out that coloured rain is reported from different parts of the world, but scientists often attribute these to environmental pollution.
25. Ibid.

References
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