Science is beautiful

by Dr Andrew French

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A monochrome glacierscape. Numb fingers and slow thoughts. Footfall after footfall. I develop a somewhat unorthodox crampon augmented gait, attempting to mirror a thrice-Everest summiteer intriguingly called Karma. Well, intriguing for less oxygen starved low-altitude brains. I have an unreasonable desire to ascend; to reach the ridgeline tracery above and cease this nocturnal purgatory. I turn East to watch the sunrise, and all perspective is transformed. I am familiar with the physics. Let us begin with the Sun; a near-spherical nuclear furnace of 73% Hydrogen and 25% Helium residing in a void of space, 150 million kilometres from its tiny blue satellite. One hundred and nine Earths would span a diameter of our nearest star, and 330,000 Earths would balance its mass. A standoff between solar heat and gravity has persisted for 4.6 billion years. A by-product of this extremely energetic tension is about 0.4 billion, billion, billion watts[1]; a light-source so fantastically powerful that even a faraway tiny blue planet can receive up to one kettle-boiling kilowatt for every square metre of illuminated surface. On that most sublime of mornings on Mera Peak in the Hinku Valley of the Nepal Himalaya, the photons, released from the surface of the sun eight minutes and nineteen seconds earlier, completed their journey by colliding with tens of millions of ocular photoreceptor cells. And then onwards, via an electrical cascade, to a complex stimulation of tens of billions of neural cells, each one smaller than a thousandth of the width of a human hair, yet each connected to a thousand others.

The vista was awesome; an intense red, gold band illuminating countless jagged pinnacles. The massive dark anvil of Kangchenjunga rose above them through a perfect blue colour grade; from cerulean, cobalt, ultramarine, navy, black. The intensity of these sun-waves dramatically separated in hue as the fourth power of their frequency. I continued upwards to my own personal summit, a mere pimple upon the immense furrows of the Sargarmatha National Park, with a quickness in my step.

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[1] Williams, D. R. (1 July 2013). "Sun Fact Sheet". NASA. Retrieved 12 August 2013.

"Do not all charms fly at the touch of cold philosophy?" [2] John Keats, Edgar Allen Poe[3] and many others seemed to think so in the 1820s. This ideological phase separation of the romantic and the rational[4] has long infected Western culture. In 1959 the British scientist and novelist C.P Snow delivered an influential lecture[5] in which he proposed the intellectual outlook of society was effectively segregated into the sciences and humanities. Despite high degrees of education, each group would typically deem the other illiterate. I hope all of you have been sufficiently broadened by your education to be open to many different manifestations of knowledge and ways of thinking. However, it is a natural consequence of the practical necessity of separating your classes into Art, Sciences, English, Modern Languages, Mathematics etc that the foundations of intellectual division have already been unknowingly set. I hope you will allow me to entertain the notion that one can perceive this truly beautiful world with many different lenses and filters. I encourage you to embrace both emotion and reason, intuition and analysis. It is very important that you reject the artificial apartheid of the mind that our current culture appears to foist upon us. C.P. Snow suggested that the split between the sciences and humanities was a major hindrance to solving the world's problems. Your parents' generation survived a potentially lethal epoch, where many of the world's scientists spent their careers developing systems of nuclear annihilation. What could have been achieved given a peaceful goal? Your generation faces an even greater danger in the form of an inhospitable climatic future, fuelled in no small part by a society driven by unsustainable economic and population growth. We need to utilise all aspects of our humanity, all disciplines of our collective intellect, if we are to engineer a happy future for our species.

In a small way I would like to add to this debate. I want to inspire you, especially those of you whose preference is not to "conquer all mysteries by rule and line," [6] spectrometer and microscope; that the Universe viewed via a scientific lens is one of beauty, delicacy, grandeur, symmetry. I think there are two main ways in which an application of Science can enhance our appreciation of the aesthetic. Firstly, use of instruments which greatly

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[2] *Lamia*, John Keats, 1819.
[3] *Sonnet to Science,* Edgar Allan Poe, 1829.
[4] *Zen & the Art of Motorcycle Maintenance*, Robert. M. Pirsig, 1974
[5] *The Two Cultures*, C.P. Snow. Rede Lecture, 1959.
[6] *Lamia*, John Keats, 1819.

enhance our own human senses can enable us to explore a significantly more varied and interesting natural world. Secondly, I will argue the case for 'structural' or 'functional' beauty, which is revealed by a scientific analysis of how and why things work.

The Nobel Prize winning American physicist, bongo player and painter Richard Feynman is often quoted[7] for his view that application of science can only augment, not diminish an artistic experience:

“I have a friend who's an artist and has sometimes taken a view which I don't agree with very well. He'll hold up a flower and say "look how beautiful it is," and I'll agree. Then he says "I as an artist can see how beautiful this is but you as a scientist take this all apart and it becomes a dull thing," and I think that he's kind of nutty. First of all, the beauty that he sees is available to other people and to me too, I believe. Although I may not be quite as refined aesthetically as he is ... I can appreciate the beauty of a flower. At the same time, I see much more about the flower than he sees. I could imagine the cells in there, the complicated actions inside, which also have a beauty. I mean it's not just beauty at this dimension, at one centimetre; there's also beauty at smaller dimensions, the inner structure, also the processes. The fact that the colours in the flower evolved in order to attract insects to pollinate it is interesting; it means that insects can see the colour. It adds a question: does this aesthetic sense also exist in the lower forms? Why is it aesthetic? All kinds of interesting questions which the science knowledge only adds to the excitement, the mystery and the awe of a flower. It only adds. I don't understand how it subtracts.”

A Scanning Tunnelling Microscope, developed in 1981 by Gerd Binnig & Heinrich Rohrer of IBM Zurich, can allow us to 'see' surfaces at an atomic level. This technology can also enable manipulation of individual atoms. The analysis of the products of head-on collisions between atomic nuclei, accelerated via enormous magnets to near light-speeds within the Large Hadron Collider in CERN, enables us to infer structural features of the nucleus itself at an unbelievably small scale of one femtometre, that is 10^{-15} metres or a hundred-thousandth of the size of an atom. At the other extreme, measurements from the Planck space observatory operated by the European Space Agency enabled the creation an image in 2013 of the *entire Universe* as viewed from the Sun-Earth L_2 point, that is a

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[7] *Ode to the Flower.* Transcript of BBC interview with Richard Feynman, 1981.

point in space where the balance of gravity is such that the satellite will co-orbit with the Earth about the Sun and thus appear to be stationary. Planck mapped the cosmic background radiation at microwave and infra-red frequencies. Fascinatingly, matter and radiation are *not* uniformly distributed. These, and other experiments, show that the Universe appears to be expanding, and also that the Universe is estimated to be around 13.8 billion years old (three times the age of the Earth). Accounting for expansion we can therefore theoretically 'see' to a distance of up to 47 billion light years. In summary, scientific instruments allow us to observe structures on the scale of 10^{-15} to 10^{26} metres, that is a factor of ten magnification, forty one times.

Although we can only see via optical light, that is a range of colours from low frequency red to high frequency blue, instruments can extend this from radio signals of kilometre wavelengths, to microwaves of centimetre wavelength, to infra red, to ultra-violet, X-rays and gamma rays. The latter have wavelengths of sub-atomic dimensions. The responses of a sensor tailored to a particular variety of electromagnetic wave can always be numerically mapped to hues on a visible colour scale, and hence these 'false-colour' images can reveal fascinating and previously hidden insights. Infra-red radiometers aboard the Meteosat geostationary satellites allow us to track cloud patterns on a global scale, and hence make weather predictions during night as well as day; ultra-violet photography reveals a startling and often surprisingly patterned plant world as seen by many insects, and X-rays have a scope of vision that ranges from the bones and living tissue within our bodies, to the maelstrom of hot gases encircling a super-dense cosmological object such as a Black Hole. We can also 'see' sound by electronically recording the movement of a diaphragm in a microphone and then displaying this signal using a computer. The shape of the waveforms this process reveals is the key to understanding how animals communicate; measuring the depth of the ocean; understanding the geological internal structure of our planet; the nature and location of earthquakes; and the artificial synthesis of speech and musical effects.

Many authors of Mathematics books talk of *symmetry*. This is not just about clear visual presentation or the elegant typography inherent in Donald Knuth's TeX system. The concept of symmetry in Mathematics is as foundational to the subject as counting. It is essentially the idea that certain attributes remain the same under a *transformation*. There is a direct connection to Physics, which at root is a mathematical description of things in the world that we can quantify, based upon laws which state certain properties are conserved; i.e. remain the same. All the equations of Physics are essentially accountancy for a fixed quantity of mass, charge, energy, linear and angular momentum under a translation or rotation of the geometry associated with space and time. Some scientists such as Rowlands[8] suggest these fixed quantities must be exactly zero in order for Physics itself to be truly symmetric. I find the audacious simplicity of this idea incredibly beautiful.

As Eric Idle of *Monty Python* sang cheerfully in *Always Look on the Bright Side of Life:* "You come from nothing - you're going back to nothing. What have you lost? Nothing!"

The more you learn, the closer and further you look, the more beauty you will discover. The *Andromeda Galaxy*. The *Cat's Eye Nebula* in the constellation of Draco. The accretion stream between a Black Hole and a companion star. Jupiter's giant red spot. The Sun's magnetic field. A satellite image of a hurricane. The Karakorum viewed from an aeroplane window. Alpenglow of Makalu at dawn. Sunrise at the summit of Snowdon on a clear winter's day. The shape of a violin, mandolin or guitar. The human hand, the human eye, the human cell, the human mind.

I shall end with a final riposte to Keat's poem *Lamia*, which contains many delicious phrases that I have used throughout this lecture. I believe we do not destroy a rainbow when we un-weave it with our instruments of science. Instead we create a much richer and permanent rainbow *of the mind*; viewable from all angles; a system connecting our nearest star, via billions and billions of atmospheric water-molecule prisms, to our own eyes.

AF, August 2014.

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[8] *Zero to Infinity*, P. Rowlands, 2007