text & photos YD BAR-NESS

BEYOND COLOUR

Darker than black, brighter than white

Israel: Sedom in the Dead Sea area, a salt cave created by water erosion

Whiter than white in Sapporo, Japan

Topic Photo Agency/Corbis

Ali Kabas/Corbis

WHAT IS darker than black and what is brighter than white? What is longer than red, and what is shorter than violet? We are sensitive to the electromagnetic spectrum in fixed amounts and at fixed wavelengths. Our eyes have distinct limitations and we can only detect a narrow range of colours and a certain amount of light intensity. To experience these limits, and to go beyond them, we will visit two geographical extremes.

DARKER THAN BLACK

As we rappel down a rope into a cave's vertical entrance, the bright world diminishes to a circle of light above us. The montane forest above is sparse and meagre, but it is still a productive, photosynthesising ecology with patterns of green that defy classification. Moving into the depths of the Earth, we leave this world of vital energy behind.

Deep inside these chambers, formed by the slow chemical dissolution of water on calcium rock, there are strange ecosystems of blind residents and temporary visitors. We ourselves can be only temporary visitors, for these caves are inhospitable and challenging places.

Slowly, we reach the floor of the cave and land on a pile of sticks and leaves. These bits and pieces of the subalpine forest are the fuel that feeds this dark ecosystem; where there is no light, there are no green plants.

Illuminated only by the sphere of light from our helmet torches, we continue into the depths by squeezing through crevices, wading through streams and climbing over tumbled rocks. Accidents in caves can quickly turn into emergencies and the imagination recoils from the complexities required for a rescue.

We don't need to go far before the last photon of natural daylight has been left behind and we are travelling by our own light. The pools and drips of water reflect and shimmer, and the rays flash onto intricate crystal formations sculpted by slowly deposited limestone. Here, we stop and experience the darkest possible environment – we switch off our torches and we are in the dark.

Babies in the womb can detect sunlight through their mother's skin and some blind people can perceive changes in light. On a still night, the human eye can detect small traces of light from distant stars. But in a cave, there is nothing to see.

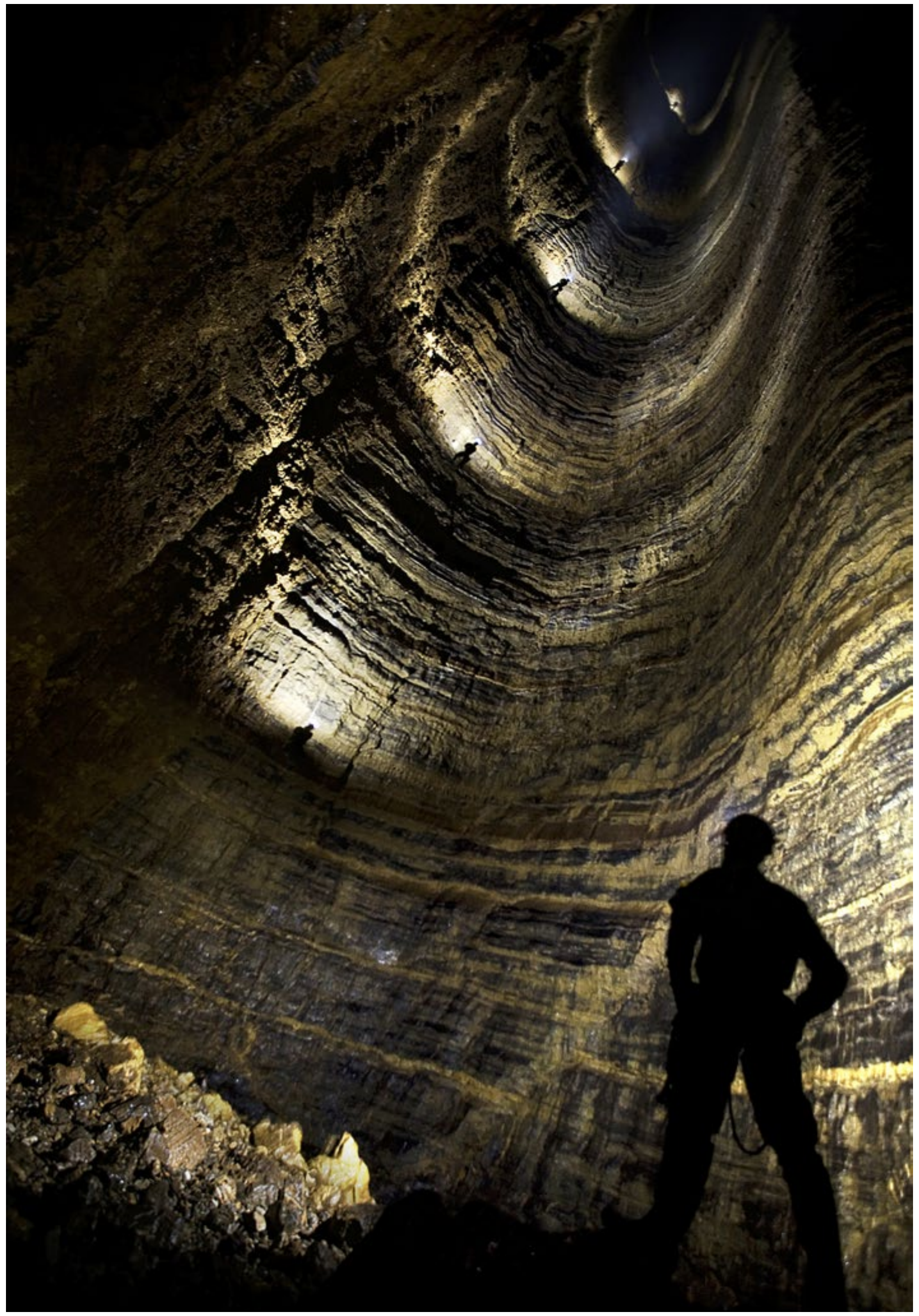
ELECTROMAGNETISM

What we can perceive as visible light is only a small portion of the entire electromagnetic spectrum. Energy exists in the universe in different levels, which can be classified by the length of its wave. The shorter wavelengths carry the most energy. Visible light spans the band between 380 and 760 nanometres. (A nanometre is one billionth of a metre.) We can subdivide this band into the familiar colours, from violet (shorter wavelength, higher frequency) to red (longer wavelength, lower frequency).

We can also place this band into position on the greater electromagnetic spectrum. At shorter wavelengths are colours we cannot see, the ultraviolet (UV). At lengths even shorter are the X-rays, used regularly in medical imaging, and gamma rays, used in astronomy, nuclear medicine and food sterilisation.

◄▲ Mzaar Kfardebian, Lebanon: A popular ski resort an hour from the capital, Beirut

► Wulong, Chongqing Province, China: One of the world's deepest underground shafts, Miao Keng is 506 metres deep and the descent takes about two hours. Miao Keng joins to another shaft plunging a further 500 metres into the rocky depths



Robbie Shone/Aurora Photos/Corbis

In the other direction, the longer wavelengths are the invisible infrared "colours", the microwaves, and radio waves, which we use, respectively, to cook food, transmit messages and interpret the universe around us.

The spectrum that we can detect with our eyes corresponds to the electromagnetic band that the sun radiates and which then reflects off of objects in our environment. Our eyes have evolved to take advantage of this source of information. Other creatures may have more or less ability to perceive wavelengths. For example, light penetrating underwater loses the longer, redder wavelengths as it goes deeper. Animals in this environment have no use for the ability to detect red. Flowers perceived in the ultraviolet display elaborate patterns for attracting pollinating insects. With the aid of recent technological innovations, we can begin to see the invisible "colours" longer than red and shorter than violet.

Topic Photo Agency/Corbis

◄ A cave in Byeonsanbando National Park, Buan-gun, Jeonbuk, Korea

►▲ Japan: A woman trudges through thick snow

Jeremy Woodhouse/Blend Images/Corbis

CAPTURING THE INFRARED

Underground in the dark, we carefully feel inside our rucksack for a special piece of equipment: a camera designed to capture infrared radiation. Many digital camera sensors can record non-visible wavelengths, but they are fitted with filters to remove this extraneous information. Our camera, however, works only in the infrared.

Objects radiating heat are also emitting infrared electromagnetism. As we look through the camera, we can see our own limbs and equipment glowing in outline. The software of the camera doesn't distinguish infrared wavelengths in the way we can distinguish colour. We are not seeing a rainbow of invisible colours. Rather, it shows us visible colours based on mathematical relationship with the heat energy radiated: it shows hotter objects as red and cooler objects as blue. The cave itself is a cool place and as we scan the chamber, we can see the slight heat marks of our footprints.

A small spot of light is moving purposefully along the clay of the cavern floor. It is a living creature – a blind cave cricket. While much cooler than any warm-blooded mammal, it is still producing a small spark of heat.

The electromagnetic spectrum

shortest wavelength, highest frequency, highest energy

GAMMA-RAYS
Wavelengths **the size of an atomic nucleus**

X-RAYS
Wavelengths **the size of an atom**

ULTRAVIOLET
Wavelengths **the size of a virus**

VISIBLE (VIOLET TO RED)
Wavelengths **smaller than a bacterium, larger than a virus**

INFRARED
Wavelengths **the size of a biological cell**

MICROWAVE AND RADAR
Wavelengths **the size of a pinhead or a honeybee**

RADIO
Wavelengths **the size of a human, a city block, and longer**

longest wavelength, lowest frequency, lowest energy

It feels its way carefully with long and sensitive antennae, searching for a bit of forest biomass that has washed its way into the cave. In this completely dark environment, the species has evolved into an eyeless form. So far from the green plants of the surface, there is little energy available for cave animals. This is a rare and delicate creature. Its body heat – far cooler than our own – is radiating in the infrared, at wavelengths too long for our eyes to detect naturally.

Capturing a thermal photograph of this tenacious inhabitant of a marginal environment, we turn back towards the daylight world. Before we can return to the forest, we must navigate our way past rock fall and constriction to the rope and inch our way up its slender length to the sunlight of the day. Unlike the cave cricket, we have no antennae to guide us – we are completely reliant on our electric torches.

BRIGHTER THAN WHITE

Safely on the surface, we are surrounded by the cheerful green of the montane trees and the deep blue of the clear sky. Our expedition continues upwards onto the slopes of the mountain, reaching a glittering white snowfield. Here, we are experiencing too much visible light: our eyes are dazzled by the reflected sunlight and we must put on dark sunglasses to make our way. Furthermore, in these higher altitudes, the atmosphere provides less protective filtration from the sun's ultraviolet radiation. Both are dangerous.

White light is the combination of wavelengths of the visible colours and the human eye can only stand a limited amount of its energy before temporary or permanent blindness results. Welders, solar scientists and observers of lightning must all take care to protect their eyes, and those unfortunate victims witnessing an atomic weapon blast may receive such intense light bombardment that they are permanently blinded.

Humans in snow-covered regions will instinctively squint their eyes and shield their faces with their hands. Before the invention of darkened glass and plastic lenses, an opaque blindfold with a narrow slit would serve to block the snow's bright reflections. However, some dark plastic glasses only filter the visible light, and not the invisible ultraviolet. Wearing these lower-quality glasses can be dangerous, as the pupil expands in the darkened environment, simultaneously letting in greater levels of ultraviolet radiation.

Topic Photo Agency/Corbis

Kaare Iverson/Aurora Open/Corbis

► Hampi, India: Traversing a sloping granite edge

◄▼ South Korea: A lonesome tent on a frozen lake in Gwangju, Gyeonggi Province

SHORTER THAN VIOLET

The shorter wavelength, invisible rays – ultraviolet, X and gamma – are especially dangerous to living organisms. The chemical molecules containing genetic information, DNA, are disrupted by these high electromagnetic energies. High levels of exposure to ultraviolet radiation can cause sunburn, blistering or even trigger cancer-causing cell mutations. While X-rays and gamma-rays are negligible in the natural world, we are often exposed to ultraviolet during the daytime.

Much of this UV radiation is blocked by naturally occurring atmospheric oxygen and nitrogen or by ocean water. The evolution of dry-land life on Earth has been chronologically linked to the development of these gases in the ancient atmosphere: before their presence, the chemical transmission of genetic information could not be conducted properly without UV disruption.

At higher altitudes, this atmospheric protection is lessened in the thinner air. For the mountaineer, this means sunblock, long sleeves and trousers, and broad-brimmed hats. The reflecting snow makes the situation worse. It bounces the radiation upwards from below and it is not uncommon to find sunburn in unexpected places – nostrils, chins and ears. The UV radiation also damages the chemical bonds of plastics and dyes. Equipment left in the mountain sunlight will have its colours fade and its plastic components slowly disintegrate.

The damaging effects of ultraviolet are a major public health concern for people at all altitudes and of all skin colours. The World Health Organization reports that a third of all detected cancers are skin cancers. Many of these will be lethal. Tragically, many of them were triggered or hastened by cosmetic sun tanning, where high levels of UV radiation are sought, either indoors on tanning beds or outdoors on sunny days.

IN THE MIDDLE

Looking down the mountain to the cave entrance, we can't help but think of how hostile these two environments are. Humans are happiest somewhere in the middle: not too bright and not too dark.

Our eyes are the products of evolution in an environment with intermediate intensities of light, within a specific range of wavelengths. Too much energy and we are dazzled. Too little and we are blinded. Wavelengths too short or too long and the light is simply invisible. With the aid of technology and a bit of knowledge, we can detect the presence of light outside of these limits. There are colours longer than red, shorter than violet. There are shades brighter than white and darker than black. AG

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