Teacher's Notes

Overview

The Questacon travelling exhibition *Colour—See the World in a New Light* is targeted at visitors aged 5 to 12 years, but has experiences suitable for a wide range of ages and abilities.

There are 25 exhibits in the *Colour* suite including museum-style collections, colour illusions, and exploration-based interactive experiences.

Themes

The *Colour* exhibition covers themes and ideas from a range of scientific disciplines.

Physical Sciences

- The behaviour of light including absorption, reflection, refraction, and diffraction;
- Properties of materials including chemical composition and pigmentation;
- Dispersion of light and light spectra;
- Polarisation of light; and
- Luminescence including incandescence and fluorescence.

Biological Sciences

- Colour vision in animals and humans;
- Colour vision deficiency (colour blindness); and
- Adaptive colour including camouflage and signalling.

Social and Psychological Sciences

- Symbolic colours, e.g. traffic lights;
- Cultural colour significance;
- Colour perception including synaesthesia; and
- Colour illusions.

Technology

- Additive and subtractive colour spaces;
- Artificial light sources and colour temperature;
- Digital display technology including quantum dots and colour mixing; and
- False colour and using colour to represent data.

Support Questions

Use the following questions to start discussions around the exhibition topics. Use the questions to strengthen the educational experience of students, and to help connect exhibition concepts to their everyday lives.

- What is colour?
- How do we see colour?
- How do we use colour?
- How do other animals see colour?
- How do cameras sense colour?
- Do we see colours the same as each other? How could we know?
- Why do people sometimes disagree about colour?
- What would it be like to see colours differently?
- Why do some things seem to change colour in certain situations?
- Where does colour come from?
- Is white a colour? Why or why not?
- Is gold a colour? How is it different from yellow?
- Why are different materials different colours?
- What can we learn about an object by looking at its colour?
- Why are animals such as birds and insects colourful?
- What do animals use colour for?
- How do colours influence our choices?
- How do colours influence our behaviour?

Curriculum Links

The *Colour* exhibition has links to specific National Curriculum outcomes from Foundation Year through to Year 5, as well as broad conceptual links to the National Curriculum *Science Enquiry Skill* strand.

Strands

Science Inquiry Skills

Visitors are encouraged to engage in behaviours from the *Science Enquiry Skills* strands such as: pose and respond to questions; make observations; and compare observations.

Foundation Year Outcomes

Science Understanding

Chemical Sciences

ACSSU003 Objects are made of materials that have observable properties.

Science Inquiry Skills

Questioning and predicting

ACSIS014 Pose and respond to questions about familiar objects and events.

Planning and conducting

ACSIS011 Participate in guided investigations and make observations using the senses.

Communicating

ACSIS012 Share observations and ideas.

Year 1

Science Understanding

Physical Sciences

ACSSU020 Light and sound are produced by a range of sources and can be sensed.

Biological Sciences

ACSSU211 Living things live in different places where their needs are met.

Science Inquiry Skills

Questioning and predicting

ACSIS024 Pose and respond to questions, and make predictions about familiar objects and events.

Planning and conducting

ACSIS025 Participate in guided investigations to explore and answer questions.

Evaluating

ACSIS213 Compare observations with those of others.

Year 2

Science Understanding

Biological Sciences

ACSSU030 Living things can grow, change and have offspring similar to themselves.

Science Inquiry Skills

Questioning and predicting

ACSIS037 Pose and respond to questions, and make predictions about familiar objects and events.

Evaluating

ACSIS041 Compare observations with those of others.

Year 3

Science Inquiry Skills

Planning and conducting

ACSIS054 With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment.

Year 4

Science Understanding

Biological Sciences

ACSSU073 Living things depend on each other and the environment to survive.

Chemical Science

ACSSU074 Natural and processed materials have a range of physical properties that can influence their use.

Science Inquiry Skills

Planning and Conducting

ACSIS065 With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment.

Year 5

Science Understanding

Biological Sciences

ACSSU043 Living things have structural features and adaptations that help them to survive in their environment.

Physical Sciences

ACSSU080 Light from a source forms shadows and can be absorbed, reflected and refracted.

Exhibit Overviews

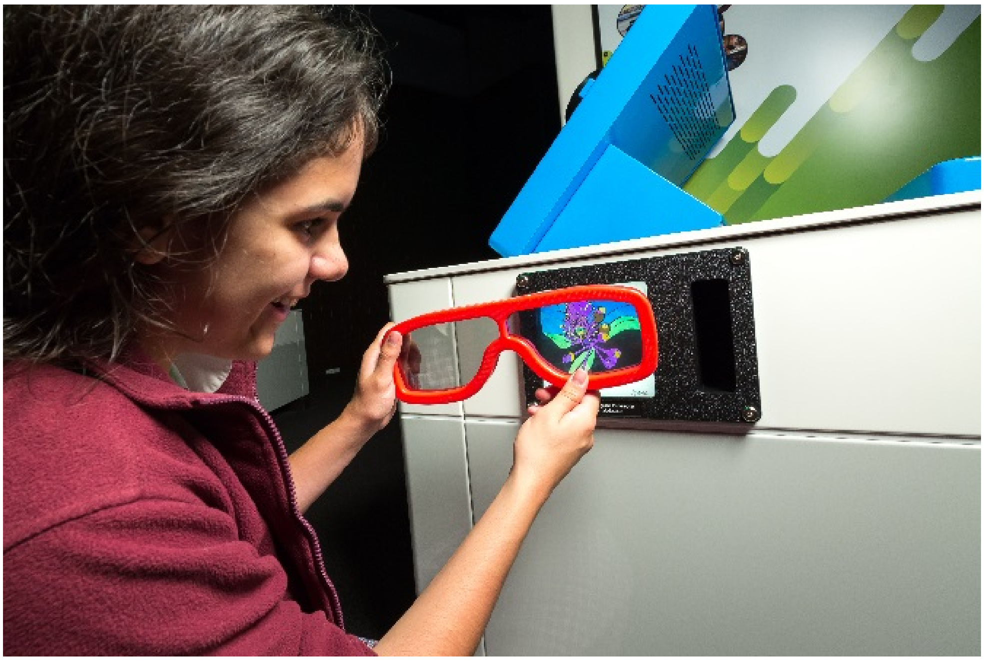
Exhibit Name	Exhibit Description	Key Themes
Kids' Trail	Visitors look through the provided polarising glasses at the artworks to reveal the colours hidden in plain sight. The colours are created by polarising film, which polarises certain colours of light. The glasses show which colours have been polarised to align with the film in the glasses.	*Polarisation, light as a wave*
What is White	Visitors look through the glasses and see the light split into its component colours. The dispersion of light is created by a diffraction grating – a series of fine grooves in a clear film.	*Dispersion, spectrums (spectra), diffraction, rainbows*
Quantum Colour	Visitors turn the wheel and watch the solutions in the test tubes glow different colours. The solutions contain nanomaterials called quantum dots which change colour depending on their size.	*Fluorescence, technology, nanomaterials, quantum effects*
Fluoresce	Visitors turn ultraviolet lights on and watch a collection of otherwise dull minerals become spectacular! The minerals fluoresce under ultraviolet light. The display also contains human-made pigments and objects that fluoresce, including highlighters and Australian passports.	*Fluorescence, mineralogy, wavelength of light, light as energy, atomic shell model of the atom*
Colour Temperature	Visitors select a colour temperature and notice how the colours in a doll's house scene are affected.	*Colour temperature, incandescence, distribution of colours*
Reflected Light	Visitors look through a spectroscope at colour swatches to see which colours of light each pigment absorbs or reflects.	*Pigment, spectrums (spectra), diffraction, distribution of colours*
Coloured Reflections	Visitors turn the wheel to create a bubble, then experiment with combinations of red, green, and blue light to see where each reflects and how they mix.	*Interference, colour mixing, structural colour*
The Room of Missing Colours	Visitors in an immersive room observe that the colours of objects change with the colour of the light. They use the provided torches to reveal the true colours.	*Pigment, monochromatic light, absorption, reflection, colour perception*
Creating Colour	Visitors look at a display case filled with colourful insect specimens, and at how they create their colours. This exhibit is a collaboration between the Australian National Insect Collection, CSIRO, and Questacon.	*Pigment, structural colour, dispersion, scattering, polarisation, biology, nature, interference, iridescence,*

Exhibit Name	Exhibit Description	Key Themes
See Colours Combine	Visitors slide filters into provided slots to remove colour from a white light box. They use buttons to add colour to a dark box.	*Dispersion, diffraction, colour mixing, additive colour, subtractive colour, filters, spectra (spectrums)*
Mixing Pixels	Visitors move coloured spots on a touch screen under a magnifying glasses to see the pixels up close. They use a phone or tablet screen with the microscope to see the pixels up close.	*Pixels, additive colour mixing, technology, microscopes*
Colouring with Light	Visitors play with a digital colouring game. They choose a scene, then use the on-screen tools to add or subtract light directly to the 'canvas'.	*Pixels, additive colour mixing, technology, colouring in*
Colours of the Earth	Visitors look at a display case filled with colourful mineral specimens. This exhibit is a collaboration between the Geoscience Australia and Questacon.	*Pigments, dispersion, diffraction, interference, thin-film interference, chemistry, geology, mineralogy, gemmology, absorption, reflection*
Stop & Go	Visitors run on the spot to move their character up the screen. When the prompt is red, stop! When the prompt is green, go! Can they ignore the written instruction and respond only to the colour?	*Psychology, colour symbolism, traffic symbols, Stroop effect*
The Taste of Colour	Visitors watch videos exploring the experiences of people with synaesthesia—people with experiences such as seeing colours when hearing certain words.	*Psychology, senses, personal experience, video*
Colour In Action	Visitors look at a display case filled with colourful insect specimens and how the use their colours. This exhibit is a collaboration between the Australian National Insect Collection, CSIRO, and Questacon.	*Camouflage, defence, warning colours/aposematism, mimicry, biology, nature*
Colourful Language	Visitors select a colour in response to the word prompt on screen. They view statistics about what others chose.	*Psychology, language, culture, colour associations*
Frequencies	Visitors touch a colour on the screen and listen to the sound created.	*Frequencies, wavelength, sound, light, wave motion, amplitude*
Galactic Colour	Visitors explore an interactive image of the night sky, and change between images of different spectral regions such as x-rays and radio waves.	*False colour, spectrum, electromagnetic spectrum, x-rays, gamma rays, infrared, ultraviolet, radio waves, digital imaging, astronomy*

Exhibit Name	Exhibit Description	Key Themes
Colour Blindness Simulators	Visitors see the world as a colour vision deficient person would, or use a colour-correcting lens to compensate for colour vision deficiency.	*Colour blindness, colour vision deficiency, red-green colour blindness, blue-yellow colour blindness, colour perception*
Ultraviolet Vision	Visitors use an ultraviolet camera that shows pigments that are invisible to our eyes.	*Pigment, ultraviolet light, human vision, animal vision, nature, biology*
Your Yellow	Visitors turn a wheel until the colour of a true yellow light source seems to match a mixture of green and red light. This shows differences between individual's colour perception including colour vision deficiency (colour blindness).	*Colour vision, colour vision deficiency, colour mixing, colour perception*
How Do You Look?	Visitors take high resolution images of their eyes, noting common features and colours.	*Anatomy, photography, eyes*
Impossible Colour	Three colour illusions take advantage of the workings of colour-sensitive cells in our eyes to produce unexpected colour effects.	*Colour vision, colour perception, visual illusions*
The Eyes Are All Grey	A colour illusion where three sets of grey eyes all appear to be coloured differently. This experience uses an effect known as colour constancy.	*Colour constancy, white balance, complementary colours, visual illusions, colour vision, colour perception*

Exhibit Details

Kids' Trail



Polarised light artworks of Australian plants and animals are hidden on other exhibits. Polarising glasses reveal colour in the images.

How to Use It

Look through the provided polarising glasses at the artworks to reveal the colours hidden in plain sight.

What Science Tells Us

The artworks are made from varying thicknesses of cellulose film. A polarising film sits between the lightbox and the artwork, so the light coming through is highly polarised. The cellulose film is birefringent**:** colours in the white light are split between two polarisations depending on how thick the cellulose film is. This means that some colours are polarised one way and the remainder are polarised the other way. Our eyes cannot see polarisation so without the glasses we only see the combined white light.

The polarising glasses only allow through the colours that are polarised in alignment with the filter. This lets some colours through and absorbs others. Each colour in the artwork is a different thickness or orientation of cellulose film.

Things to Try or Ask

- Do your sunglasses do the same thing that the provided glasses do?
- What happens when you view the artwork with the glasses turned sideways?

Finding the Science in Your World

The blue sky is polarised. Tilting your head from side to side while wearing polarised glasses and looking at the sky will change its colour from light to dark blue. Reflections from water are also polarised, and polarised glasses help to filter out this glare.

Themed Area—Coloured Light

Colour begins with light, and all light has colour. In this context, the word 'colour' refers to the wavelength of, or distributions of wavelengths within, a light source. Exhibits in this area explore light and light energy.

What is White

White light can be split to create a rainbow.

How to Use It

Look through the glasses and see the light split into its component colours.

What Science Tells Us

A diffraction grating in the glasses creates interference patterns. The grating contains many fine grooves, which cause light waves to spread out and overlap. At certain angles the colours overlap in just the right way to become brighter. This angle differs only slightly for light of different colours, resulting in dispersion: each colour appears bright in sequence, creating a spectrum.

Things to Try or Ask

- How do other light sources look through the glasses? Try ceiling lights in the exhibition space or the flash on your mobile phone.
- Is white a colour?
    - Why or why not (what definition of 'colour' is being used)?

Finding the Science in Your World

Dispersion can be seen when rain splits white sunlight into a rainbow. Most colour in the world around us starts as white light from the sun.

Quantum Colour

Crystals of the same material change colour depending on the crystal size.

How to Use It
Turn the wheel and watch the solutions in the test tubes glow different colours.

What Science Tells Us
Cadmium selenide is a semiconductor, with unusual electrical and optical properties. Large crystals scatter light like a metal, appearing shiny. In powder form, scattered light from the fine grains is quickly absorbed by nearby grains and appears black appearance.

When the crystals are very tiny, they fluoresce under ultraviolet (UV) light. Due to certain quantum effects, the colour of this fluorescence changes with the size of the crystal—from red for larger crystals to blue for smaller ones.

Things to Try or Ask
- Are there other things that change colour with size?
- Would you expect a green pencil to turn blue when broken in half?

Finding the Science in Your World
Nanomaterials such as these are on the cutting edge of technology. Some manufacturers are including quantum dots in their newest television technologies for their superior ability to produce colour.

Fluoresce

A collaboration between Questacon and Geoscience Australia showing fluorescent minerals and everyday objects.

How to Use It

Turn the ultraviolet lights on or off, and watch the dull minerals become spectacular!

What Science Tells Us

Fluorescence is the emission of light by a substance that has absorbed light. The absorbed light forces electrons into unstable higher energy orbits. They quickly relax to their low energy 'ground' states, releasing excess energy as light in the process. The particular chemical structures in the minerals determines which wavelengths of light are most easily absorbed, and which are emitted when they relax.

Some everyday objects also fluoresce. Daylight-fluorescing pigments are used to give objects such as toys or safety equipment a vibrant appearance. UV-fluorescing pigments are naturally present in substances such as olive oil and tonic water, and are added to secure documents such as drivers' licenses and passports to discourage counterfeiting.

Things to Try or Ask

- Where else might you find fluorescing pigments in your everyday life?

Finding the Science in Your World

Your washing powder contains fluorescing pigments called optical brighteners. These fluoresce blue in daylight. This counteracts the yellowing of white clothes as they age, keeping your 'whites whiter' for longer.

Colour Temperature

Home lighting comes in different colour temperatures, which change how colours appear.

How to Use It

Select a colour temperature and notice how the colours in the scene are affected.

What Science Tells Us

All objects emit light due to temperature. For room temperature objects, the light they emit is in the infrared portion of the spectrum. Very hot objects glow red, orange, yellow and white hot. This change of colour affects how surfaces appear.

Things to Try or Ask

- How do coloured objects in the scene change?
- Which colours change the most?

Finding the Science in Your World

When you buy lightbulbs, they have a ‘correlated colour temperature’ (CCT). Lower CCTs are associated with redder ‘warm’ light, while higher CCTs are associated with bluer ‘cool’ light. These will have an effect on the colours in any room you put them in.

Reflected Light

Most surfaces are coloured by absorbing some colours of light and reflecting others.

How to Use It

Look through the spectroscope to see which colours of light each pigment absorbs or reflects.

What Science Tells Us

The spectroscope contains a diffraction grating which splits light up into a rainbow. The printed backboard contains some common colours: red, green, blue, cyan, magenta, yellow, and white. The light reflected from these panels enters the spectroscope and diffracts, resulting in a spectrum that shows which colours have been reflected and which have been absorbed.

Things to Try or Ask

- What colours would you expect a black surface to reflect? What about a grey surface?
- How do other objects or colours around you look?

Finding the Science in Your World

The objects around you all behave in a similar way to the coloured stripes in this exhibit—we see the combined colours that they reflect.

Themed Area—Changing Colours

Colour perception is useful because it allows animals to distinguish and differentiate objects and materials in their environments. The behaviour of each wavelength (colour) of light is unique, meaning that they interact with matter in different ways. Each wavelength bends, scatters, transmits and is absorbed differently. This area in the exhibition explores some of the mechanisms by which colours can change and mix.

Coloured Reflections

Bubble films reflect different colours depending on how thick they are.

How to Use It

Turn the wheel to create a bubble, then experiment with combinations of red, green, and blue light to see where each reflects and how they mix.

What Science Tells Us

Bubble films comprise three layers: a layer of water sandwiched between two layers of detergent. The total thickness of this sandwich averages only a few micrometres (millionths of a metre). Light reflecting from the front and back surfaces can undergo interference. Depending on how the reflections line up, some colours of light can be reflected and some cannot.

When the thickness of the film is odd-quarter-multiples (¼, ¾, 1¼, 1¾…) of a given wavelength (colour) of light, the two reflected waves line up such that the crest of one wave meets the trough of another. These are said to be out of phase. These waves undergo destructive interference, and that wavelength of light cannot reflect in that part of the bubble.

When the thickness of the film is half-multiples (½, 1, 1½…) of a given wavelength of light, the two reflected waves line up so that the two crests meet each other. These are said to be in phase. These waves undergo constructive interference and that part of the bubble reflects twice as much light of that colour as normal.

This happens for different colours in different parts of the bubble. By pressing the buttons in the exhibit, you can see how as the bubble changes thickness (thin near the top, thick near the base), each colour cycles through reflecting and not reflecting in turn. When white light is present, the coloured reflections overlap with each other, mixing to create the secondary colours of light; cyan, magenta and yellow.

Finding the Science in Your World

Thin films like this are also responsible for colour in many insects and minerals, and in a film of oil or diesel on water.

The Room of Missing Colours

A room is lit by a single colour of light, changing the appearance of the objects within

How to Use It

Observe the colours of objects in the room change with the light. Use the provided torches to reveal the true colours.

What Science Tells Us

This room is lit by three colours of monochromatic light. Colour is generally useful to us as it allows us to tell objects apart that might otherwise be similar. In normal white light, the multiple colours of light create a wide range of possible appearances to the human eye.

When only one colour of light is present the ability to tell objects apart by colour is much more limited. If an object absorbs that particular colour, it will appear dark. If it reflects or transmits that colour it will appear light or clear. This creates an environment where everything seems to be shades of black, white or grey.

Things to Ask or Try

- How do the coloured sweets change under each colour of light?
  - How do the coloured filters in some of the jars behave?
- How does your clothing behave in the room?

Finding the Science in Your World

Many streetlights are monochromatic: sodium lamps that emit only one specific colour of yellow-orange light. Take notice next time you are around them of how colours appear.

Creating Colour

A collaboration between the Australian National Insect Collection, CSIRO, and Questacon, showcasing mainly Australian insects that use a wide variety of methods to create their colour.

What Science Tells Us

Insects create their colour with a wide variety of mechanisms.

Reds, yellows, oranges and browns in insects tend to be created by pigments, which are chemical substances that absorb light. Greens, blues and purples tend to be structural in nature, and arise from the interaction of light with microstructures in the insects' wings, elytra, carapaces or scales.

Tyndall scattering is an unusual mechanism for the creation of colour in insects, and is shown through three dragonfly specimens. Fine particles scatter blue light from the environment more than green light, and green light more than red light. This scattering includes backscattering, away from the insect and towards an observer. The resulting mix of scattered colours we see as a pale blue. This is the same type of scattering that causes the blue colour in human eyes, and is similar (but not identical) to the scattering that gives the sky its colour.

Some of the specimens shown circularly polarise the light. This is a special type of polarisation also used in 3D cinema. A special circularly polarising filter filters out the colour from these specimens, while their reflection in a mirror remains colourful.

Things to Try or Ask

- Do you recognise any of the insects in the display?
- Do you have a favourite insect? How do you think it creates its colour?

Finding the Science in Your World

A historically popular food colouring, cochineal red, comes from the pigment in ground-up cochineal bugs. Australia's attempt to produce cochineal red in commercial quantities led to the introduction of the prickly pear cactus as food stock. The population of the cactus quickly went out of control, and it is now considered an invasive species.

See Colours Combine

See two ways of mixing colours, and how each affects the spectrum of light.

How to Use It

Slide filters into the slots to remove colour from a white light box. Use buttons to add colour to a dark box.

What Science Tells Us

Human eyes typically have three types of colour receptor: ones most sensitive to long wavelengths (red light); ones most sensitive to medium wavelengths (green light); and ones most sensitive to short wavelengths (blue light). Both additive and subtractive colour mixing control how much light falls on each of these receptor types, but from opposing starting points.

Additive colour mixing simply adds a little of each colour—red, green or blue—to stimulate each receptor type in just the right way to create a certain mix.

Subtractive colour removes a little of each colour—red, green or blue—from white light so that what is left over stimulates each receptor type in just the right way. Removing red light results in a cyan appearance, so pigments that absorb red light appear cyan in colour. Removing green light results in magenta, and removing blue light results in yellow.

Things to Try or Ask

- What happens if you place the filters over the 'additive' lights and turn them on?
- What happens if you place the filters over a phone or tablet screen?

Finding the Science in Your World

Your printer mixes colour the same way as the filters – with yellow, cyan, and magenta inks. Your TV and mobile phone screens mix colour the same way as the lights, with red, green, and blue pixels.

Mixing Pixels

See pixels turn on and off to create colour.

How to Use It

Slide coloured spots under the magnifying glasses to see the pixels up close. Use your phone or tablet screen with the microscope to see the pixels up close.

What Science Tells Us

Human eyes typically have three types of colour receptor: ones most sensitive to long wavelengths (red light); ones most sensitive to medium wavelengths (green light); and ones most sensitive to short wavelengths (blue light).

Additive colour mixing simply adds a little of each colour; red, green or blue, to stimulate each receptor type in just the right way to create a certain mix.

Things to Try or Ask

- Do screens from different manufacturers use the same colours and arrangements of pixels?

Finding the Science in Your World

All colour screens that emit light mix colour additively: they start with black, then add measured amounts of red, green and blue light to achieve a desired mix.

Colouring with Light

Colour a scene by turning red, green, and blue pixels on and off.

How to Use It

Choose a scene, then use the on-screen tools to add or subtract light directly to the ‘canvas’.

What Science Tells Us

Human eyes typically have three types of colour receptor: ones most sensitive to long wavelengths (red light); ones most sensitive to medium wavelengths (green light); and ones most sensitive to short wavelengths (blue light).

Additive colour mixing simply adds a little of each colour; red, green or blue, to stimulate each receptor type in just the right way to create a certain mix.

Things to Try or Ask

- What happens when you create a triangle pattern by adding a spot of each colour at the corners that overlap in the centre?
- If you create a white area by adding red, green, and blue, what happens when you create a triangle pattern by *removing* a spot of each colour at the corners overlapping in the centre?

Finding the Science in Your World

All colour screens that emit light mix colour additively: they start with black, then add measured amounts of red, green and blue light to achieve a desired mix.

Colours of the Earth

A collaboration between Geoscience Australia and Questacon, showing the various ways that minerals take colour.

What Science Tells Us

Clear gems such as diamond and cubic zirconia disperse light like a prism. Light that meets these gems at an angle bends, and each colour bends a different amount. This causes dispersion—the colours split into a spectrum, like a rainbow. The gem is often cut to maximise the number of internal reflections, which also maximises the dispersion.

Thin layers of metal oxide on the surfaces of minerals such as bornite (also called peacock ore) and bismuth cause the same type of interference—and colours—as found in the surface of a bubble.

Gems such as opal cause an optical effect called diffraction - when light meets the edge of an object, the waves spread out. This can be seen in the soft edges of shadows that are far away from a light source. When many 'edges' are present in a very ordered fashion—such as in the tiny array of silica spheres in an opal—diffraction can combine with interference to create colourful effects.

The remaining minerals are coloured because their chemical structure allows them to absorb some colours of light, and to reflect or transmit others. The absorbed light energy is taken up by electrons in the atoms of the mineral. Different colours of light have different amounts of energy, and can only be absorbed by electrons in certain configurations.

The electrons from certain metal ions are responsible for much of the colour in minerals—particularly copper, iron, manganese, vanadium, chromium, cobalt, nickel and titanium. These electrons are frequently in a configuration able to absorb some colours of light and not others.

Things to Try or Ask

- Which minerals have you heard of or seen before?
- Do you have a favourite mineral or gemstone?
    - How do you think it creates its colour?

Finding the Science in Your World

Minerals such as gold and silver are valuable, and have been historically been used as currency and in jewellery around the world. In Australia, ochre of varying colours has been used in indigenous artwork for tens of thousands of years.

Themed Area—Making Sense of Colour

For colour to be useful to an organism, it must ultimately be perceived as information that influences behaviour or decision making. Colour is extremely important in the plant and animal kingdoms for essential processes like signalling, attracting mates or pollinators, hiding (e.g. camouflage) and finding food. Colour affects our own lives in a myriad of ways, from understanding traffic lights and the expected flavour of ice-cream, to cultural iconography and emotional signalling. This part of the exhibition explores the subjective experience of colour, and the effect it has on us and other animals.

Stop & Go

Play a racing game with a twist.

How to Use It

Run on the spot to move your character up the screen. When the prompt is red, stop! When the prompt is green, go! Can you ignore the written instruction and respond only to the colour?

What Science Tells Us

The Stroop effect is interference effect—tasks competing for attention cause a delay in reaction time as the brain recruits additional resources to deal with the conflict.

This effect is particularly noticeable when under pressure, such as when playing a competitive game.

A few theories have been proposed for exactly how the Stroop effect works: it may be that the brain is naturally quicker at reading words than recognising colours; that recognising colours requires more focus; that reading is somewhat automatic, and therefore reduces the amount of brainpower available for colour recognition; or that for most people the pathways for reading are stronger (and therefore faster) than those for naming colours due to practise.

Finding the Science in Your World

The colour of instructions is often carefully chosen by designers to match expectations. Green ticks and red crosses are preferred over red ticks and green crosses because it is easier for people to process the message when it aligns with previous experiences.

The Taste of Colour

Watch videos exploring the experiences of people with **synaesthesia**—people with experiences such as seeing colours when hearing certain words.

How to Use It

Select a video to watch the story.

What Science Tells Us

Historically, the experiences of synaesthetes have been met with scepticism. The first case notes reporting on synaesthesia in the scientific literature are by Francis Galton in the 1800s. Some scientists thought that the subjects were perhaps just overly imaginative, and questioned whether the reports were of genuine sensory experiences.

In the last few decades, new technologies such as functional magnetic resonance imaging (FMRI) and diffusion tensor imaging (DTI) have allowed researchers to determine that there are distinct differences (neural correlates) in both brain activity and brain connectivity between synaesthetes and non-synaesthetes.

Synaesthesia is not thought of as a disorder or disease; it is a condition that differentiates individuals, but is not something that requires treatment.

Things to Try or Ask

- Do any you experience colour associated with numbers, letters, days of the week, personalities, music, months, etc.?
- Can you think of phrases that are somewhat synaesthetic?

o Examples might include a sharp taste, a loud shirt, feeling blue, or seeing red.

Colour In Action

A collaboration between the Australian National Insect Collection, CSIRO, and Questacon, that explores the ways that insects use colour.

What Science Tells Us

Insects mainly use colour for two reasons: camouflage and warning colouration (aposematism). Insects, unlike birds, do not generally use colour for attracting mates (sexual display). The visual system of most insects is too primitive, with poor colour differentiation and distance vision.

This means that most of the brightly coloured insects we see are either distasteful or dangerous to eat, or are pretending to be distasteful or dangerous to eat (mimicry). ‘Dangerous to eat’ in this instance includes both insects that are toxic to ingest, or that vigorously defend themselves, such as the bees and wasps in this display.

Things to Try or Ask

- What colourful insects have you seen?
    - What do you think they were using the colour for?
- How many insects do you see that are camouflaged?
    - How many have you not seen because they were camouflaged?

Finding the Science in Your World

Humans use warning colouration in danger and hazard signage. Bright reds, yellows and oranges are applied to signs to warn people of hazards in the environment.

Colourful Language

Can ideas have colour? See what you and others think!

How to Use It

Select a colour in response to the word prompt on screen. View statistics about what you and others chose.

What Science Tells Us

The colour words available in a language determine largely how native speakers of that language identify colours. For example, in languages that lack a word for orange, the colour that we recognise as 'orange' will be identified as either a shade of yellow or of red. This is believed to show that colour perception and identification more a cultural phenomenon than a neurological one.

The cultural links between colour and emotions or other ideas are just that: cultural. Little exists in the scientific literature to explain why this occurs, although some speculate that synaesthesia may play some role in the origins.

Things to Try or Ask

- Why do some words have clear colour associations?
- Why do some words not have clear colour associations?
- Can you think of other words or ideas that have strong colour associations?

Finding the Science in Your World

Designers often choose colours that have strong cultural associations with certain ideas. Ecologically-minded brands often have green logos; medical and dental products often feature the colour white; and luxury products often include the colours black or gold.

Frequencies

A computer maps sound onto the visible spectrum, creating an audible tone that varies depending on what colour is touched.

How to Use It

Touch a colour on the screen and listen to the sound created.

What Science Tells Us

While sound and light are both forms of energy that behave as waves, the waves behave quite differently. Sound waves are compression waves: the air compresses and expands rhythmically as energy moves through it. Electromagnetic waves, such as light, behave like waves or ripples moving along a string.

We can detect both forms of energy (sound and light) with our senses, and changing the properties of the wave corresponds with a change in perceptual experience. Larger waves are experienced as louder sounds or brighter lights; longer and shorter waves are experienced as notes of different pitches, or light of different colours; and single wavelengths are perceived differently to many wavelengths together.

Finding the Science in Your World

Our ability to tell things apart by sight or sound depends on our senses' abilities to tell the differences between large and small; long and short; and simple and complex waves.

Themed Area—Seeing Colour

The retina in an eye and a sensor array in a camera are both detectors that perceive colour. Different detectors have varying sensitivities to colour. This means that colour perception can vary greatly between individuals, species, and technologies. This area of the exhibition explores the functions and variation of some of these detectors.

Galactic Colour

Explore an interactive image of the night sky, and change between images of different spectral regions such as x-ray and radio waves.

How to Use It

Tap to select a spectral region; pinch and drag to zoom and pan; and turn labels on or off to show constellations and other astronomical objects.

What Science Tells Us

Human eyes are only sensitive to a small range of wavelengths of electromagnetic (EM) radiation (light). These correspond strongly with the most intense range of wavelengths present in the sunlight that falls to Earth.

Certain scientific instruments are capable of capturing and measuring wavelengths that we cannot see. In the same way human eyes use colour to learn about the properties of the world around us (ripe fruit vs unripe, time of day, fresh vs dry grass), this data can be used to understand the universe around us more deeply.

Colour can be used to present data in a way that allows quick visual differentiation of regions. Several techniques for colouring data in this way exist, many of which are represented in the exhibit.

Things to Try or Ask

Where else is false colour used?

Can you find features in one spectral region that are not visible in others?

Compare one part of the night sky across several spectral regions. What changes do you observe?

Finding the Science in Your World

False colour is used in many places to represent data so it is easy to see. From rainfall radars to satellite imagery, thermal cameras, and population maps, colour coded data is all around us.

Colour Blindness Simulators

See the world as a colour vision deficient person would, or use a colour-correcting lens to compensate for colour vision deficiency.

How to Use It

Hold up a graphic to a camera paired with a digital screen to see how it appears in simulations of two types of colour vision deficiency.

What Science Tells Us

Genetic conditions or injury can affect one or more of the types of colour-sensitive eye cells that give us colour vision, resulting in a change in colour perception. When this negatively affects the range of colours that an individual can see, it is called colour vision deficiency (CVD).

There are different types of CVD, categorised by which colour-sensitive cell is affected and by how much. Mutations to the 'green' sensitive cell are the most common type, with approximately six per cent of men of European descent being affected. Proteins for this cell-type are coded on the X-chromosome, making men much more likely to be affected as they lack a second X chromosome to correct the defect.

More severe forms of CVD can occur when one detector-type is missing entirely. This makes colour distinctions much more difficult. The two types of CVD simulated in this exhibit are both of this type.

The colour-correcting lens is coated with a special optical coating provided which filters out some yellow and cyan light—colours that are particularly troublesome for individuals with CVD. Removing this light can improve colour distinction for some people.

Things to Try or Ask

- What everyday tasks do you think might be difficult for a person with CVD to undertake?

Finding the Science in Your World

Some computer games include 'colour-blind' modes which change the colours so that players can more easily tell teams apart. Graphic designers often need to take care to make sure that colour-coded charts and graphs are coloured in a way that does not exclude people with CVD.

Ultraviolet Vision

An ultraviolet camera shows pigments that are invisible to our eyes.

How to Use It

Hold up a graphic to see how it appears on the two cameras, and learn how animals use UV sensitivity in the wild.

What Science Tells Us

Ultraviolet (UV) light is light with wavelengths from 10 nm to 400 nm. Most people cannot see UV light, or see it only very weakly. The cornea (lens) of the eye naturally filters out some UV, and the strength of this filter increases with age. Young people or people who have had corneal replacement surgery can see further into the UV than other people.

Human eyes cannot distinguish ultraviolet light from violet light – we see them as the same colour. Animals with a UV sensitive cone cell see UV light as a different colour to violet. This can offer an evolutionary advantage for a number of reasons, some of which are explored on the cards in the exhibit.

Things to Try or Ask

- How does skin with sunscreen or freckles appear on the two cameras?
- How do prescription glasses appear on the two cameras?

Finding the Science in Your World

We protect our skin from the intense ultraviolet component of sunlight using sunscreen and protective glasses. They both contain pigments that absorb ultraviolet light, so they appear dark on the camera.

Your Yellow

Match true yellow light to a light source that mixes red and green, showing differences in colour perception.

How to Use It

Turn the wheel until the two light panels match as closely as possible. Lock it in and see how your perception of yellow compares.

What Science Tells Us

Our brain interprets input from our eyes to arrive at a perception of colour. Humans have only three types of colour-sensitive cell. One type is most sensitive to long wavelengths (red light), one is most sensitive to medium wavelengths (green light) and one is most sensitive to short wavelengths (blue light). Other colours—such as yellow—are the result of multiple cone types being stimulated at the same time.

Physiological differences between individuals—including number, density and spectral sensitivity of each type of cone cell—can affect how sensitive people are to each colour of light.

In this exhibit the true yellow light has a wavelength of approximately 580 nm. This stimulates both the 'red' and 'green' cone cells in a typical eye, however the *degree* to which each cone type is stimulated varies between people. This mean that when they are asked to match a mixture of red and green to true yellow their selection will fall within a range. People who fall to the edges of this range may have a colour vision deficiency.

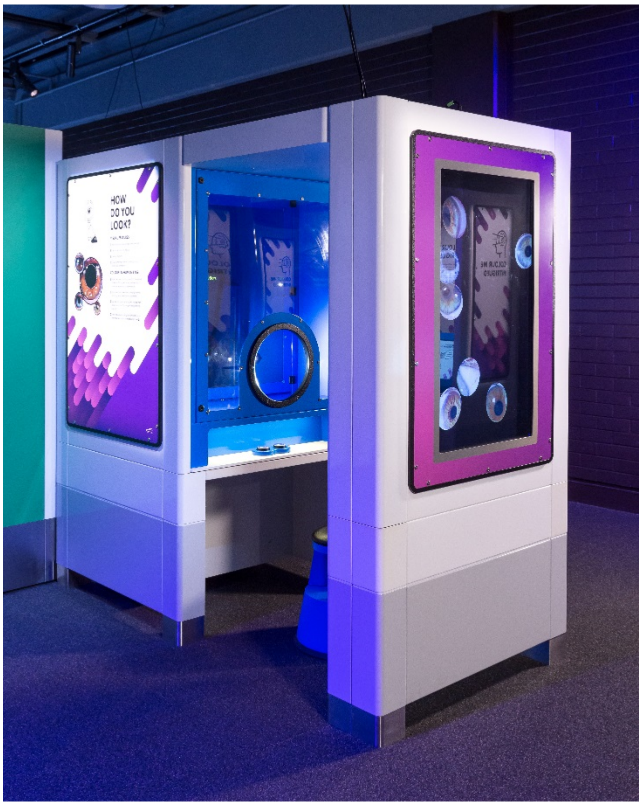
Things to Try or Ask

- Look at the coloured light panels through the viewfinder of a camera. Do they appear to match? Can you get them to match?
- Have you ever disagreed with someone about what a colour is?
    - Do you think this was related to a category error—such as defining where green ends and yellow begins—or a fundamental difference in colour perception?

Finding the Science in Your World

Digital displays in objects such as televisions and mobile phones take advantage of the fact our eyes have only three types of colour receptor. By stimulating each of these individually with red, green, and blue pixels, these displays can simulate almost all the colours we find in nature.

How Do You Look?



A camera takes high resolution images of visitor’s eyes.

How to Use It
Align your eye with the viewfinder on-screen, then press the button to take a snap!

What Science Tells Us
Several mechanisms are responsible for colour in human eyes. Pigments produce deep browns, orange-browns and yellows. Blue and grey are the result of Tyndall scattering, a type of structural colour. Greens are the combination of yellow-brown pigments and scattered blue light.

Tyndall scattering is a colour-dependant scattering effect. Fine collagen fibres in unpigmented eyes scatter short wavelengths of light more than long wavelengths. In normal white light, this means that blue light is scattered strongly; green light moderately; and red light weakly. We see this combination of colour (lots of blue, some green, not much red) as pale blue/cyan.

Other features that can be seen include fissures and concentric rings, both produced by folding or a ‘concertina’-like effect when the iris dilates. Freckles—areas where dark pheomelanin pigment has been produced, usually as a protective response to ultraviolet light—may also be seen.

Things to Try or Ask
- Do family members show similar colouration or structure in their eyes?
- What features (freckles, fissures etc.) can you find in your eyes?

Finding the Science in Your World
The Tyndall scattering in blue eyes is similar to the Rayleigh scattering that colours the sky blue. It differs in that the particle size for Rayleigh scattering is much smaller—down to individual molecules—while for Tyndall scattering the structures are about the same size as the wavelength of light.

Impossible Colour

Three colour illusions take advantage of the workings of colour-sensitive cells in our eyes to produce colour effects.

How to Use It

Stand a meter or two away from the image, and stare at the dot in the centre. What happens?

What Science Tells Us

The colour-sensitive cells in human eyes are called cone photoreceptors. These provide frequent updates about colour to the brain via the optic nerve, and are also responsible for some of the processes involved in edge-detection.

These updates slow considerably, or even stop, when there is no 'new' information to send—such as when staring at a fixed point for a considerable amount of time. This leads to a reduction in the colour and edge-sensitivity of the eyes. Our brains often attempt to 'fill in' the missing information, making assumptions about what colour 'should' be there.

This results in a few different effects: in the 'coloured spots on grey' image, we lose the ability to see the coloured dots until we move our eyes, which triggers an update from the colour-sensitive cells. In the 'red on green' or 'yellow on blue' images people see different things. For some people the colour of the centre spot expands to fill the scene; in other people the edge colour expands to 'take-over' the centre spot. For a few, the resulting colour is neither of the starting colours but a combination of the two—a 'reddish green' or a 'yellowish blue'. These colour combinations are not perceivable under normal circumstances, being so-called 'impossible' colours.

Things to Try or Ask

- Which colours disappear the most quickly? Which disappear the slowest?
- Does the 'red on green' spot or the 'yellow on blue' spot work most easily for you?

Finding the Science in Your World

If you have ever noticed that when staring into the distance or daydreaming that your eyesight changes or diminishes, it may be partly due to the effect demonstrated here.

The Eyes Are All Grey

A colour illusion where three sets of grey eyes all appear to be coloured differently.

How to Use It

Look closely at the eyes—do they appear to be the same or different? Ask a staff member to demonstrate that they are the same with a grey card.

What Science Tells Us

It is highly beneficial for our perception of colour to remain fairly stable between different lighting conditions. For example, objects change colour (get darker) in shadow, but we don't tend to recognise this. Cues from the light —highlights, shadows, general colour cast—all influence our perception of the world around us. A surface under blue lighting will be assumed to be more yellow ('less blue') than it appears, and our brains automatically adjust to account for this.

The images of the eyes here have coloured overlays, changing how 'black' the black areas are, and the colour of the highlights in the eyes. This leads our brains to assume that the lighting is similarly coloured. To correct for this, our brains 'subtract' the colour of the light from the colour of the surface. This results in neutral greys appearing to be the complementary colour of the light source.

Things to Try or Ask

- Use a piece of grey card or fabric to check the colour of the eyes.
- Take a photograph of the eyes and zoom in—what colour are they?

Finding the Science in Your World

At sunset the light from the sun is very orange/red and everything around you changes colour. Most of the time we don't notice due to colour constancy. For this reason photographers also often adjust the light source (or colour temperature) setting on their camera so that colours are rendered properly.