Visual Thinking

Colour

Colour Processing

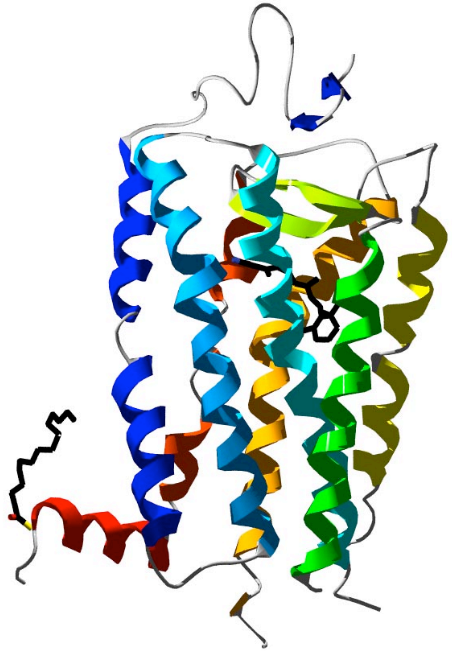
- humans, like other apes, most primates, and birds, have colour vision
  - humans have 3 dimensions of - we are *trichromat*
    - birds have 4
    - cats have 2 (bichromat)
  - Why the differences?

Colour Processing

- humans, like other apes, most primates, and birds, have colour vision
  - humans have 3 dimensions of - we are *trichromat*
    - birds have 4
    - cats have 2 (bichromat)
  - Why the differences?
    - fruit eaters require colour vision
    - trichromacy may assist primates in spotting ripe fruits and young leaves
    - bichromacy is better for detecting and catching camoflaged prey

Colour Processing

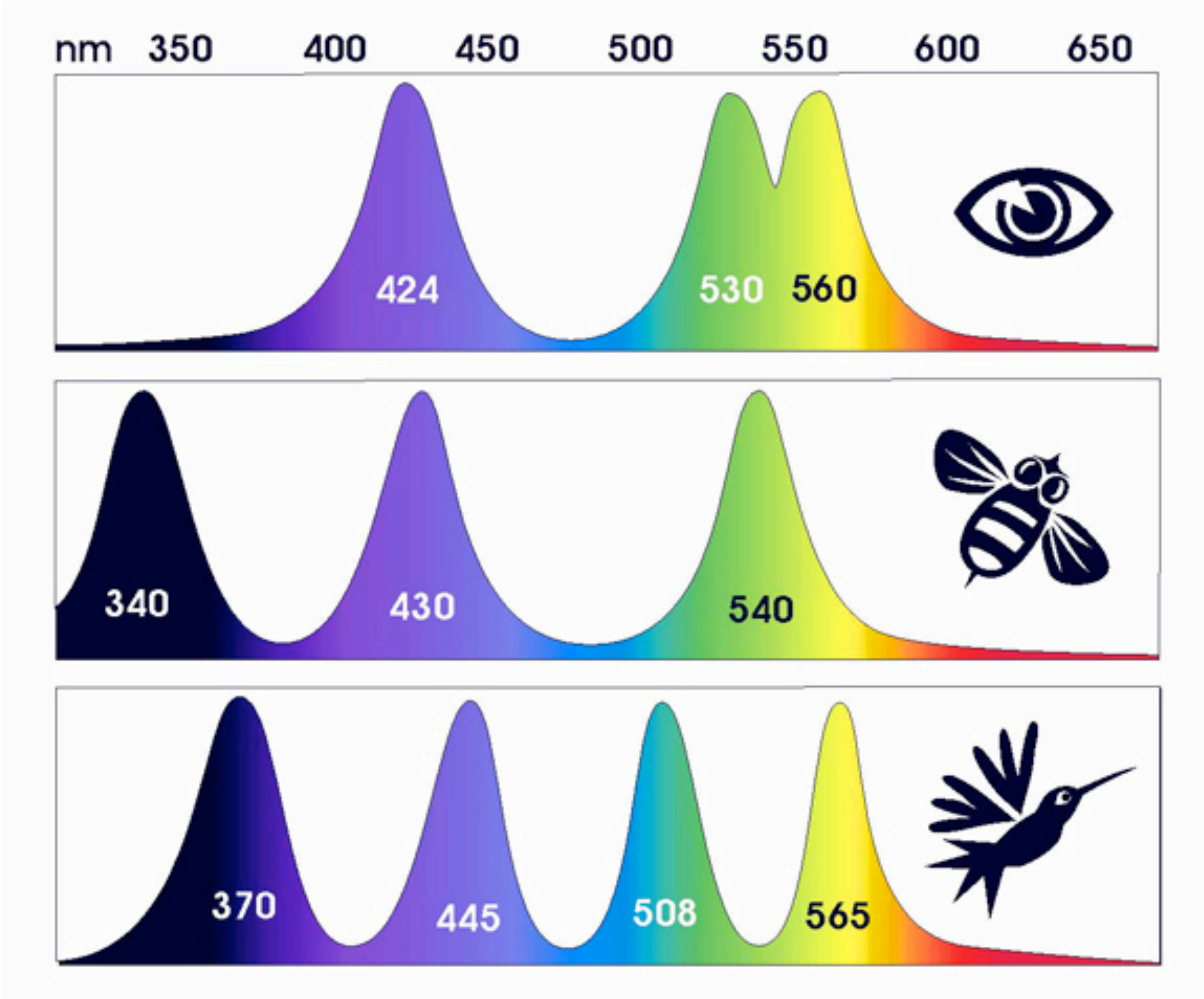
– we have two basic receptors on the retina: rods and cones
– **rods**
  • contain rhodopsin
  • confer high sensitivity to light (night vision)
  • provide a low-resolution (grainy) image
  • wasted on modern humans



– **cones**
  • contain different pigments
  • confer lower sensitivity to light (day vision)
  • provide a high-resolution (sharp) image

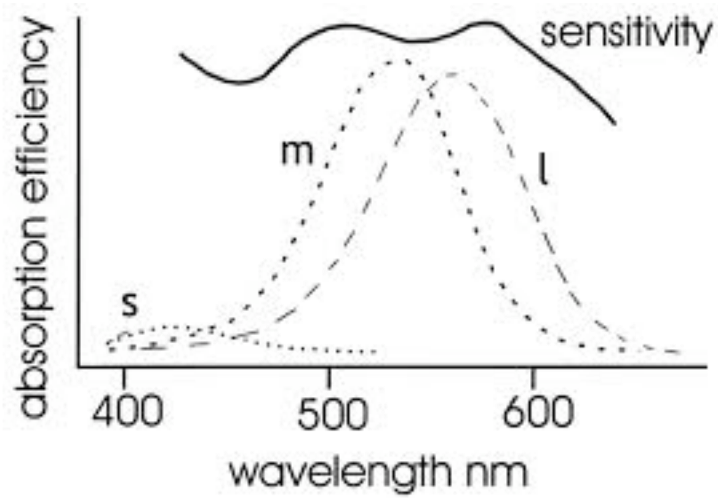
Colour Processing

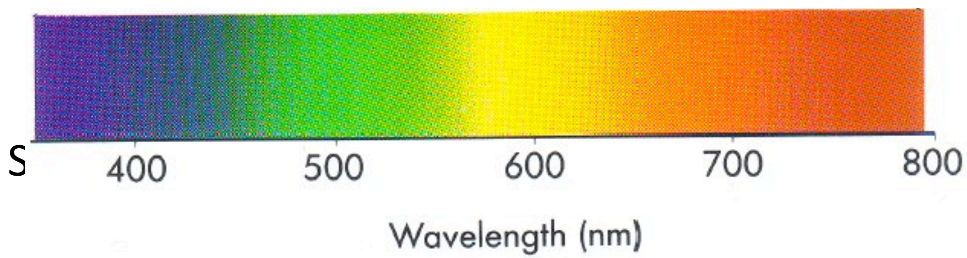
- cones confer color vision, if more than one type of cone



Colour Processing

- humans have far fewer short wavelength (blue) cones than long or medium wavelength cones





Colour processing

SO don't show small blue text on a dark background

- Insufficient luminance contrast

- Related problem for yellow:
  - pure yellow excites many middle and long-range cones, making it the lightest of all hues

yellow looks terrible on white

but great on black

Colour processing

- Because cones only have to differentiate between light and dark, we find it much easier to see detail in black and white than when the differences are purely chromatic.

Opponent process theory

- In the V1 cortical region, neural networks add and subtract cone signals to transform them into 3 *colour-opponent channels:*

  1. red-green
     – represents **difference** between middle and long-wave sensitive regions
     – we are highly sensitive to red-green contrasts

Opponent process theory

- In the V1 cortical region, neural networks add and subtract cone signals to transform them into 3 *colour-opponent channels:*

    2. **yellow-blue**
        - represents **difference** between luminance and short-wave (blue cone) regions

Opponent process theory

- In the V1 cortical region, neural networks add and subtract cone signals to transform them into 3 *colour-opponent channels:*

  3. black-white or luminance
     - combines middle and long-wave sensitive regions

Channel properties

Most of the important principals for effectively using **colour** in **design**

come from an understanding of the

red-green,

yellow-blue and

black-white

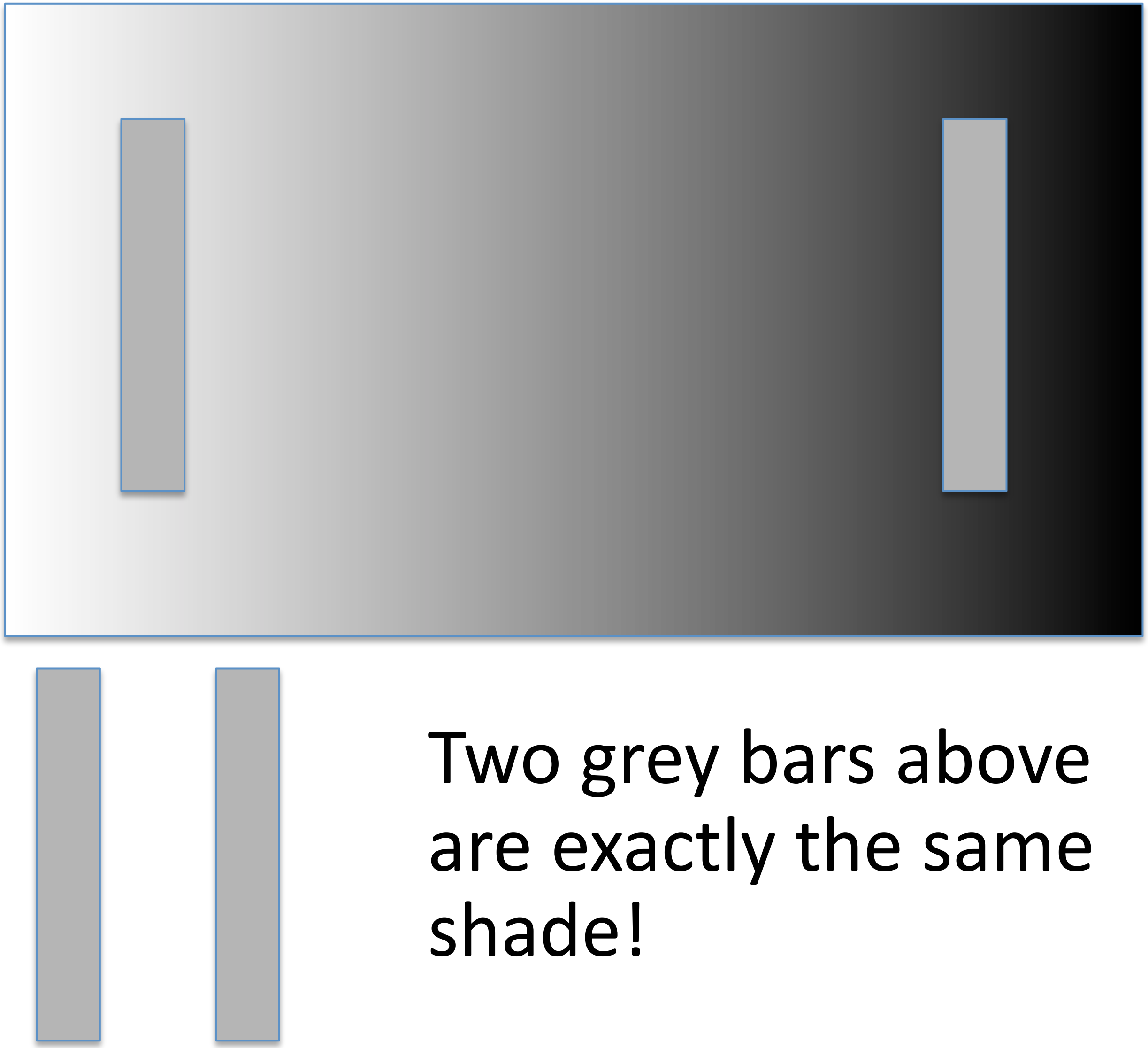
colour channels

Brightness Contrast

Simultaneous contrast phenomenon occurs in each of the channels.

This is a distortion of the appearance of a patch of colour in a way that increases the difference between a colour an its surroundings.

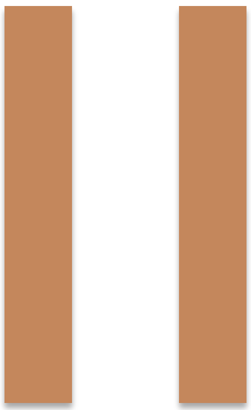
Called lightness or brightness contrast for black and white channel, or chromatic contrast for red-green or yellow-blue channel



Two grey bars above are exactly the same shade!

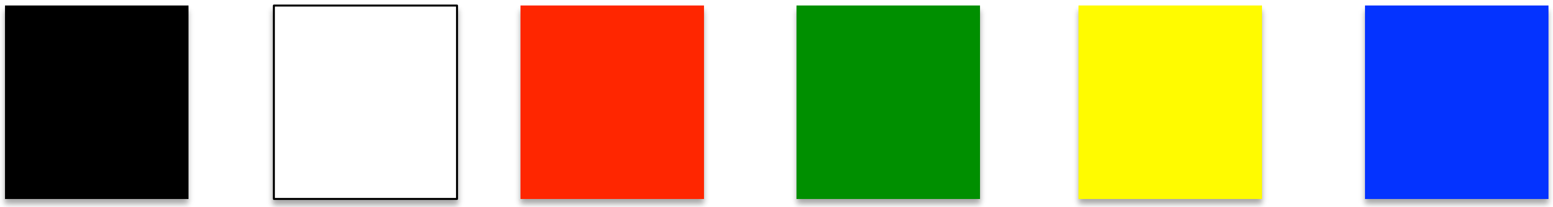
Chromatic Contrast

Contrast occurs because the visual system is better at determining **differences** between light than absolute values of light



Two bars above are exactly the same shade!

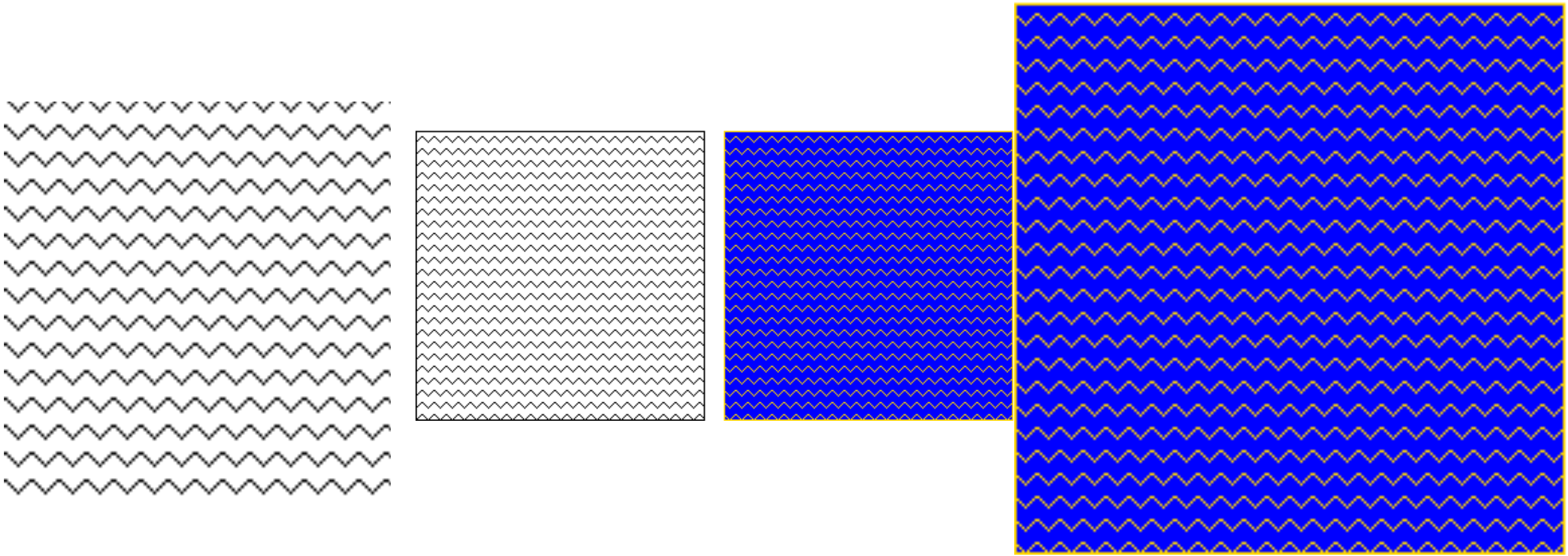
Unique hues for humans



- these special colour have a strong signal on one of the channels and a neutral signal on the others

Sensitivity to spatial detail

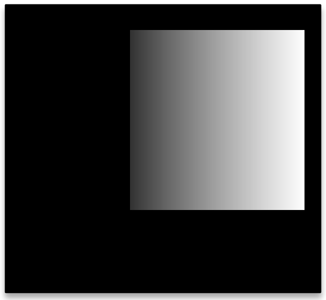
- Luminance channel greater capacity to convey detailed information than the chromatic channels – fine pattern is harder to see with chromatic differences

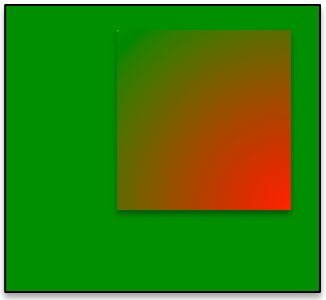


Motion

luminance channel conveys motion much more effectively

- When moving shapes are shown only in red and green, their motion appears to slow down, or stop



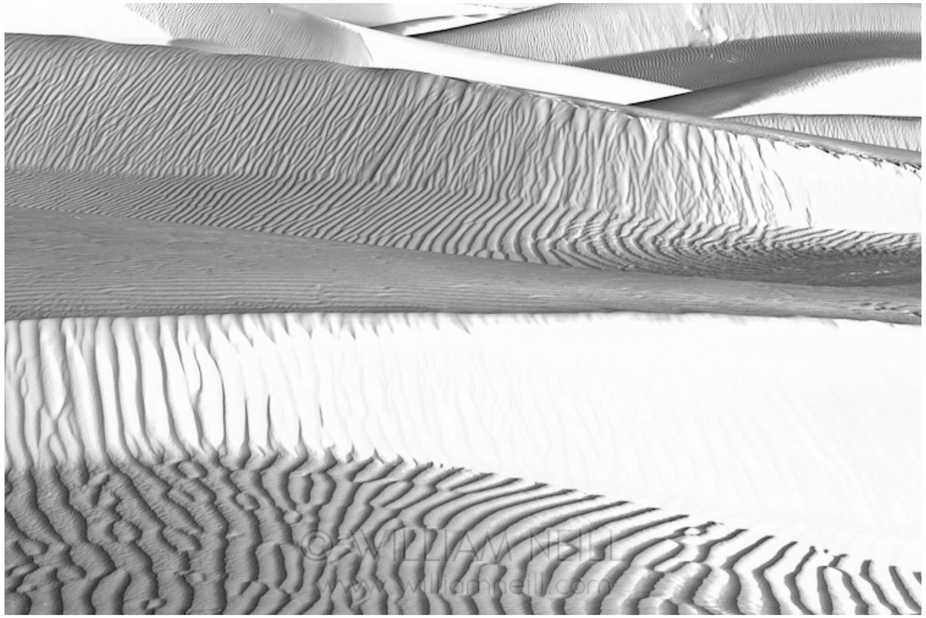


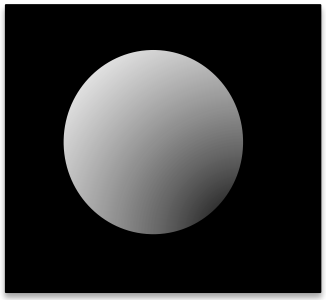
To demonstrate this effect, the colours have to have equal luminance and the transition between the colours needs to be gradual.

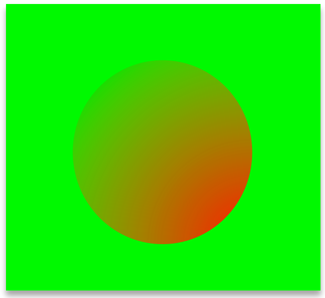
It is difficult to get equiluminance and smooth transitions without specialized monitors and control programs

Stereoscopic Depth

- Brain’s processing of stereoscopic depth occurs through the luminance channel
- We can only see shape-from-shading in the luminance channel







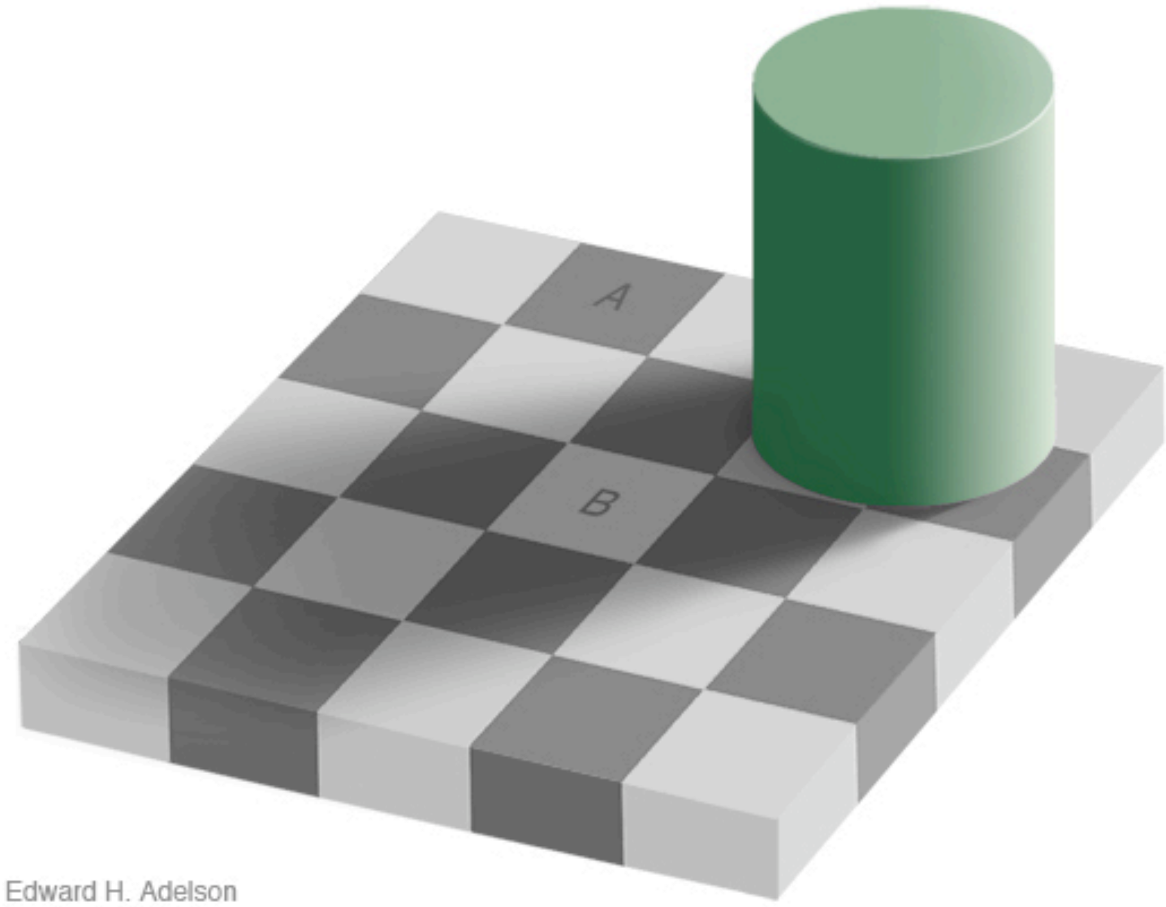
Colour blindness

- People who are colour blind (8% men, 1% women) are missing red-green channel
  - 2D (not 3D) colour space
  - can still distinguish yellow and blue, and the grayscale

- Yellow-blue colour blindness is very uncommon

Colour appearance

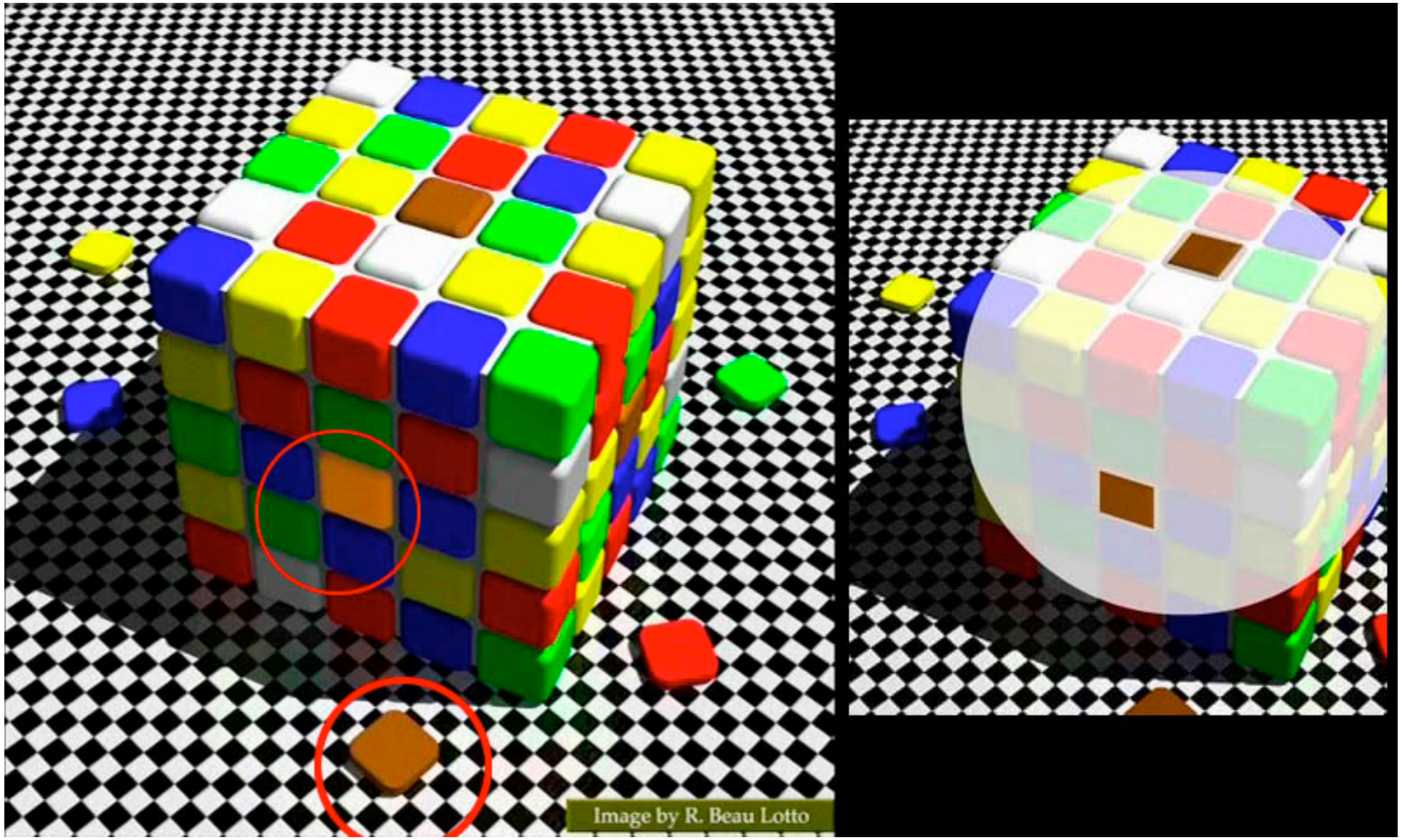
- The checkerboard illusion of Edward Adelson.



The squares marked A and B are the same shade of gray.

Colour appearance

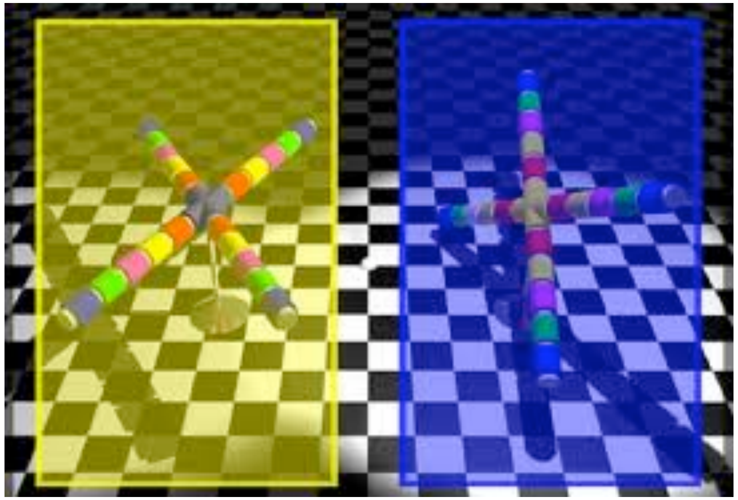
- The cube illusion of R. Beau Lotto. C.



The orange and brown squares are actually the same colour! We **see** the same image colour as being dark brown in the context of strong lighting, and light orange where the same image colour appears in a deeply shaded context.

Colour appearance

- The cross-piece illusion of R . Beau Lotto



The colour at the intersection of the two rods is actually an identical colour (grey) in both cases, but in the context of apparently yellow illumination on the left and blue illumination on the right, this is judged, **and seen**, to be the reflectance of a blue-grey object and a yellow object respectively.

Principles for design

- A set of principles for the use of colour in design, emphasizing clarity and support for visual tasks

1. When small **detail** is important, luminance contrast is necessary:
   - black on white
   - dark blue on white
   - yellow on black

When text is small, it is essential that there is luminance contrast with the background colour. Notice how the text is hardest to read where the contrast is lowest.

ISO recommends a luminance ratio of at least 3:1 between text and background

Colour names

What colours are these?

- teal
- mauve
- khaki
- puce
- ochre
- terracotta

Colour names

"Brownie-green is a real colour for boys."

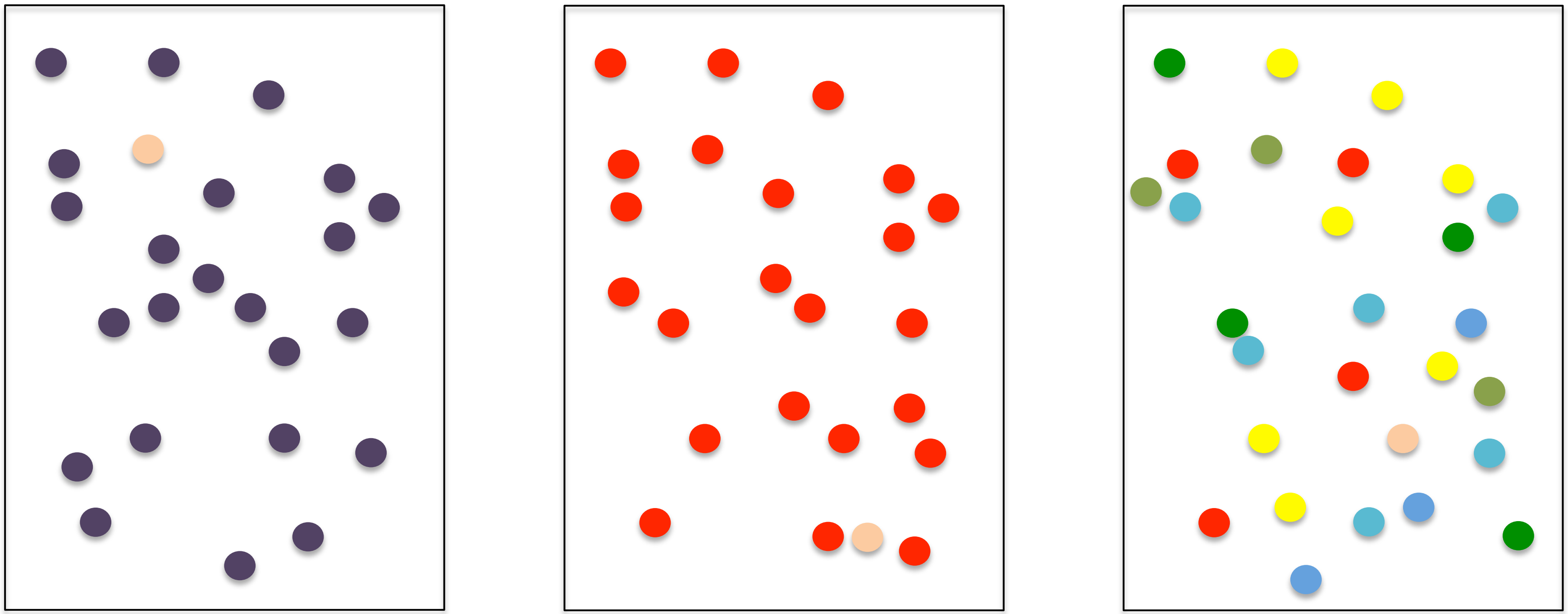
Bryan Davies, VIS exam 2012

2. Colour-coding information

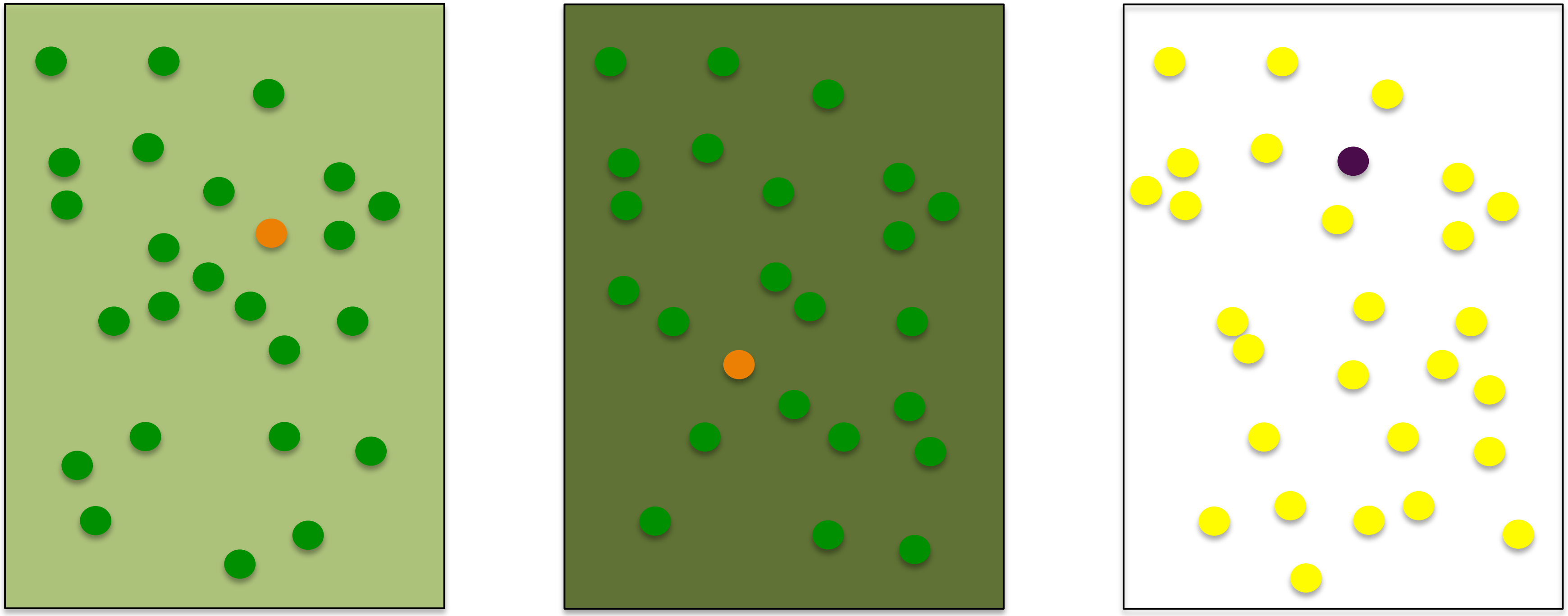
- The most important use of colour is to indicate categories of information
- When designing colour codes need to be concerned with:
  - **visual distinctness**, to support visual search queries
  - **learnability**, so colours come to stand for particular entities
    - for learnability, it is important that unique hues are used first – **red, green, yellow, blue**, - followed by colours that have relatively consistent names: **pink, brown, orange, grey and purple**

2. Colour-coding information

- If a design is complex and symbols are quite small, no more than a dozen codes can be used reliably
  - backgrounds can distort a patch of colour
  - ease of a visual search depends both on the colour and on the background colour
  - small areas should be strongly coloured and have black-white channel differences from large areas to be distinct
  - large areas can have more subdued colours
    - use low saturation colours for large areas



- the larger the chromatic difference between the target symbol and other symbols the easier the search
- when there are many non-target symbol colours, the search is much more difficult



- When non-target symbols are similar to the background, they are easy to exclude from the visual search
- A luminance difference plus a chromatic difference from the other symbols and the background leads to the easiest search
- a dark target on a light background with light target symbols can be as effective as the reverse

Emphasis and highlighting

- To use orange for highlights would be a mistake – why?

Emphasis and highlighting

- To use orange for highlights would be a mistake – why?
  - luminance contrast with background is reduced, so less distinct
  - more **effective** to reduce the contrast of the **other text**, but not so much that you loose **clarity**

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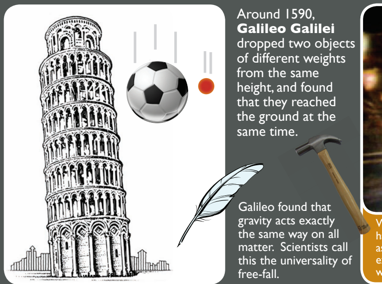
THE WONDERS OF GRAVITY

The Mystery of Falling Objects



Around 1590, **Galileo Galilei** dropped two objects of different weights from the same height, and found that they reached the ground at the same time.

Galileo found that gravity acts exactly the same way on all matter. Scientists call this the universality of free-fall.

Would a feather will fall at the same speed as a hammer? Not on earth! Why? Amazingly, when astronauts of the APOLLO 15 mission did this experiment on the moon, they confirmed that Galileo was correct. Why did it work on the moon?

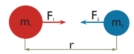
TRY THIS AT HOME

1. **T**ake an empty cooldrink can and make a small hole at the bottom*.
2. **F**ill the can with water. Notice that if the can is held up, the water flows out the bottom.
3. **N**ow drop the can. Does the water still flow out the can while it is falling? WHY?

* Always get an adult to help you.

The Case of the Falling Moon

UNIVERSAL GRAVITY

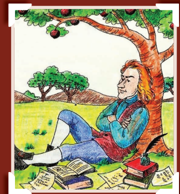


$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

Every object with mass in the universe attracts every other object with mass.

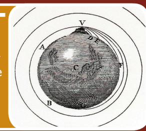
DID YOU KNOW?

The speed that a rocket must blast off with in order to leave the Earth's gravitational pull is 11.24 km/s ? How fast is that in km/hr?



In 1665, Isaac Newton discovered the science of optics, the laws of mechanics, invented calculus and also wrote down the laws of gravity. Newton was sitting under an apple tree when he noticed an apple fall and wondered if the same force that made the apple fall also kept the moon in orbit around the earth. Today we call this idea, the **universality of gravity**.

Suppose you are standing on the top of a very high mountain with a canon (V). The first shot you fire lands a short distance away at (D). By adding more gunpowder and firing, the cannonball it will go further to (E) or maybe even to (B). **If you get the canonball moving fast enough it will eventually be put into a low orbit (A) and come right back to (V).**



Newton realized that the moon's curved path in the sky could be caused in exactly the same way as the cannonball's orbit! He was also able to calculate that **the moon falls toward the earth at a rate of 1.37mm every second**. Why does it not crash into the Earth?

The Darkest Place in the Universe

Ten years before writing down his famous General Theory, Einstein developed a **Special Theory of Relativity**. According to this theory, the speed of light is the ultimate speed limit in the Universe. **Nothing, not even light, could travel faster than the speed of light.**

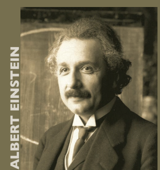
The escape speed needed by a rocketship to completely leave the gravitational pull of a planet is inversely proportional to the density (mass/ volume) of the planet. The greater the density, the harder it is to leave the planet. A **Black Hole** is an object that is so dense that the escape speed is greater than the speed of light. It is black because no light can get to us from it.

DID YOU KNOW?

Scientists use the speed of light, **299 792 458 km/s**, to define the meter! What do you think this definition is?

The **event horizon** is the point of no return for an astronaut falling into a of the black hole. Once crossed, not only will the astronaut not be able to return but she will also not be able to communicate with anyone outside the hole!

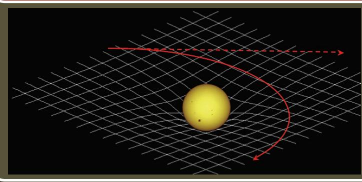
The Geometry of Gravity

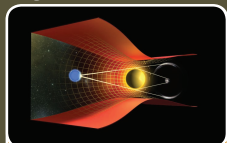


ALBERT EINSTEIN

Newton was the king of gravity, until a young Swiss patent clerk called **Albert Einstein** changed the way we understand the force of gravity. Einstein realised that there was way for someone sitting in a closed room to tell if they were in a gravitational field (like on Earth) or accelerating (say out in space). This is the principle of equivalence between gravity and acceleration and forms the foundation of Einstein's theory of General Relativity.

According to this theory of gravity, all of space and time become one **spacetime continuum**. Anything with mass (like the Sun, for example) will bend the spacetime around itself. The bigger the mass, the more the bending. Any other body that finds itself moving near such a massive body will be forced to move in this warped spacetime along a **geodesic**. In this way, the 'force of gravity' that attracts the two bodies is the geometry of the spacetime continuum around them.



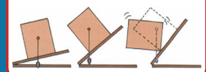


According to **General Relativity**, even light falls in a gravitational field. This causes light rays to be bent around a massive object; a phenomenon known as **gravitational lensing**. This prediction of Einstein's theory was confirmed by Sir Arthur Eddington during the solar eclipse of 1919. Why do you think that a solar eclipse was necessary to carry out this test?

The Magic of Gravity

Weighing something on a scale measures the force of the earth's gravity on that object. This force acts as if all the mass of the object were concentrated at one point, called the **centre of mass**.

The centre of mass can sometimes lie outside of the object itself. For example, the centre of mass of a donut is at its centre which is not actually part of the donut! The idea of centre of mass is crucial to the **physics of balance**. When the centre of mass of an object is no longer above its base of support, the object will topple over.



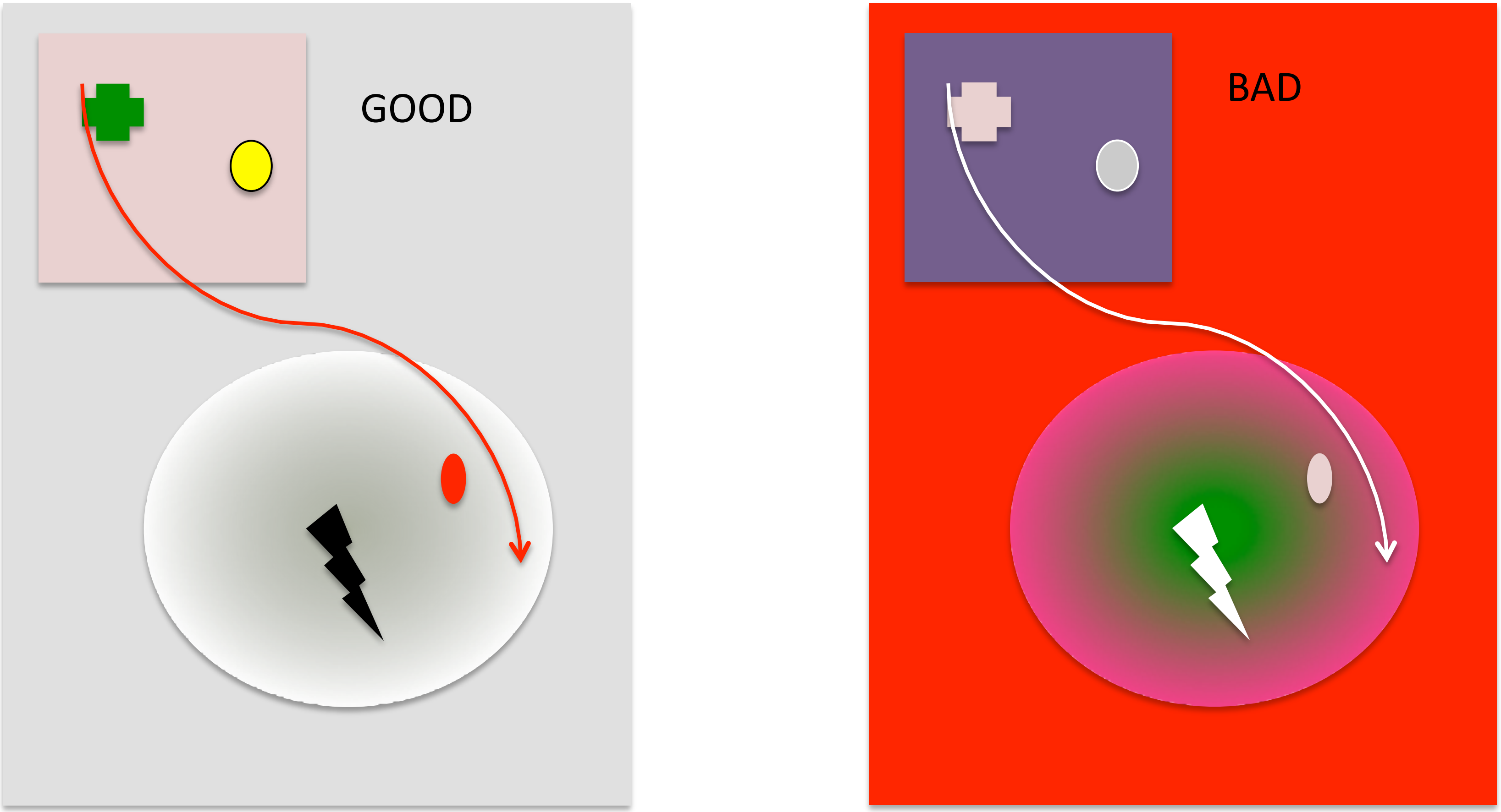
TRY THIS AT HOME

1. **T**ake a can of cooldrink and drink about 2/3 of the contents.
2. **T**ip the can over until it makes an angle of about 45°.
3. **L**et go of the can! What happens? Can you explain why, using the ideas of centre of mass?

ACKNOWLEDGEMENTS
Content: Dr Jeff Murugan (UCT, Department of Mathematics and Applied Mathematics);
UCT Faculty of Science Marketing Committee
Design and layout: Evolution Marketing CC

National Science Week

NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement



- The good example uses high saturation colours for small areas, such as symbols and lines. Larger background areas are all light and low saturation
- A black border is used for the yellow circle to separate it from the background.
- In the (hideous) bad example, this approach is reversed

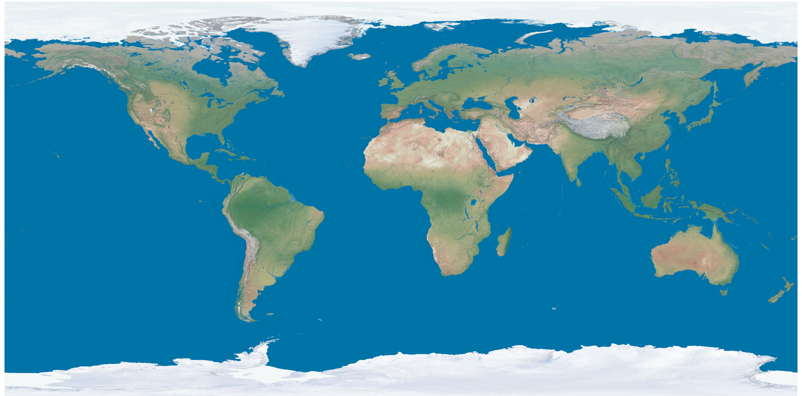
Colour Sequences

colour sequences in maps allow perception of patterns – ridges- valleys, hills – and reading of quantitative data – heights

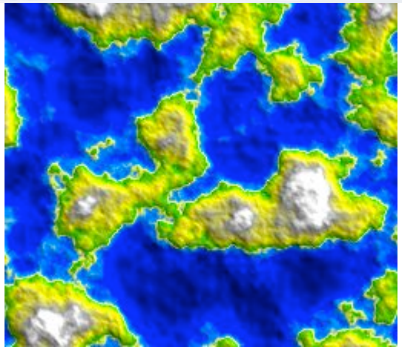
colour sequences which vary in luminance will be most helpful for revealing patterns in data

dark-light contrast is essential for detail

however, for reading values, grey scales are very inaccurate – rather use difference in colours



- some maps have well defined colour sequences, which you should not tamper with
  - e.g. height of land in maps : green, light – dark brown, white at peaks



Semantics of colour

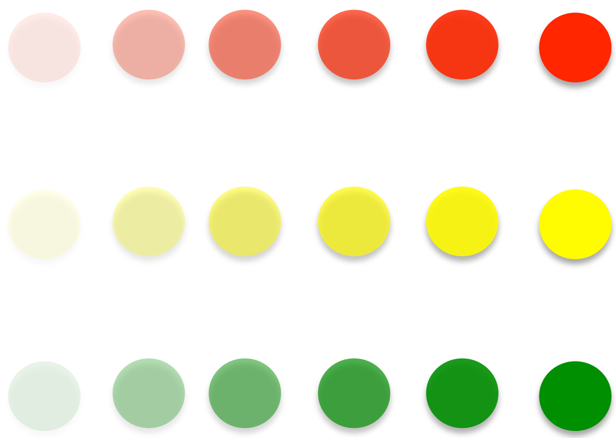
- colours are often used symbolically
- these are not universal
- in western culture:
    - red:
    - green:
    - blue:
    - white:

Semantics of colour

- colours are often used symbolically
- these are not universal
- in western culture:
  - red: danger, heat and stop (china: good fortune and renewal)
  - green: go, safety (china: can mean death)
  - blue: cold
  - white: purity (mourning in most of Asia)

Semantics of colour

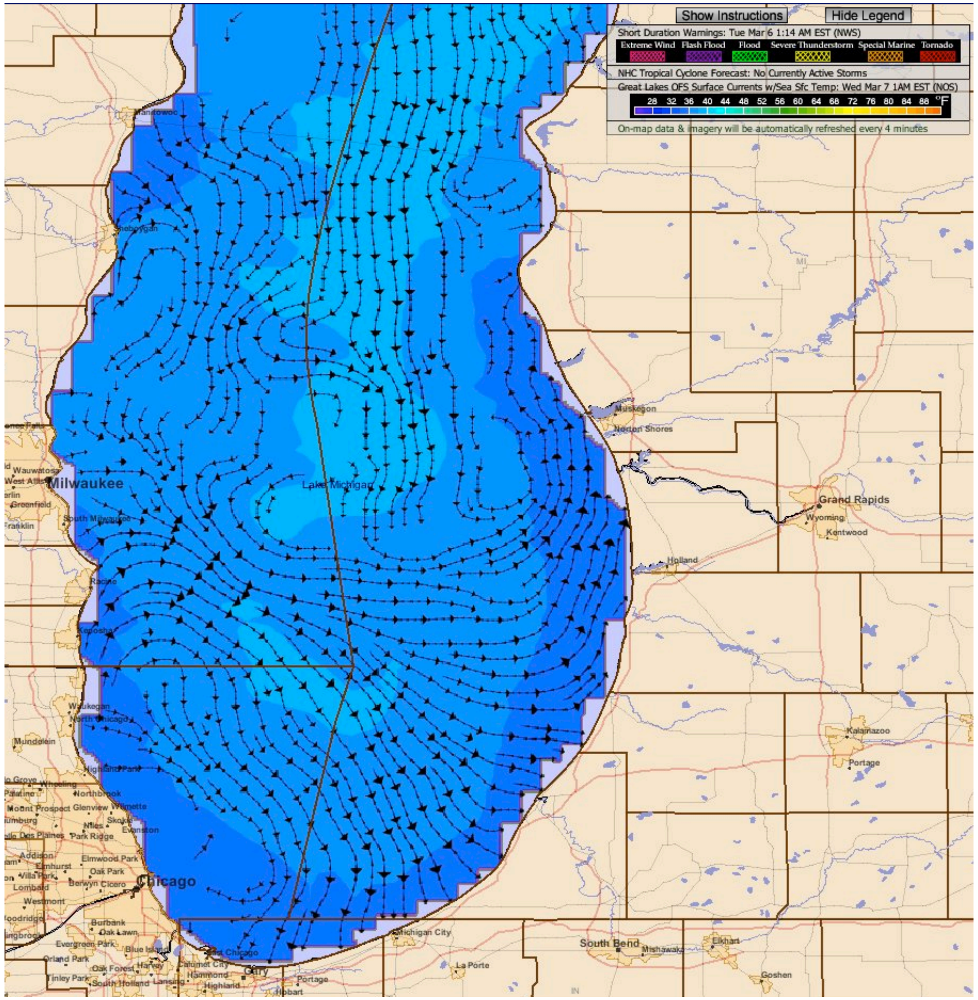
- some mappings are more universal
  - more saturated colours represent greater quantity



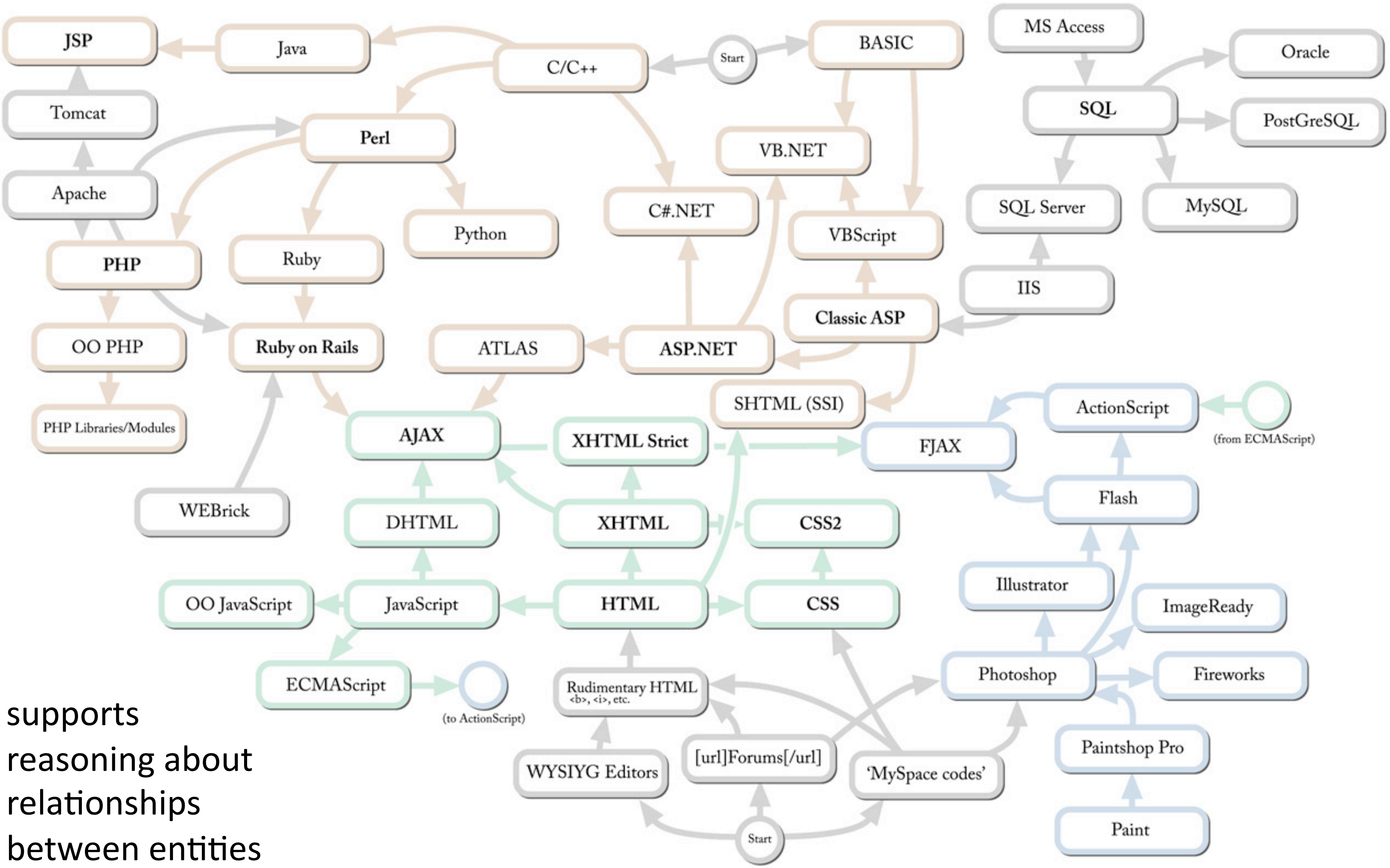
Conclusions

- choice of colour is a complex problem which requires tradeoffs
- every piece of information can't be made maximally distinct
  - most common and most important visual queries should be given the most weight

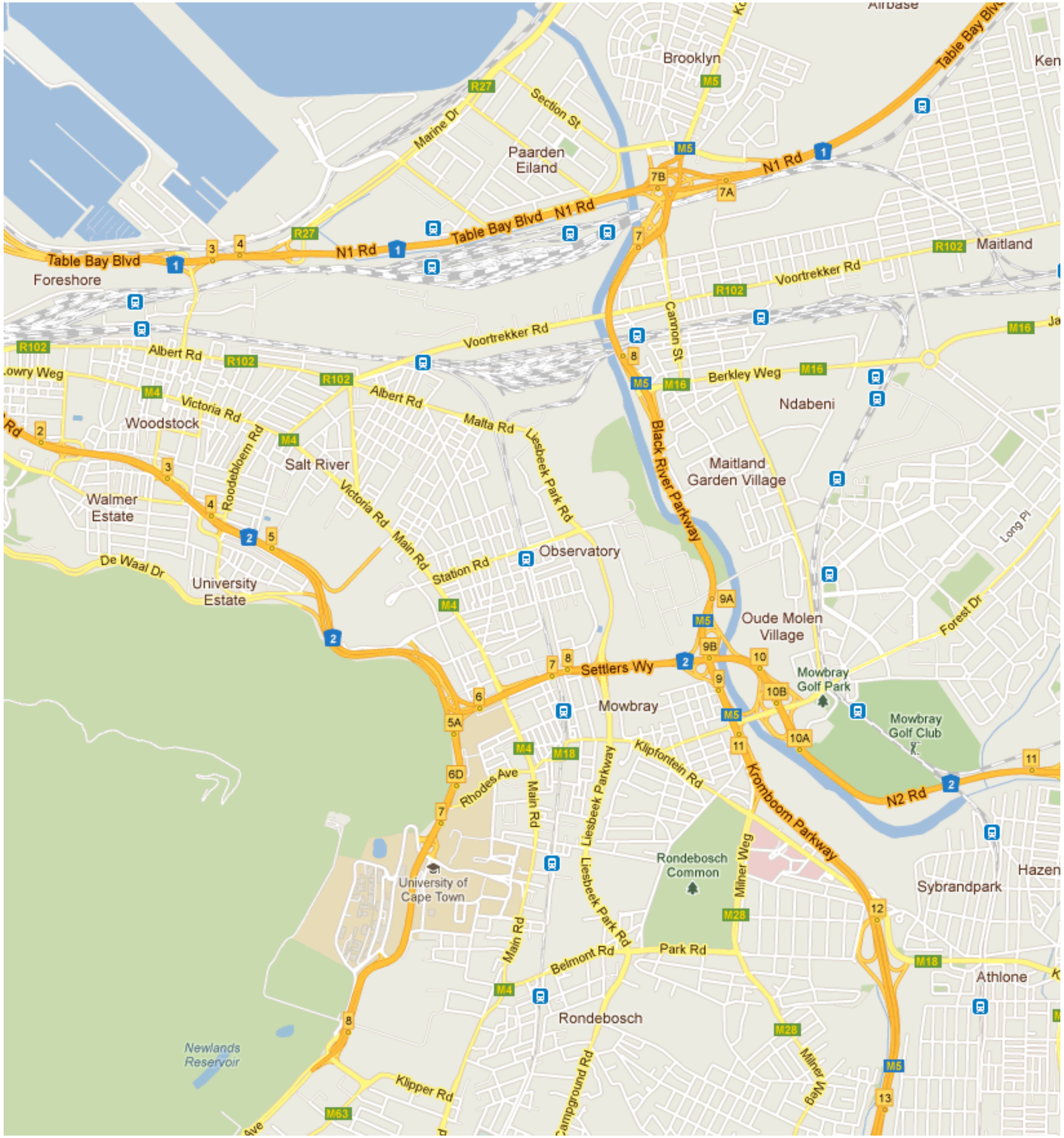
Screenshot of nowCOAST Viewer, showing detailed view of the Lake Superior OFS Surface Water Currents nowcast. The background colors shown indicate Sea Surface Temperature.

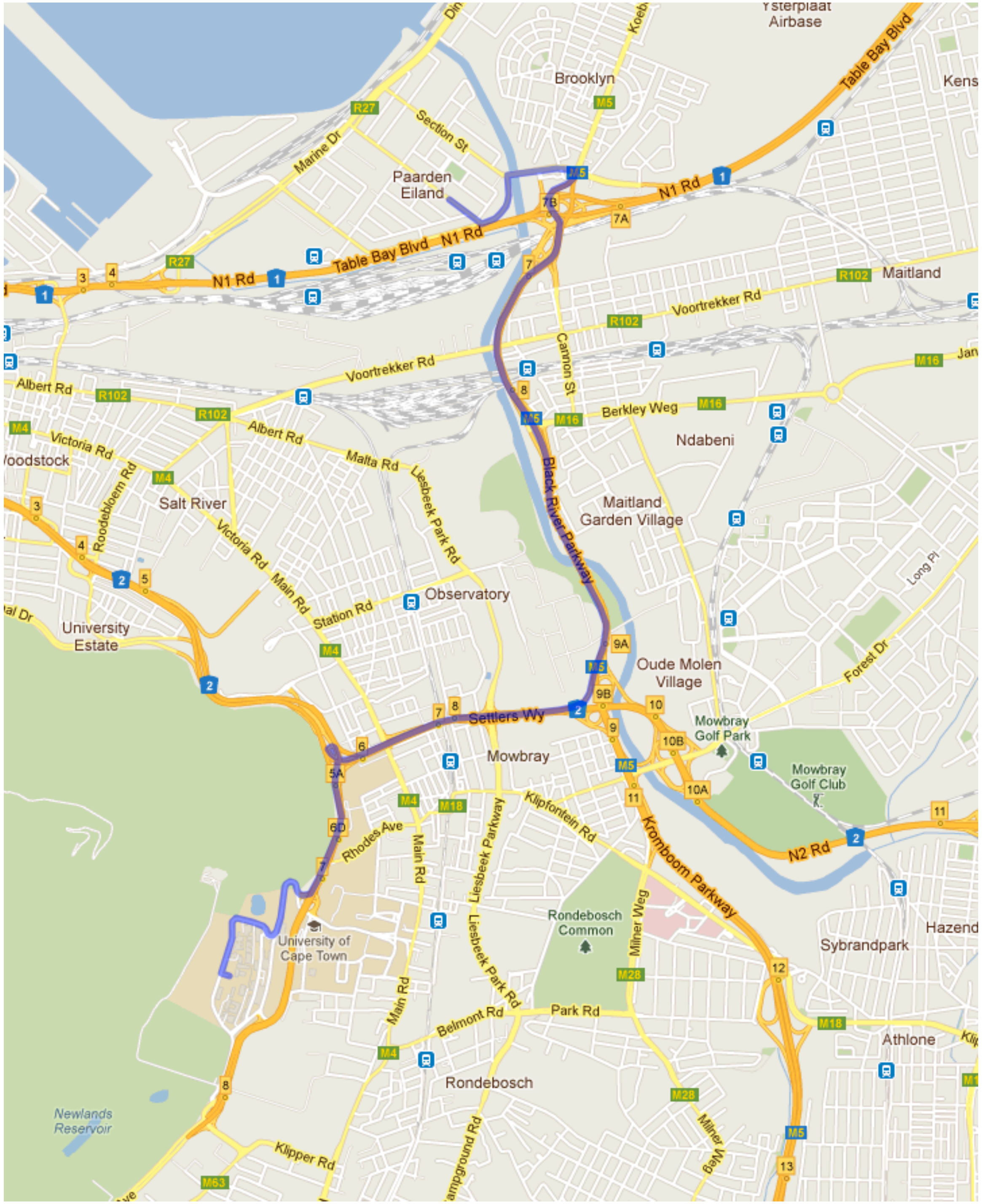


node –link diagram

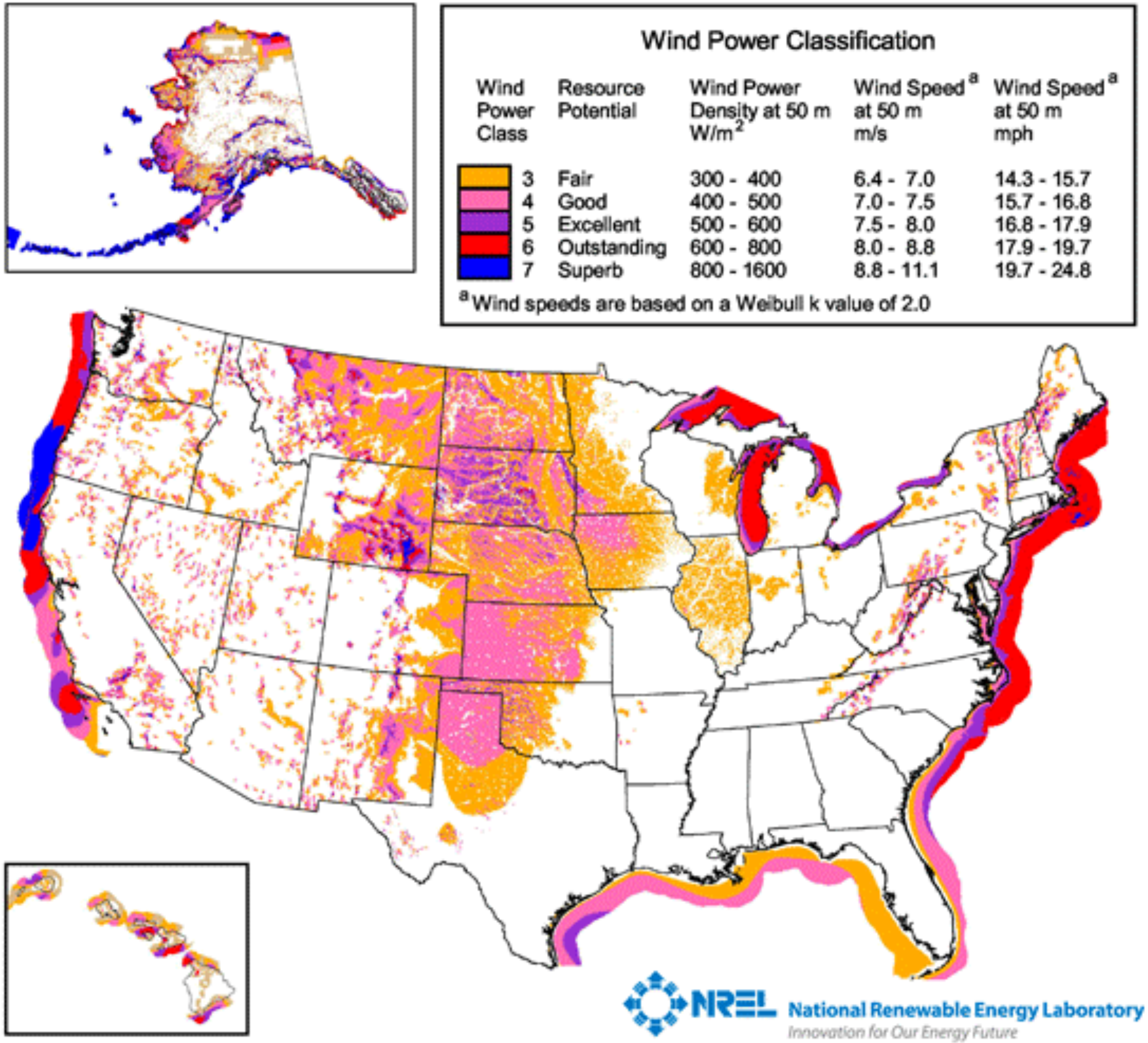


supports
reasoning about
relationships
between entities


Brooklyn
Paarden
Eiland
Section St
Marine Dr
Table Bay Blvd
N1 Rd
Foreshore
Maitland
Voortrekker Rd
Albert Rd
Woodstock
Victoria Rd
Salt River
Roodebloem Rd
Walmer
Estate
De Waal Dr
University
Estate
Malta Rd
Liesbeek Park Rd
Cannon St
Berkley Weg
Ndabeni
Black River Parkway
Maitland
Garden Village
Observatory
Station Rd
Main Rd
Oude Molen
Village
Settlers Wy
Mowbray
Mowbray
Golf Park
Mowbray
Golf Club
Forest Dr
Long Pl
Klipfontein Rd
Kromboom Parkway
N2 Rd
Rhodes Ave
Liesbeek Parkway
Rondebosch
Common
Milner Weg
University of
Cape Town
Belmont Rd
Park Rd
Rondebosch
Sybrandpark
Athlone
Newlands
Reservoir
Klipper Rd
Campground Rd
Airbase



Ysterplaat Airbase
Brooklyn
Table Bay Blvd
Section St
Marine Dr
Paarden Eiland
N1 Rd
Table Bay Blvd N1 Rd
Maitland
Voortrekker Rd
Cannon St
Albert Rd
Berkley Weg
Ndabeni
Victoria Rd
Woodstock
Roodebloem Rd
Salt River
Malta Rd
Liesbeek Park Rd
Black River Parkway
Maitland Garden Village
Observatory
Station Rd
Main Rd
University Estate
Oude Molen Village
Forest Dr
Long Pl
Settlers Wy
Mowbray
Mowbray Golf Park
Mowbray Golf Club
Klipfontein Rd
Rhodes Ave
Liesbeek Parkway
Kromboom Parkway
N2 Rd
University of Cape Town
Rondebosch Common
Milner Weg
Sybrandpark
Hazend
Belmont Rd
Park Rd
Athlone
Rondebosch
Newlands Reservoir
Klipper Rd
Campground Rd


Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m2
Wind Speed a at 50 m m/s
Wind Speed a at 50 m mph
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
a Wind speeds are based on a Weibull k value of 2.0
NREL National Renewable Energy Laboratory
Innovation for Our Energy Future