A lot of what people use computers for involves images. Most web pages are now absolutely stuffed with colourful pictures, and we all love taking holiday photos on a digital camera or looking at pictures of our friends online. But all of this would be impossible if computer scientists hadn’t developed clever ways to store and transmit images digitally.

First we’ll talk about the simplest way that pictures can be digitally encoded then we’ll go onto a much better method called run-length encoding. After that we describe a game you can play with your friends at home or school by becoming human fax machines. Finally, we’ll look at the weird effects that are possible with other methods of encoding photos.

**BLACK OR WHITE**

Turning an image into a string of information that a computer can read is called *encoding* it. Suppose we want to encode an image so that we can save a version of it on our computer and email it to a friend. The diagram on the right shows the Royal Institution logo using only black and white squares in a 16 x 16 grid.
Each of these squares in the image is called a ‘picture element’ or pixel. If we wanted to describe this picture exactly we could just list in order what colour every pixel in the picture is. So, for example, the middle row of the image (the eighth row down) would be:

BWWBBBBBWWWBBWWB

And we would need to list 256 letters to describe the image. This is fine, but it’s not a particularly efficient way to encode the image. It takes quite a lot of computer memory to save an image this way.

You’ll notice with the pixels list that a lot of the time the same colour is repeated a number of times in a row. So, if we want to be cleverer about our image encoding, why don’t we just say how many pixels in a row are the same colour? This is called run-length encoding because it records how long the run of each colour is in a row.

RUN-LENGTH ENCODING
If we describe the same image of the Royal Institution logo using run-length encoding, we write down the number of repeated squares and their colour. So the middle row of pixels in the logo would be encoded as:

1 black, 2 whites, 5 blacks, 3 whites, 2 blacks, 2 whites, 1 black

Or shortened to:

1B2W5B3W2B2W1B

This is a slight improvement as it encodes the middle row of pixels in 14 pieces of information, rather than 16 as with the simplest encoding before. And if we used run-length encoding on the first row of the image we would only need two pieces of information – much better! The run-length encoding for each row of the RI logo is shown below.
Run-length encoding is very effective at reducing the amount of information we need to describe an image. This is called image compression and is widely used. Run-length encoding is used, for example, to transmit the scanned image whenever you send a fax to someone.

What do you notice about how effective run-length encoding is for different rows of the image? Which rows of the image can be written really simply using run-length encoding, i.e. which parts are compressed most efficiently? Which rows of the image are not encoded very efficiently using this system? What sort of image would be very poorly compressed using run-length encoding?

Print out the two 16 x 16 black and white images below. Use the empty lines alongside the top one to practise writing down the run-length encoding for the image of the Earth. Then have a go at reconstructing the image in the bottom one from the compressed run-length information.
HUMAN FAX MACHINES

Now try drawing some black and white images of your own using the 16 x 16 grids on the following pages. Use a pencil so you can rub out any mistakes. Once you have finished it, pair up with a friend (but don't let them see your picture). The two of you can now work together like a human fax machine!

The person to go first is the transmitter. You read out the run-length encoding of your picture row by row, whilst your friend writes down this compressed information on the lines alongside the blank grid. Once you have finished the transmission, your friend can reconstruct your original picture from the run-length compression. After that, your friend can become the transmitter and 'send' their image to you for decompressing.

Or you could transmit the data for both of your images to each other and then see who can decompress their image fastest. Why not try to go for some really long-distance image transmission – phone your friend to send them the encoded information?
In the picture

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7W2B7W
6W4B6W
4W8B4W
2W12B2W
1W14B1W
1W14B1W
1W1B5W2B5W1B1W
1W1B5W2B5W1B1W
1W1B5W2B5W1B1W
1W14B1W
1W14B1W
1W14B1W
1W2B3W4B3W2B1W
1W2B3W1B2W1B3W2B1W
1W2B3W1B2W1B3W2B1W
1W6B2W6B1W
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JPEG COMPRESSION

JPEG is a popular form of image compression that works well with colour photographs. It is used to save photos from a digital camera or send pictures over the internet. One advantage of JPEG images is that they have been compressed – computer software has reduced the amount of memory needed to store the image (like run-length encoding). But, unlike run-length encoding, JPEG compression is lossy.

Lossy means that information is actually lost when the image is encoded in JPEG format. If you try to compress an image too much using JPEG, then the image begins to look pretty distorted and loses a lot of the detail of the original photo.

Two versions of a photograph of the front of the Royal Institution have been saved in JPEG format (see below). The image on the left has been saved at a high resolution, whereas the image on the right has been over-compressed. The image on the right would take up less computer memory space, but looks distorted compared to the original.
The odd features in the right-hand photo, called *compression artefacts*, are the result of trying to compress the image too much. You can see jagged edges along lines (the rooftop), contouring instead of smooth gradients of colour (the clouds) and blockiness in richly patterned areas (the inscription along the top of the building). Also, the flagpole on the roof is almost completely invisible, having been covered by the blotchiness of the sky.

It’s not just images that can be compressed as computer files. Films can be saved on a computer using MPEG compression and music recordings can be compressed using the MP3 format (MPEG-3). Both are lossy compression methods, however, and so may develop artefacts if they are compressed too much.

Try the ‘ear ‘ear game on the Royal Institution Christmas Lectures 2008 website to hear what the artefacts sound like when audio files are compressed too much using a lossy method.