Can we use artificial intelligence (AI) and light to identify cells?

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What is the problem?

Our immune system protects us against harmful agents, including bacteria and viruses. There are lots of different types of cells that make up our immune system and their numbers found in blood changes during disease and infection. Being able to quickly and easily distinguish and identify the subsets of immune system cells in blood is important when diagnosing and treating patients, however, current methods available are time consuming and expensive.

What are we interested in?

We know that the way light behaves when it is shone at biological materials is characteristic of the material. We want to exploit the behaviour of light and the properties of the immune cells to see if we can identify the equivalent of a "fingerprint" for each of the different immune system cells when a laser (light of single colour or wavelength) is shone on the cells. We hope to use this technique to develop a quick, accurate and cheap way to differentiate and identify different types of immune cells.

What did we do?

We used Raman spectroscopy - a method of detecting the light scattered from a sample - to help identify the "chemical fingerprint" of the cells. We also used digital holographic microscopy (DHM) – an optical technique to calculate how much light bends when it passes through the cells. Figure 1 shows a lab based optical setup which we used to gather the data we needed.

After collecting the data, we analysed it using Artificial Intelligence (AI). AI provides a way by which computers learn to solve problems in a sequential process. Specifically, for identification of patterns, computers progressively learn their presence in the data. In this study, we tested if AI could identify the different cells using the patterns present in the Raman or DHM data. In particular, we focussed on two types of immune cells called eosinophils and neutrophils. Figure 2 and Figure 3 show two different types of AI based methods we used.

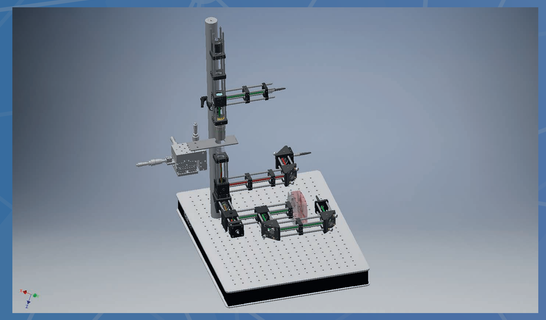

Figure 1 Schematic of our micro-spectroscopic Raman DHM system. The setup with the green central tube and green/red central tube represents the digital holographic microscope (DHM) whereas the setup with the red central tube and green/red central tube represents the Raman spectrometer.

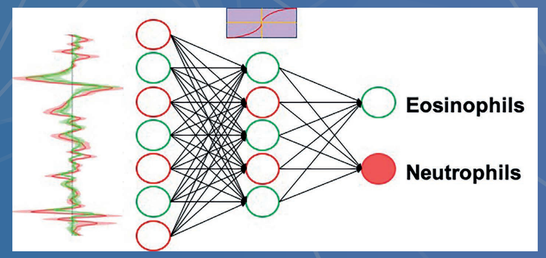

Figure 2 Schematic of a multi layered perceptron to classify the wavelength modulated Raman spectrum. Eosinophils and neutrophils are two of the different cells of the immune system.

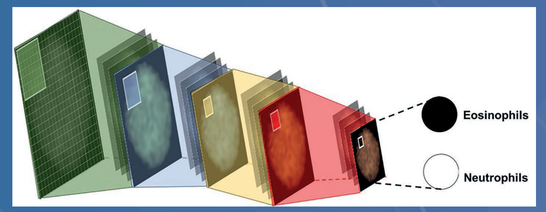

Figure 3 Schematic of a convolutional neural network to classify the DHM based phase images. Eosinophils and neutrophils are two of the different immune system cells.

What did we find?

We found similarities in the DHM data (representing the bending of light as it passed through the cells) for the eosinophils and neutrophils (see Figure 4). The cellular structures of both are round with similar size (about 10 µm in diameter: 1µm = a thousandth of a mm) with differences across the central structure.

The data collected using Raman spectroscopy (here wavelength modulated Raman spectroscopy – a way to increase signal to noise ratio by systematically accumulating the Raman spectrum at 5 different wavelengths of incident light) represents the chemical fingerprint of the cells. As can be seen in Figure 5, the two cells show big differences in their chemical fingerprint.

We found that AI can be easily applied with Raman spectroscopy and DHM to identify these cells of the immune system. By using the "chemical fingerprint", our artificially intelligent system can correctly identify 98 eosinophils and neutrophils out of every 100 eosinophils and neutrophils. However, when the images accumulated using DHM are considered, the AI based system can correctly identify 91 eosinophils and neutrophils out of every 100 eosinophils and neutrophils.

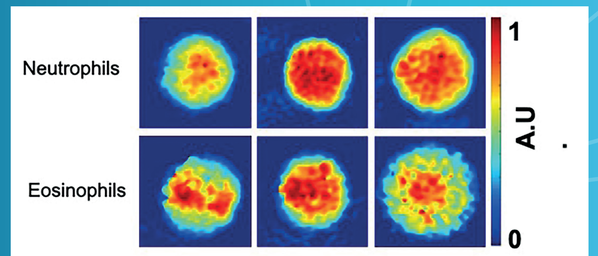

Figure 4 DHM based phase images of two cells of the immune system. Upper row shows neutrophils and lower row shows eosinophils.

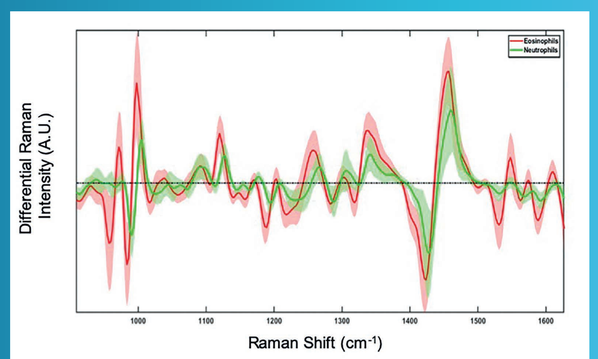

Figure 5 Wavelength modulated Raman spectra illustrating pairwise comparison between neutrophils and eosinophils. Solid lines show the mean (average) spectrum from each cell subset and shadowed regions represent the standard deviation (a measure of variation in our results).

What does this mean?

This means that AI, when combined with optical techniques, can provide a route towards an automated, stand-alone and fast method to identify cells of the immune system, which we hope can be developed for use in diagnosing and treating patients. Our study also paves a way towards miniaturising blood testing equipment as we believe a hand-held device of our system can be developed in the future.

Who am I?

I am a fourth year PhD student in the School of Physics and Astronomy and the School of Medicine at the University of St Andrews. I completed my Integrated BS-MS studies in Physics from the Indian Institute of Science Education and Research Kolkata, where I worked on my master's thesis on 'Magneto-optical Kerr effect in correlated electronic systems', which involved investigating how materials with the properties of magnets and superconductors affect the reflection of light.

Roopam started his PhD project entitled *"Label-free raman micro-spectroscopic optical characterisation of the immune system"* in 2016 and while principally based at the University of St Andrews, supervised by Dr Simon Powis and Professor Kishan Dholakia, he is also working closely with M Squared Lasers Ltd.