Developing the next generation of medical devices

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Introduction

The term ‘biomaterial’ is used to describe any material or device that treats, augments or replaces the function of living tissue for any period of time. This definition could include Captain Hook’s hand, Wolverine’s adamantium skeleton and Darth Vader’s breathing apparatus.

Some very real examples include basic medical equipment like blood bags, bandages and contact lenses as well as complex devices like artificial pacemakers and prosthetic limbs.

These biomaterials can be made from many different materials, such as metals, ceramics and glass. However, the most widely used biomaterials are made from polymers or plastics.

Polymers are large molecules made up of many smaller building blocks or ‘monomers’ (see Figure 1). Depending on which monomers are joined (polymerised) together the polymer can be designed to have certain attractive properties.

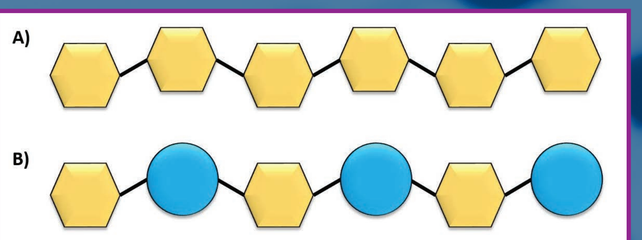

Figure 1 Polymers can be made of only one type of monomer (A) (known as a homopolymer) or of more than one type of monomer (B) (known as a co-polymer).

What is the problem?

Imagine that we have an idea for a new device that will help many patients. How do we decide which polymer to make it out of?

While we can design polymers that have certain basic characteristics, we cannot reliably predict the complex interactions that happen between a living tissue and any given material.

Additionally, if we synthesised and tested polymers one at a time until we got something that worked it might take a very long time.

What are we interested in and what did we do?

By taking hundreds of different biologically compatible polymers and printing them all onto a microscope slide, we can investigate all of them simultaneously in a single experiment. This is called a polymer microarray (see Figure 2).

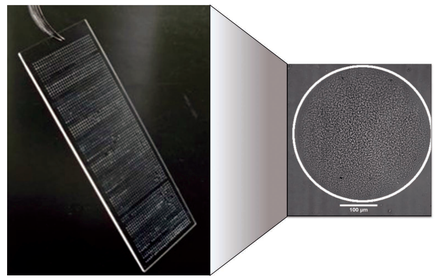

Figure 2 Polymers spots are printed as small as 200-300µm (micrometres) in diameter, about the thickness of three hairs. Each spot is its own individual experiment, conducted at the same time as thousands of others.

In our research we are looking to use the polymer microarray approach to identify materials that could help a variety of patients with different conditions, for example:

1. Biomaterials that reduce inflammation

mtDNA (mitochondrial DNA) is a molecule that is released from dying cells and acts as a signal to the immune system that there has been damage. During major injuries, too much mtDNA is released resulting in the immune system becoming overactive, causing inflammation and harming the patient. A potential new biomaterial could bind to mtDNA and remove it so that the immune system does not get a chance to see it.

We extracted mtDNA from cells and incubated it with our polymer microarray. When we applied a dye that only lights up in the presence of mtDNA, we were able to clearly identify the polymers that bound to it (see Figure 3).

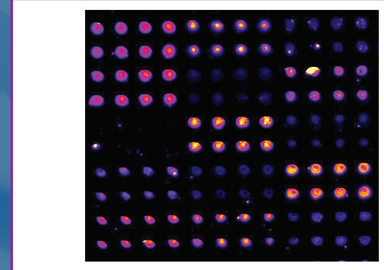

Figure 3 Brighter polymer spots have more mtDNA bound to them and could, therefore, be good at preventing adverse effects of an overactive immune system, such as inflammation.

2. Biomaterials that improve cancer screening

Cervical screening programs are concerned with finding the early and treatable stages of cervical cancer. This involves taking a collection of cells from the uterine cervix and looking through them for cells that look ‘abnormal’. This can be quite difficult if you are looking for one unhealthy cell surrounded by a million healthy cells.

We are investigating whether precancerous and cancerous cells bind to our polymer microarray differently to healthy cells. By incubating the cells with the polymers and then staining their nuclei, we are able to quantify which polymers binds which cells (see Figure 4).

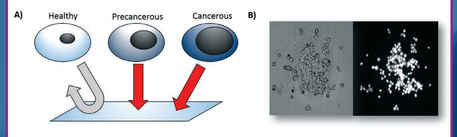

Figure 4 A) Cartoon illustrating the scenario where healthy cells do not bind to a polymer but precancerous and cancerous cells do.

B) Example of a polymer spot that has successfully bound fluorescently-labelled cancer cells, shown as white light (left) and fluorescent (right) images.

What does this mean?

The polymers which we have identified that bind specifically to mtDNA could be used to develop a filter that removes mtDNA from the blood and reduces inflammation in critically ill patients.

If we find a polymer which only binds cancerous and precancerous, but not healthy, cells then it could be used to make cancer screening more efficient.

Who am I?

I am in the final year of my PhD in Chemistry at the University of Edinburgh, funded by Medical Research Scotland. My undergraduate degree is in Biomedical Science, which I obtained from Edinburgh Napier University. Following a short break I returned to education to complete a Masters in Neuroscience at the University of Edinburgh.

Matthew started his PhD project entitled *“Polymers and their Functional Biomedical Applications”* in 2012 and while principally based at the University of Edinburgh, supervised by Professor Mark Bradley, he is also working closely with Altrika Limited.