

JOINT VENTURE

TEAM RESULTS DOCUMENT - JOINT VENTURE

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1 Summary

We are a team of eleven students from nine countries studying at Imperial College London. We have spent the summer designing and building a biosensor from scratch. Our biosensor was made to measure the concentration of Adalimumab (ADL) in plasma for patients with Rheumatoid Arthritis (RA).

We have learnt a lot from working together over the summer and are very thankful to the SensUs organisation for planning such an exciting event. We hope our biosensor is the most accurate, reliable and sustainable. It makes use of $\text{TNF-}\alpha$ bound to magnetic beads and ADL bound to gold nanoparticles (AuNPs) within the sensor. The concentration of ADL is calculated from an absorbance value by spectrophotometry.

The biosensor is accompanied by our app, *ADA*, connected through WiFi, where data can be collated and symptoms logged in a calendar. The app can be accessed by both the patient and doctor, allowing doctors to monitor specific symptoms, customisable for each patient. The app is expected to help patients detect symptoms of side effects including infections and reactivation of diseases such as Hepatitis B and Tuberculosis early. If anything unusual is detected by *ADA*, an alert will appear telling the patient to seek advice from a GP.



Figure 1: Meet the team

2 Biosensor System and Assay

2.1 Molecular Recognition and Assay Reagents

Our point-of-care system makes use of a magnetic microparticle centrifugation technique coupled with the characteristic bright red colour of AuNPs^{1,2} to give an optical readout proportional to the concentration of ADL in the patient's plasma. In recent times, magnetic biosensors based on superparamagnetic bead labels have attracted the attention of scientists worldwide due to their potential in the development of high-sensitivity biomolecular monitoring systems.³ Compared to other immunosensing techniques, magnetosensor-based biosystems are easy to operate, give a fast response, are entirely lab-free and are highly sensitive. Therefore, immunosensors which rely on magnetism techniques are highly applicable for point-of-care biomolecular monitoring systems.

The conjugation of different functionalised groups to AuNPs and magnetic beads is crucial for their stability, functionality and biocompatibility.¹ Antibodies and antigens such as TNF- α can be attached to the surface of magnetic microparticles and AuNPs using a variety of conjugation techniques such as streptavidin-biotin attachment, carbodiimide coupling and passive adsorption. Our assay uses streptavidin-biotin bridges due to their well-established chemistry and the strong non-covalent interaction between the proteins.⁴ The biotin label is small and stable and as such rarely interferes with the function of labeled molecules, enabling the streptavidin-biotin interaction to be used in the development of robust and highly-sensitive assays such as ours.⁵ Our sensor relies heavily on this coupling technique as this is what forms the bridges between not only our magnetic beads and TNF- α , but also between ADL and the AuNPs.

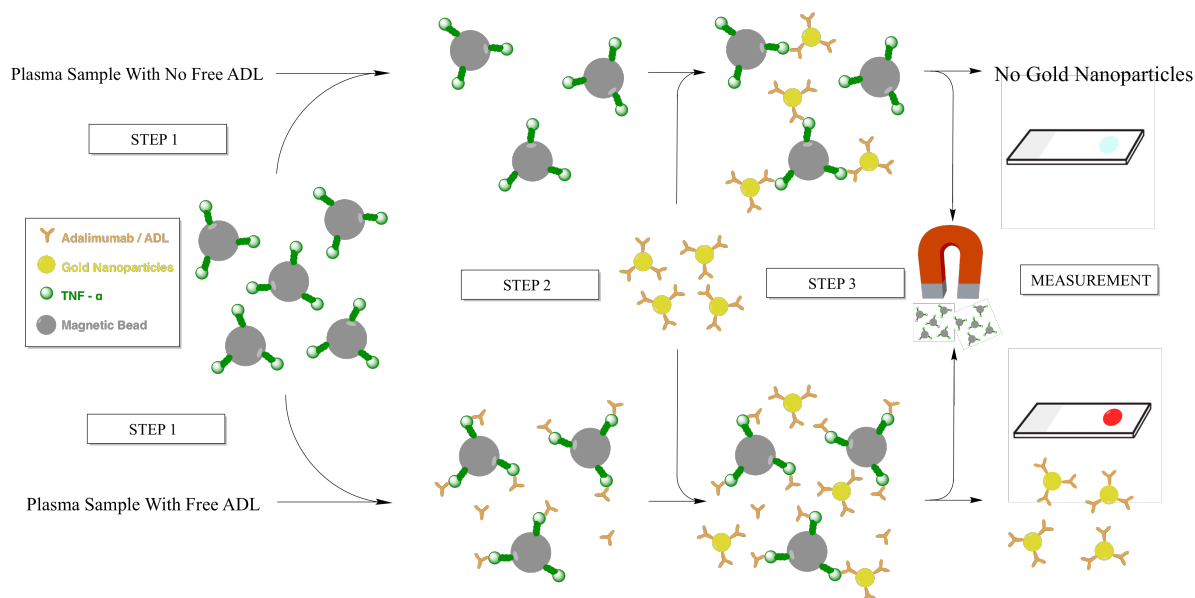


Figure 2: Schematic of the Reaction Occuring Within our Sensor

In the first step of sensing, a sample of serum from the patient is added to a solution of TNF- α coated magnetic beads. The resulting solution is mixed and allowed to incubate for one minute on our slide. This allows any free ADL in the patient's serum to bind to the TNF- α on the surface of the magnetic beads. An ADL concentration of 10 $\mu\text{g/mL}$ in the plasma will occupy all of the available sites on TNF- α . In the next step, the detection molecules (ADL-coated AuNPs) are added to the solution and allowed to mix and incubate. The ADL bound to AuNPs then binds to any remaining unoccupied sites on TNF- α . A magnet is used inside our biosensor to remove the complex of magnetic beads and AuNPs that has been formed, resulting in a pellet at the bottom of our cartridge. This leaves any unbound AuNPs in the supernatant. The absorbance of this supernatant is then measured independently of other components in the reaction, with the intensity being proportional to the ADL concentration.

2.2 Physical Transduction

A blood plasma sample with a high concentration of ADL will give the strongest coloured solution. Conversely, a blood plasma sample with a much lower concentration of ADL will give a near colourless supernatant.

The intensity of the coloured AuNP solution is proportional to the concentration of ADL in the sample, this

intensity is measured as an absorbance value. This is carried out within our biosensor by AS7262 the spectrophotometer with an open-source Python Library. The spectrophotometer has 6 channels in the visible light spectrum each with a resolution of 40 nm. 540 nm light is shone on the slide cavity with the solution. The depth of the slide is chosen to optimise the distance over which light travels. The light absorbed with the solution will be compared to that of clear water and absorbance will be measured. The sensor casing is designed to align all elements of the sensing process as accurately and robustly as possible while also blocking external light sources which would be represented as noise in our measurements.

2.3 Cartridge Technology

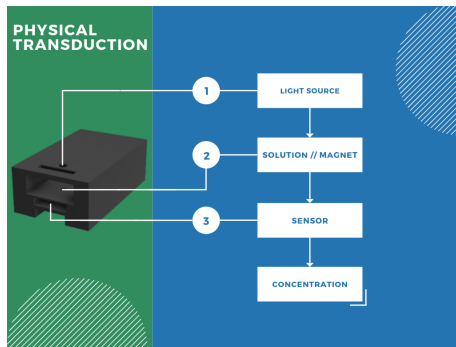


Figure 3: Schematic of the Cartridge in our Sensor

channel has been engraved to side of the cylindrical hole in the slide for the magnetic beads to be pulled out of the light path with the magnet. The slide is inserted into the cartridge holder which is seen in Figure 3, the slide is easy to handle and very robust making it perfect for use in a biosensor.

2.4 Reader Instrument and User Interaction

As mentioned in the previous section, the design of our current biosensor relies on manual handling of the three reagents onto the cartridges. This increases the risks associated with cross-contamination and patients being exposed to potentially harmful chemicals. In the future, we are planning to eliminate these risks by developing an automated sensor. The user has to place the cartridge into the cartridge holder as shown in Figure 3, the clear acrylic cartridge fits into the holder and can be placed in easily.

Our biosensor's screen is the main communication point for the patient, with our app *ADA* acting as a tool to use alongside for tracking and management. There is a large, easy to use touch screen (7 inches - See Appendix II), housed in a sensor 20 by 14 by 10 cm in size. The large screen is especially important for patients with severe RA who have lost some dexterity in their fingers. This consideration was highlighted in our survey of RA sufferers, carried out in large RA Facebook groups.⁶ Replies included "simple tasks are painful" and "...hands and wrists are swollen". This has guided our app and interface design to ensure that the technology is as accessible as possible. The interface is run on a Raspberry Pi Model 3 with a display module, and the *ADA* app was written with the support of the KiVi Library in python.

The market research also guided the direction in which development of the sensor progressed. Looking at the responses to the question regarding the preference of an app or a physical sensor, 61.5 % preferred a physical sensor whilst the remaining 38.5% would prefer an app. We used this as an indication of our market preference and hence designed a simple physical sensor accompanied with an app to please both groups, as both represent a significant portion of the RA community.

The app *ADA* enables patients to rank their daily symptoms on a sliding scale from red to green, customising which symptoms they wish to track alongside ADL concentration. This allows patients to feel involved in their treatment, which is shown in studies to be beneficial in therapies as participants can see how the drug is working for them⁷. Another feature of *ADA* is plotting graphs of the past concentrations and symptom severities recorded by the user. This feature is helpful when a relation between symptom severity and concentration is necessary. For a video walkthrough of our app click [here](#).

Once the biosensor is connected to the patient's *ADA* account, a start button will automatically initialize the sensor and it will upload the data to our database server. This data will then be sent to the app *ADA* via WiFi. If no connection is available, this data can be easily added manually into the app.

3 Analytical Performance

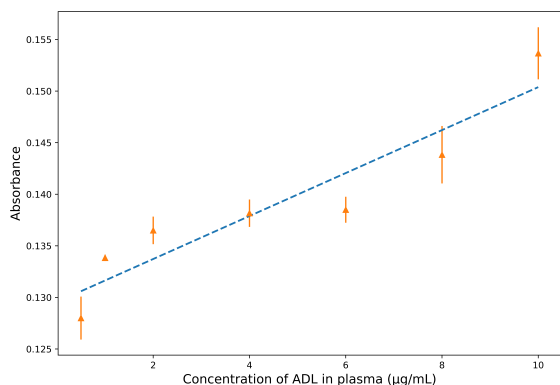


Figure 4: Graph of Absorbance against Concentration of Adalimumab in plasma using Nanodrop Spectrophotometer. The set up using our biosensor is still in the process of optimisation.

used in each assay was determined. In each attempt, the volume of AuNPs was kept constant at 5 μL and the volume of magnetic beads was varied from 5 μL to 20 μL . A final volume of 4 μL of magnetic beads was chosen making the final ratio of magnetic beads to AuNPs 4:3. This volume of magnetic beads was selected because at this volume, all the AuNPs are complexed and the absorbance of the supernatant is closest to 0.

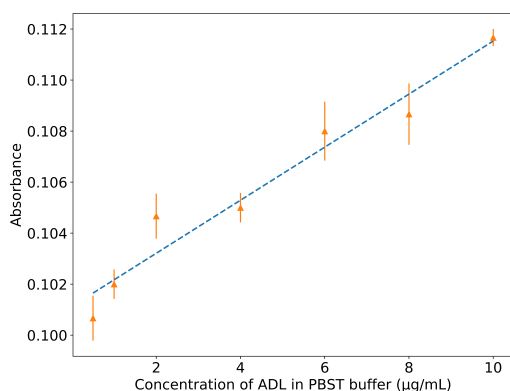


Figure 5: Graph of Absorbance against Concentration of Adalimumab in PBST buffer using Nanodrop Spectrophotometer. The set up of using our biosensor is still in the process of optimisation.

calibration curve is currently being optimised for our prototype. The equation for the fitted curve was found to be $\text{Absorbance} = 0.002 \times \text{Concentration} + 0.129$ with an uncertainty of 21.6% in the slope and 1.9% in the intercept. Our laboratory does not have clearance for human plasma, so this may cause calibration issues in the competition, we hope that our assay is robust and specific enough to avoid this.

In our final assay, 3 μL of plasma is added to 4 μL of magnetic beads. The resulting solution was mixed for 1 minute using a micropipette and allowed to stand for 1 minute as found from our kinetics study. Following this, 3 μL of AuNPs were added and allowed to mix for a further 1 minutes. The magnetic beads were then drawn across the cartridge channel using a magnet, and the absorbance intensity of the resulting supernatant was measured

Before analysis and calibration of our machine could be carried out, protocols for the synthesis of our reagents needed to be developed and optimised. With Streptavidin-biotin chemistry being so well studied, standard biotinylation protocols were available as a starting point for the conjugation of biotin to ADL.⁸

Both the attachment of TNF- α to magnetic beads and the subsequent binding of ADL to AuNPs rely heavily on Streptavidin-biotin chemistry. To quantify the degree of biotinylation of ADL, the 4'-hydroxyazobenzene-2-carboxylic acid (HABA) assay was carried out. The results of the HABA-Avidin assay showed that each molecule of ADL had approximately 31.3 molecules of biotin bound. Secondly, 81% of the biotin in human plasma exists as free biotin that is not bound to any protein.⁹ Therefore, to avoid any non-specific binding and hence interference with our assay, free biotin was added to the solution of magnetic beads to block any free Streptavidin sites that were not occupied. Finally, excess biotin was removed by centrifugation and PBST washes.

Next, the ratio of AuNPs to magnetic beads to be

Following confirmation of the success of the assay using a Nanodrop Spectrophotometer, we began to take readings within our sensor. Multiple cartridge sizes were tested, with reaction chamber ranging from 2 to 6 mm in diameter, and from 2 to 5 mm in height. Our final cartridge uses a well of 4 by 3 mm as a compromise between having a small sample volume yet a long path length.

The kinetics of our reaction were observed to progress differently when in an Eppendorf tube compared to the cartridge, so multiple tests were run to maximise the absorbance obtained in practice. Times for reaction were varied from 1 to 3 minutes between the addition of each reagent. It was found that leaving the reagents to react for 1 minutes gave enough time for a reproducible result, maintaining a short time-to-result.

The calibration curves measured on Nanodrop are presented in Figure 4 and 5, showing results in both PBST (x10 dilution of 0.2 mM Na_2HPO_4 , 0.5 mM KH_2PO_4 , 1.3 mM KCl, 135 mM NaCl, 0.05% Tween® 20, pH 7.12) and in foetal bovine plasma. The cali-

using our biosensor after 30 seconds. This gives us a reading within 5 minutes with a dilution ratio of 1:2.3.

4 Novelty and Creativity

4.1 Already Available

AuNPs are currently employed in a variety of biomedical applications by various conjugation methods due to their size dependent chemical, electronic and optical properties.¹⁰ Their characteristic bright red colour has been utilised in our assay, allowing absorbance measurements to be taken. The dimensions of AuNPs are comparable to those of biomolecules such as proteins and DNA, whose dimensions are in the range of 2-20 nm, thus imparting a structural compatibility between these two classes of materials. However, despite these developments, only a small number of biosensors using gold nanoparticles have been used in practice in the detection of analytes in biological samples.¹¹ The transition from proof of concept to market biosensors requires extensive long-term reliability and shelf-life testing, and modification of protocols to make them safe and easy to use by doctors.

Magnetic biosensors have also received significant interest as a promising candidate for the realisation of highly sensitive biosensors.¹² In addition to high sensitivity, magnetic biosensors also display the unique ability to modulate biomolecules by applying a controlled magnetic force. Immobilising biomolecules onto the particle's surface results in a number of additional functionalities. For instance, the transport of biomolecules to a specific location on the chip; on-chip magnetic immune-separation of biomolecules and accelerating biomolecular binding events.

Multiplex bead array assays such as the one used in ours have already been applied in many clinical applications to replace the traditional ELISA based assays. This is due to their ability to determine the concentration of multiple analytes simultaneously in small volumes of solution and in a short time.¹³

Despite promising research, there is no commercially ready biosensor that brings all these technologies together yet. We hope we can bring ours to the market within a few months, alongside our app - which few other biosensors currently offer. We hope to be market leaders in integrated biosensing and patient-doctor communication solutions by eventually producing a universal bioanalyte detection unit.

4.2 New Developments

The main novelty of our biosensor lies in the combination of AuNPs and magnetic beads. The measurement is fast due to the quick attraction of magnetic beads to the magnet and the intense colour of the AuNPs, giving an accurate and reliable response each time.

Our biosensor enables patients to learn more about managing their condition through tracking symptoms and ADL levels across time using our app *ADA*. Healthcare professionals will also be able to track ADL levels on their side and spot if patients need to change drug, dose or see if something else is happening. The app and the sensor help patients and doctors push towards personalised medicine, with each patient being able to change dose frequency or drug much quicker due to the amount of data collected using our app.

The app allows patients to quantify their symptoms and level of pain on a daily basis using a sliding scale of green to red, a method proven to be successful in the measurement of a patient's discomfort levels.¹⁴ This means that when patients visit healthcare professionals for their RA appointment, correlations can be drawn between pain levels and ADL concentrations for the **first time**. This incorporation of patient feedback directly into the treatment plan is *breaking new ground* for biosensors.

Since the currently available testing methods use high dilution ratios and long incubation time,¹⁵ we have developed a sensor that is fast, reliable at low dilutions and requires minimal sample preparation.

In our assay, concentrated AuNPs (3 μ L) and magnetic beads (4 μ L) lead to a small volume of plasma (4 μ L) and therefore a low dilution ratio of 2.5 for each measurement. This is much lower than an apDia¹⁵ assay, which uses a 1:99 ratio in the same concentration range and needs 10 μ L of plasma and takes 1 hour 40 minutes for a result - ours can be achieved in less than 5 minutes.

The speed of result enables doctors and patients to spend less time waiting, making face to face appointments more worthwhile as results are available immediately without the need of a full blood test. We aim to develop our sensor in future such that a single drop of blood is all that is required. This directly cuts both the cost to the patient in travel to and from the clinic, and the cost to the healthcare provider of being able to do their reading during their appointment.

We also aimed to design a sustainable prototype and minimise our carbon footprint. This led us to utilising some Green Chemistry to reduce AuClH₄ with fructose-containing honey. This is more sustainable than using reducing agents such as sodium citrate tribasic dihydrate, and can easily be upscaled.¹⁶

5 Translational Potential

5.1 Stakeholder Desirability

Distribution of ADL around the body occurs through lymphatic vessels post intravenous dosing. This is a slow process leading to large variations in the time it takes for the drug to be fully absorbed by a patient.¹⁷ Very low concentrations of the drug must be maintained in a narrow therapeutic range (between 5 and 8 $\mu\text{g/mL}$ of blood) through the administration of one or two IV doses of ADL per week.¹⁸ Dosing outside of this range has been shown to lead to sensitivity at the site of injection, and in some cases can reactivate Tuberculosis and Hepatitis B in previously infected patients. This can lead to hospital costs associated with both the treating of diseases, and the damage that often results from side effects. An accurate point of care biosensor to measure ADL concentration will help to monitor patient reaction to the drug, minimising the drug prescription volume, and can help to reduce direct and indirect costs of care for patients following this treatment plan. The accompanying app *ADA* will prompt the user to check for common symptoms of infection, which affects 36% of patients annually with an associated treatment cost of £944–1,556 per patient.¹⁹ Catching side effects such as these early will hasten recovery and minimise costs to hospital management.

Improving the reliability of ADL will reduce the frequency of observed side effects such as developing immunogenicity,²⁰ increasing the popularity of ADL as a treatment option within the RA community. This translates to a better drug reputation for pharmaceutical companies, and will increase patient confidence in the therapy. A reduction in the risk associated with prescription of the drug will benefit health insurance companies, as fewer payouts will need to be issued for the treatment of ADL induced conditions.

Current available sensors on the market rely predominantly on fluorescent ELISA based assays, which take a long time to process and must be outsourced and run in bulk to minimise costs. These large scale tests require prior dilution, increasing processing time, costing the healthcare service upwards of £140 per reading.²¹ These methods are expensive, hard to reuse, and therefore create large volumes of wastage. They often require sophisticated or expensive equipment and highly trained professionals to operate. It is also important to consider the fact the biosensors that are currently available are difficult to miniaturise, thus rendering them unsuitable for transfer to point-of-care platforms. Consequently, effective methods with high sensitivity, rapid response, low cost and easy operation are in high demand for the detection of ADL.

Our sensor provides a near instant reading of the sample, cutting down processing time from the current industry standard of two days²¹ to less than three minutes. After speaking with Dr Martin Perry, who practices Rheumatology at the University of Glasgow, we found his patients have to wait two weeks for results in their next appointment. Our sensor's speed enables patients to be able to discuss results immediately with their doctor, less travelling to and from clinics for patients. Our initial prototype fills the need of a point of care device for use by medical professionals in a hospital. Our market research through RA patient groups online (Facebook) and in person has shown that there is more demand for a device for use by healthcare professionals in the clinic than there is for a personal biosensor at the moment.⁶ We hope that in future development we can minimise the cost and size of the device, allowing a patient to monitor their own ADL concentrations at home to build up their distinct pharmacological profile. The short measurement intervals that this allows can build a clear picture of the drugs action on each individual patient, pushing treatment towards personalised medicine with the help of our app.

5.2 Financial Viability

The total cost of the biosensor prototype has been kept low through the use of cheap electronics such as the Raspberry Pi, and low-cost acrylic for the housing. The total cost of the prototype sensor excluding the cost of the biochemistry experiments came to £250, but with mass production techniques, the total sensor cost can be reduced to £220 in the first year of operation by ordering components in larger volumes. This will further decrease to £200 and £175 in the second and third year respectively when bigger investments and larger orders can be made. The total cost of the prototype development and calibrations was £2200.

The second source of expenses in terms of biosensor function comes from the development and maintenance of the accompanying app *ADA*. As our company branches out to develop detection solutions for other antibodies and proteins, the hardware will not have to change, but the software will be updated on a rolling basis to include calibration curves for all relevant analytes.

Each test costs £1.62 in reagents, the cartridge costs £0.03, giving a total cost per test of £1.65. We aim to make 60% profit on each cartridge and the refill reagents, selling the cartridges for £5.00 and the refill reagents at £253.42 for 100 tests. The cost to us will lower as the volumes increase from these initial costs from ordering

small quantities from each supplier. As our ordering volumes increase we will also have more buying power and be more able to negotiate on price, reducing the costs to the end consumer significantly.

We aim to loan our sensor out to hospitals and healthcare professionals for a nominal fee of £1200 per year which includes basic maintenance, software and hardware updates, and continued app development for all patients enrolled on the program. We have chosen a loan based system as it enables us to upgrade our sensors and ensures every hospital will have the most up to date software and hardware. It also means that we can provide support in rolling out the app to the hospitals using our sensors easily and encourage more patients to enroll on ADA.

At the moment each test costs the NHS £140 in the UK.²¹ If a hospital loaned our sensor and did 400 tests a year (an average 8 tests a week) our sensor and testing would cost just £2233.68 plus staffing costs rather than the current £56,000 per hospital. The staffing costs for our sensor would be lower than a traditional blood test as it can be done during the doctors appointment with results available straight away rather than needing a follow up appointment - potentially halving staffing costs if patients only need one appointment. The sensor and tests would cost 4% of the current NHS standard. We hope that the monetary saving alone per test would enable us to be trialled in the NHS very quickly.²²

The two main revenue streams would be the revenue generated from the loan of the sensors, and the continued selling of the refill cartridges and reagents for each test. Our main outgoings will be cost of manufacture, testing (including cost of laboratory space and prototyping), sustainable AuNP synthesis, magnetic bead synthesis, advertising and labour costs. The full cost analysis is outlined in the Appendix, we aim to either crowdfund or use investors to raise initial investment in Year 1 and Year 2 to enable us to start manufacturing and scale up ready for market within a few months and expand beyond the UK in Year 2.

Following all development and testing, our initial release into the UK market estimates a 4% first year market penetration.²³ There are at least 1140 registered rheumatologists²⁴ in the UK which gives us an estimated 46 units loaned in the first year. After the first year we would continually listen to feedback from patients and doctors leading to us being able to improve our biosensor, software and app throughout our first year. This will be before approaching large American healthcare providers such as United Healthcare and Blue Cross in our second year. However, due to the uncertainty surrounding the UK's exit from the European Union, the planning of our expansion beyond the UK market is challenging. We hope following 31st October 2019, the situation will be clearer.

According to the NRAS more than 400,000 people in the UK suffer from RA,²⁵ of which 20,000 to 24,000 are currently on ADL. An estimated 10,000 to 12,000 patients will face issues such as over and under dosing, with up to 4,000 having to change drugs as a result.^{21 26} This means our point of care biosensor, in the UK alone, could directly impact 10,000 patients on a fortnightly basis.

Looking beyond the UK market, 1.5 million people²⁷ in the USA suffer from RA, at least 75,000-90,000 of which are on ADL. An estimated 37,500-45,000 might have issues leading to 11,000-18,000 potentially having to move on to other drugs. This means our sensor could help 37,500 patients in the USA with regular ADL readings to manage their dosing. The presence of the patent in the US coupled with the lack of universal healthcare means our service will provide an even greater financial benefit to consumers compared to the UK (\$2669 in the US and \$1362 / £1126 in the UK for one month of treatment).²⁸

5.3 Business Feasibility

Mass commercialisation and widespread reach of our biosensor will require the product to undergo clinical testing to the standards of each country in question. At present, the three year plan proposes initial entry into the UK market, with an estimated market population of 1140 rheumatologists.²⁴ During the second year expansion into the US market, our sensor must be compliant with FDA²⁹ regulations for medical devices to gain approval, and initial funding for this will come from first year income and an investment of £100,000 in our second year. The US market is the largest in the world, with RA affecting 2.65% of the total population, a value which is 1104% of the worldwide average.³⁰ The renewal of the ADL patent in the US provides additional need for a sensor, as any financial benefit from the reduction of overdosing will be amplified by the increased cost of the antibody to the customer. Furthermore, the global biosensor market has an annual growth rate of 9.4%, meaning by 2027 the market will reach 1.4 billion US dollars globally,³¹ which implies that there is a large enough market for our sensor which will soon be able to detect many other antibodies and proteins just as quickly with a change of reagents.

6 Team and Support

6.1 Team Members

The team was split into two groups to make the best use of all of our skills. Minimal group division ensured the whole development ran smoothly as a collaborative project between disciplines.

Chemistry - Angharad Smith, Joe White, Sam Hopgood, Elsey Chen, Rachel Chan and Dorottya Szalay.

Engineering - João Baptista, Albert Fleta, Leonidas Goudelis, Soleiman Anwary and Jonathan Martin.

The chemistry team focused on building the assay, on binding methods of proteins to AuNPs and proteins to magnetic beads as well as the overall bio-assay optimisation. In addition, the Chemistry team was also responsible for building the business model and planning of the pitches.

The engineering team focused on designing and building the biosensor, cartridges and the app. Albert coded the app, allowing patients to track symptoms and dosage simultaneously.

6.2 People Who Have Given Support

Professor Tony Cass - Coached us and provided with lab space and chemicals from his research group

Dr Thao Le - Provided day to day support in the lab

6.3 Sponsors

We would like to thank the following companies and groups for supporting our team throughout this process:

TTP - Provided invaluable support over the phone and email, contributed towards travel and other expenses.

The Advanced Hackspace Imperial College London - provided technical support and contributed towards costs of building our sensor.

Dean of Natural Sciences Fund Award, Imperial College London - Sponsors of the Chemistry students' living costs for the summer.

Dean of Engineering Fund Award, Imperial College London - Sponsors of the Engineering students' living costs for the summer.

7 Final Remarks

We hope to make our biosensor the most accurate, user friendly and sustainable on the market. Currently, biosensors such as the widely used lateral flow assay pregnancy test have a major impact on the environment. Pregnancy tests generate 100 tonnes of non-recyclable plastic waste per year in the USA alone. This is why we have chosen Green Cast acrylic slides³², which can be recycled once sterilised. In future our biosensor will not need the solutions pipetted using micropipettes and tips. It will have a pump system with replaceable vials of GNPs and magnetic beads which will last 100 tests, reducing our environmental impact and waste per test.

In addition our biosensor is the best for the end-user as the data can be sent to their doctor/medical practitioner via the internet securely. If the levels of ADL drop above or below the expected range a notification appears suggesting you visit your doctor/medical practitioner for a check up. For a walk through of our app check out this video link: <https://youtu.be/miVT7ZejwDc>. Or scan the QR below to access our video!

In the future, we hope our biosensor is compatible with human blood and can be transformed from a prototype to a final product which could be mass market ready within a few months by working with a large manufacturer.

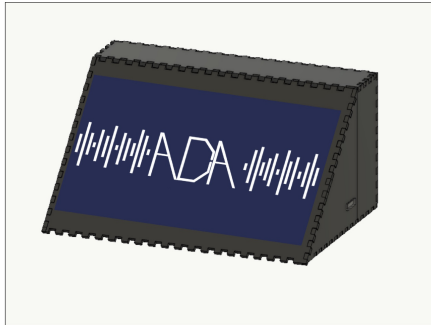
We would also like to thank SensUs for organising such an exciting opportunity, these last few months have been hard work but we are really looking forward to meeting everyone in Eindhoven!

Appendix

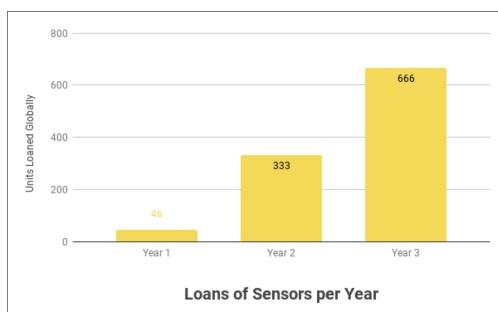
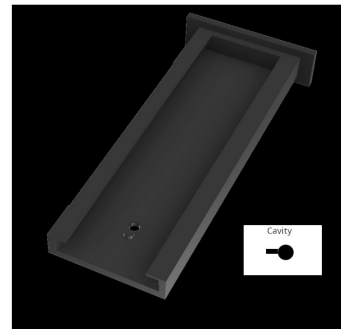
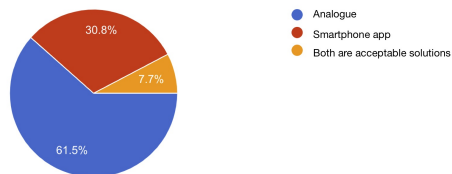
Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer Segments
<p>Many patients are non-responders to the drug, which is only currently found out following unsuccessful treatment (both costly and unpleasant for patient)</p> <p>- There is no current solution to this</p> <p>Humira has some negative side effects including vision problems and shortness of breath</p> <p>- There is no current solution to this</p> <p>Current methods of monitoring blood concentration levels require doctors' appointments booked in advance (time consuming)</p> <p>- This currently requires a Doctor's visit</p>	<p>An easy-to-use and reliable biosensor based around a complement fixation test and detection through spectroscopic analysis. With an app alongside that has results uploaded on it and day to day data is trackable.</p>	<p>Production of a portable cheap biosensor capable of measuring Humira concentration in plasma</p> <p>Readings generated in under 5 minutes</p> <p>Measure concentration of ADL in plasma, giving the amount of ADL needed in the next dose - reducing over dosing and wastage. It is cheaper to use correct amount as this minimise costs associated with side effects and the cost of treatment</p> <p>High Level Concept</p> <p>Provide a biosensor to those with arthritis in the same way glucose biosensors are available to those with diabetes</p>	<p>Exposure at SensUs conference</p> <p>Free consultancy from leading experts TTP</p> <p>Environmentally friendly sensor - reduce plastic consumption</p> <p>Mobile app allows ADL conc. tracking and symptom logging</p>	<p>Customer : Doctors and carers</p> <p>User : Patients</p> <p>Early Adopters : Recently diagnosed patients</p>
Key Metrics		Channels		
<p>Value Metric : Successful ADL concentration measurement</p> <p>Success Metric : Increase the ease and accuracy of dosing of ADL, whilst minimising the cost to medical bodies and patients</p>		<p>Outbound : Facebook, Instagram, Direct e-mail list, Exposure at SensUs conference</p> <p>Inbound : Charity collaboration (Versus Arthritis), NHS board, Private Healthcare</p>		
Cost Structure		Revenue Streams		
<p>Lab Time : £0.00/hr (provided free of charge for 8 weeks)</p> <p>Prototype Materials : Budget of £3000.00</p> <p>Reagent Cost : £2200.00 for prototype</p> <p>Break Even Point : 2.2 years</p>		<p>Subscription based service, renting out a sensor for £1200.00 per year and a 100 test refill for £253.42, and £5.00 for the cartridges.</p>		

Money Out	Year 1	Year 2	Year 3	Totals
Prototyping	£10,000.00	£20,000.00	£25,000.00	£55,000.00
Cost of Manufacturing	£6,900.00	£49,950.00	£99,900.00	£156,750.00
Cost of Cartridges	£138.00	£999.00	£1,998.00	£3,135.00
Cost of Reagents	£7,268.00	£52,614.00	£105,228.00	£165,110.00
Software Updates and Maintenance	£2,000.00	£6,000.00	£10,000.00	£18,000.00
Research into New Drugs	£10,000.00	£20,000.00	£30,000.00	£60,000.00
Labour Costs	£200,000.00	£280,000.00	£370,000.00	£850,000.00
Office/Lab Space	£40,000.00	£40,000.00	£70,000.00	£150,000.00
Promotional Materials	£15,000.00	£30,000.00	£30,000.00	£75,000.00
Travel	£16,000.00	£22,000.00	£27,000.00	£65,000.00
Exhibitions and Talks	£8,000.00	£12,000.00	£15,000.00	£35,000.00
Shipping and Packaging	£874.00	£6,327.00	£13,320.00	£20,521.00
Maintenance of Loaned Sensors	£6,900.00	£49,950.00	£99,900.00	£156,750.00
Totals	£323,080.00	£589,840.00	£897,346.00	£1,810,266.00

Money In	Year 1	Year 2	Year 3	Total
Investment	£100,000.00	£100,000.00	£0.00	£200,000.00
Sensors and Refill Sales	£67,087.32	£485,653.86	£971,307.72	£1,524,048.90
Totals	£167,087.32	£585,653.86	£971,307.72	£1,724,048.90



If you suffer from Rheumatoid Arthritis or know someone who does, would you/they prefer a physical analogue device or one based on a smartphone app?



6

August 2019

Type concentration unit

Symptom 1

Symptom 2

Symptom 3

ADD

+

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