A low cost, point-of-care device to measure blood haemoglobin levels, using calorimetry and infrared spectroscopy.

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Team

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Research associate in Microsystems with expertise in nanotechnology manufacturing processes and IC CMOS-MEMS design for integrated sensors. Will contribute to the electrical design, manufacturing and testing of electronic systems.
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PhD candidate in engineering with skills in bioinstrumentation, fluidics, electronics and molecular biology. Will contribute towards reaction vessel fabrication and general project tasks.
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Summary
Existing haemoglobin testing procedures are ill suited for hospitals with limited resources, particularly in developing countries. In collaboration with the clinicians who need it most, our primary objective is to develop a portable, cost-effective instrument capable of measuring haemoglobin levels to determine if blood should be administered to a patient. We will achieve this by designing, fabricating and optimising a platform consisting of a reaction vessel and integrated electronic systems to control actuators and sensors, for automated bedside sample analysis. We aim to combine various technologies to create a working prototype for a haemoglobin threshold test. Increased access to this test will decrease misdiagnosis rates and save blood resources which are often in low supply.

Proposal
The problem
The burden of anaemia disproportionately affects the developing world. Our survey of clinical practitioners in Zambia, Malawi and Uganda has identified the need for low-cost, point-of-care testing to determine the need for blood transfusion in low-resource contexts. Measuring haemoglobin levels is a vital determinant of anaemia; it contributes to clinical acumen in determining whether a patient is anaemic and requires a blood transfusion or may be managed by other means. Incorrect diagnosis of anaemia accompanies potentially severe consequences; it may compromise diagnosis of an underlying condition, resulting in patient harm or even death, or lead to unnecessary use of limited blood supplies on those who do not need it. Accurate and low cost point-of-care testing would reduce rates of misdiagnosis and potentially save lives by rapidly informing clinicians if a patient's haemoglobin concentration reaches a level that necessitates blood transfusion.

Biological systems
The initial design of the device will be aimed at determining haemoglobin concentration, mean corpuscular volume (MCV) and total iron binding capacity (TIBC) only, as a means of quickly distinguishing between iron deficiency anaemia, anaemia of chronic disease and anaemia secondary to B12 and folate deficiency. The scope of the device may later be expanded to include a range of red cell indices for more thorough diagnostic capacity. We will use human hemoglobin reference serum, bovine blood as a substitute for human blood, and human subjects for pulse oximetry (ear lobes and purlicue). We are also exploring an application for ethical approval use human blood.

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Hardware design goals
We have fabricated a basic colorimetry setup using Arduino starter kit components [3] and have developed accompanying code to read changes in light intensity and control DC motors for syringe pump functionality. We have also explored two iterations of custom built PDMS fluidic chips [4,5] as reaction vessels and plan to evaluate cuvettes and paper fluidics as alternatives. Our aim is to assess the sensitivity of colorimetry and IR spectroscopy[1,2] and then either focus on the method that shows the most promise, or combine both methods into a single instrument. We require the following materials and components to complete this work:

- Arduino MEGA X 1
- Various electrical components and accessories
- Colorimetry
  - LED (539nm)
  - Photodiode
- IR Spectroscopy
  - LEDs (660nm & 940nm)
  - Photodiode
- Sample manipulation
  - Open source 3D printed syringe pump components
  - Syringes, needles, tubing and various plumbing accessories
- Reaction vessels
  - PDMS elastomer fluidic devices
    - PDMS
    - Access to lithography and fluidics fabrication facilities
  - Paper fluidics components
  - Cuvettes
- 3D printed and machined housing components, see [7] for illustrated first mockup

See [8] for details, prices are given for items we are sure to get, and estimates for items we need to purchase once design of the various systems is complete.

Project implementation
We will leverage our team's expertise to simultaneously fabricate electronic instruments and explore different reaction vessel setups. We will then integrate and optimize the instrument, beginning with the simplest configuration (samples in cuvettes) to test key components. Testing of the core sensor technology will be performed alongside optimization of reaction vessels. We will then evaluate the instrument's performance against established methods. See [6] for details of the work package we propose.

Outcomes and benefits
This project will help us explore the feasibility of using off the shelf sensing components to develop a low cost instrument to measure blood haemoglobin levels. In the best case scenario, this project will yield an instrument that will lead to phase two prototyping. Otherwise, we will gain knowledge of the hardware and sensitivity requirements for performing reliable haemoglobin concentration measurements.

[1] Non-invasive blood glucose monitoring using near-infrared spectroscopy
http://www.edn.com/design/systems-design/4422840/Non-invasive-blood-glucose-monitoring-using-near-infrared-spectroscopy
[2] Pulse oximetry benefits from the latest programmable SoCs
http://www.edn.com/design/medical/4419365/Pulse-oximetry-benefits-from-the-latest-programmable-SoCs
[3] Image 1: Cardboard prototype used to test the ability to sense changes in light intensity using Arduino.
[4] Image 2: PDMS reaction vessel version_1
[5] Image 3: PDMS reaction vessel version_2
[6] Image 5: Work package timeline
[7] Image 4: Illustrated mockup of colorimetry instrument housing version_1
[8] Table 1: Budget estimate and components

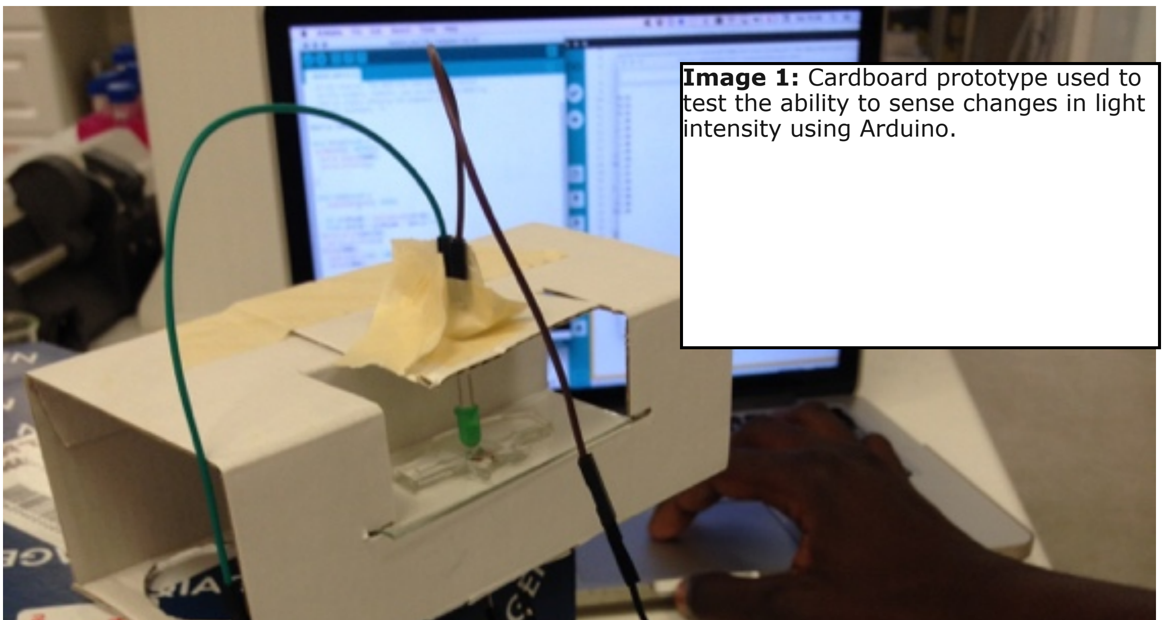
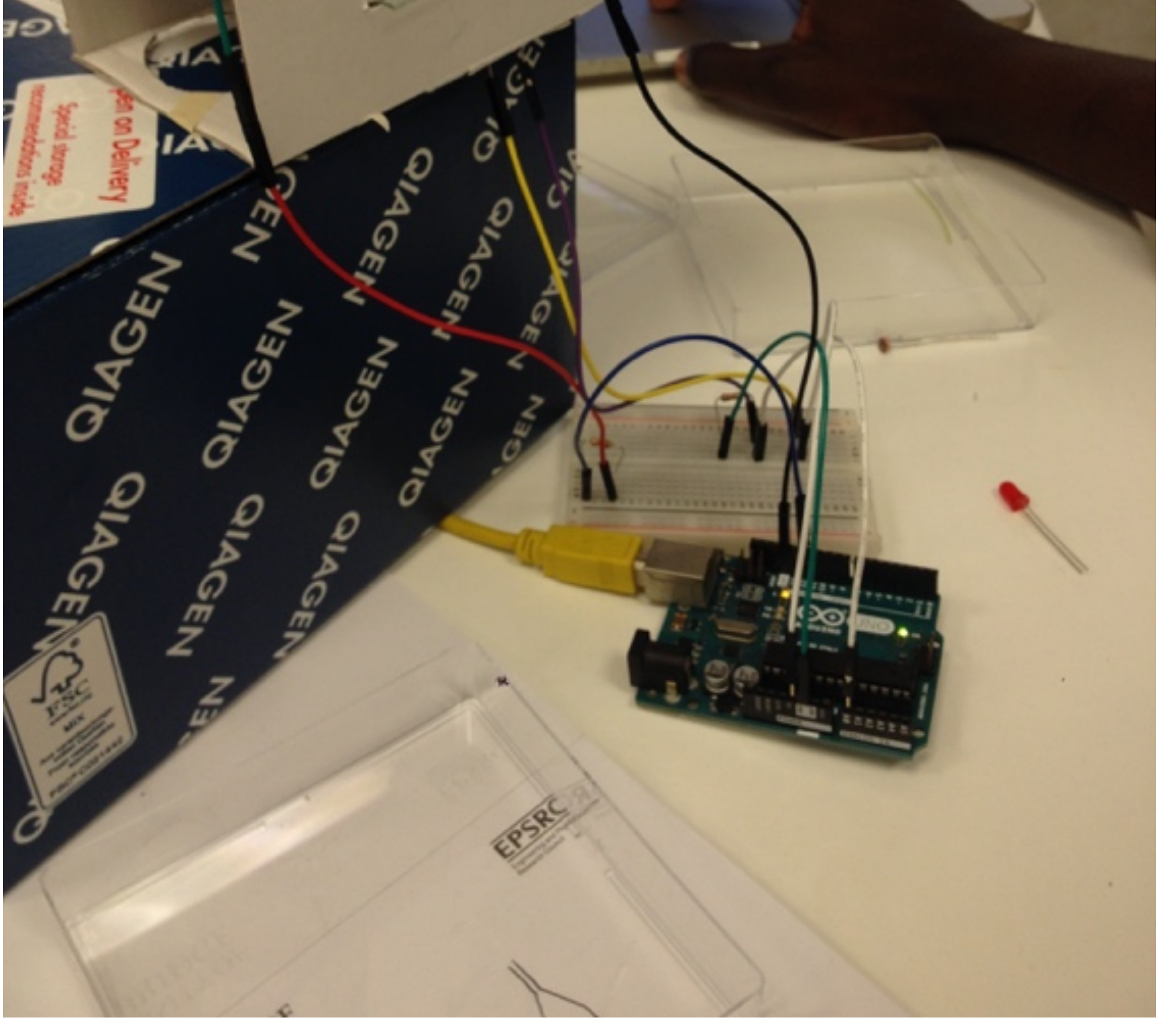


Image 1: Cardboard prototype used to test the ability to sense changes in light intensity using Arduino.



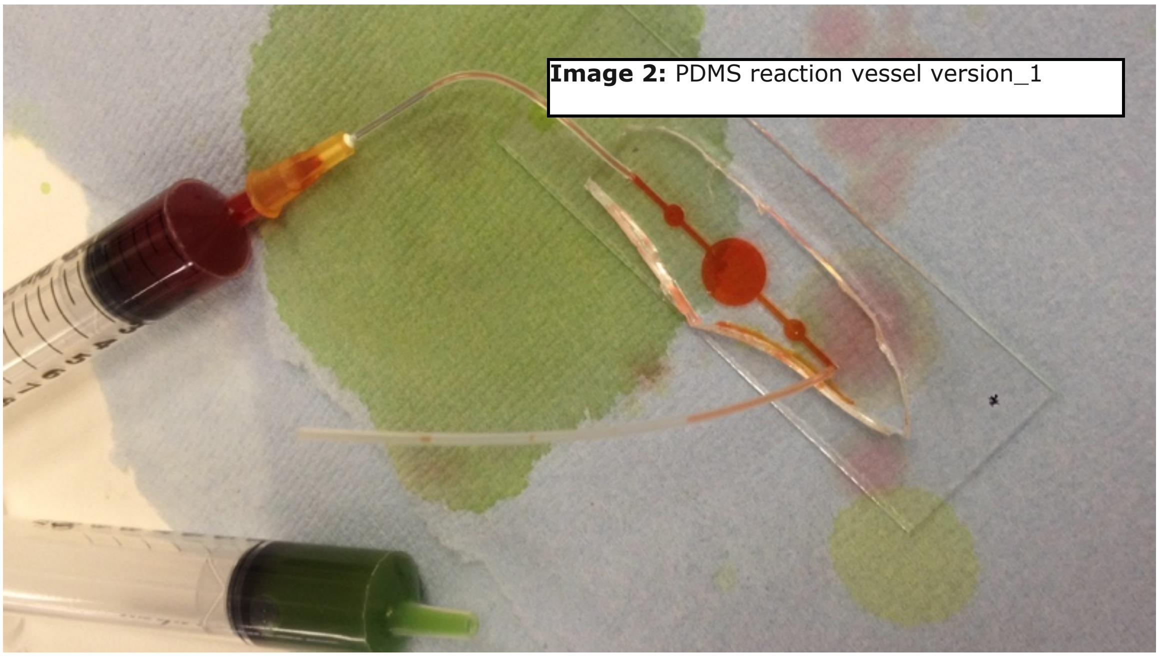


Image 2: PDMS reaction vessel version_1

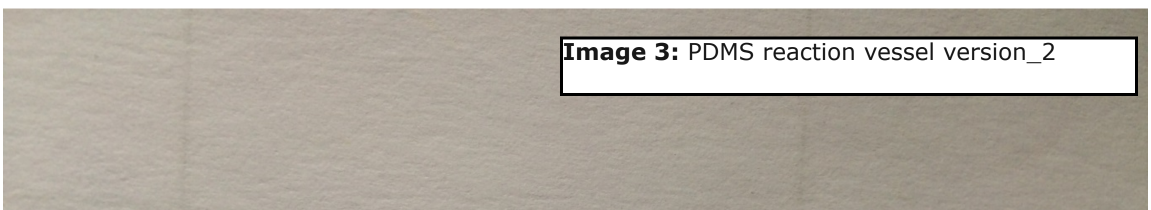
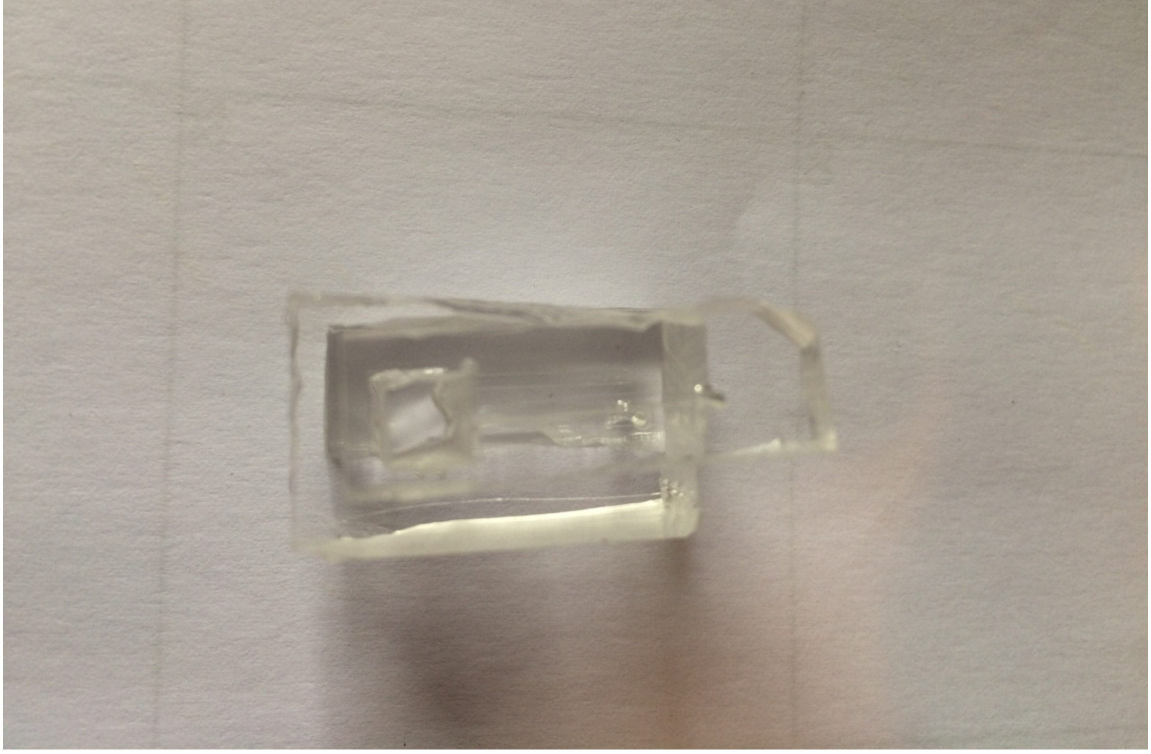


Image 3: PDMS reaction vessel version_2



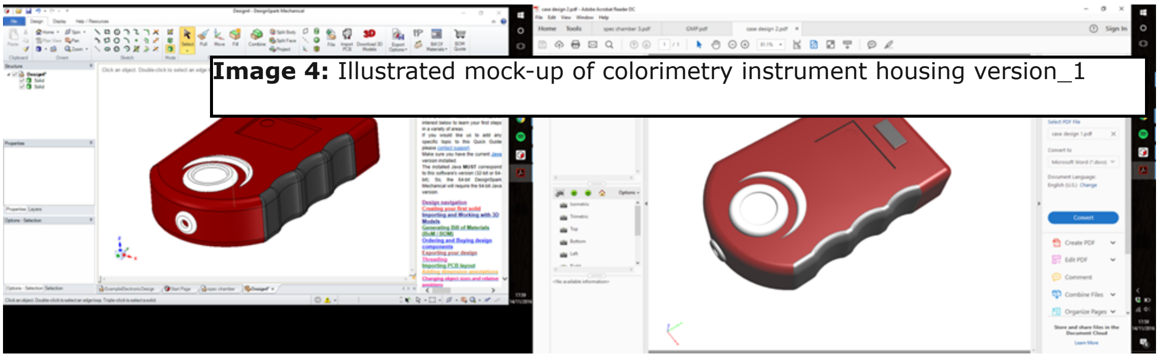


Image 4: Illustrated mock-up of colorimetry instrument housing version_1

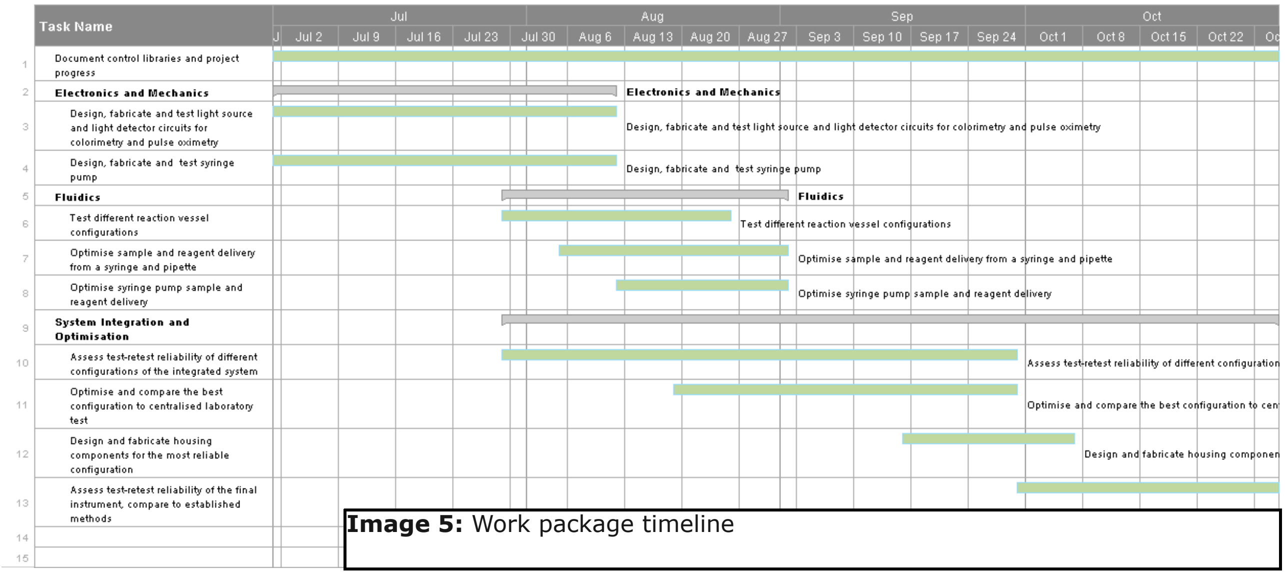


Image 5: Work package timeline

Table 1: Budget estimate and components

Item	Supplier	Cat #	Quantity	Price (each)	Marketplace Item? (Y/N)
Arduino & Electronics					
MEGA	RS components	769-7418	1	£29.74	Y
E-block MEGA shield	RS components	889-2914	1	£17.13	Y

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E-block MEGA shield	RS components	889-2914	1	£17.13	Y
Stepper mottor	RS components	383-1267	4	£10.80	
Stepper mottor	RS components	191-8299	1	£22.43	
Stepper motor drivers				£20.00	
Electronic components and accessories				£50.00	
Vishay phototransistor	RS components	710-3816	1	£1.10	
Phototransistor, 630 nm	Element 14	2453930	10	£0.35	
LED, RED, 1.6MM X 2.3MM, 63MCD, 630NM			10		
Phototransistor, 570 nm	Element 14	1497676	10	£0.64	
Thor Labs integrated sensing components				£300.00	
Reaction vessels					
Chromatography paper	Sigma	WHA3030861	1	£39.02	Y
Cuvettes	Fisher Scientific Ltd	11537692	1	£3.28	Y
PDMS elastomer kit	Onecall	101697	1	£126.26	Y
Sample manipulation					
1ml syringes	Appleton Woods Ltd	GS572	1	£6.90	Y
10ml syringes	Appleton Woods Ltd	GS576	1	£9.85	Y
2ml syringes	Appleton Woods Ltd	GS574	1	£8.56	Y
Tubing				£80.00	
Wet lab reagents					
PBS	Cambridge Bioscience	60-00010-11	1	£28.80	Y
Sodium Lauryl sulfate	Fisher Scientific Ltd	10509770	1	£22.03	Y
Triton-X	Generon	APX405-10X10ML	1	£86.00	Y
3D printing and materials				£50.00	
Other reagents				£50.00	

TOTAL				**£962.87**	