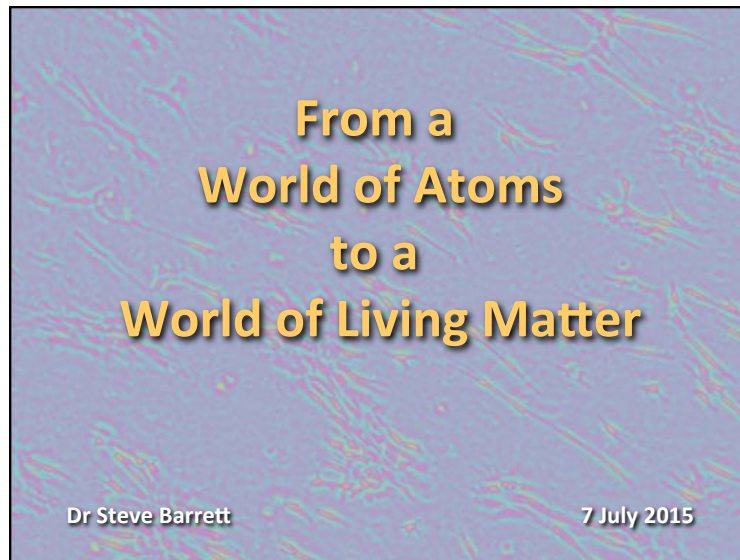


From a World of Atoms to a World of Living Matter



Introduction

A World of Atoms	Imaging atoms, molecules and nanostructures
Perception vs Reality	Why can image analysis be such a challenge?
The Spin-Offs	Applications in earth sciences and medical sciences
A World of Living Matter	Imaging more complex systems
Investigating Cancer	Spectromicroscopy and infrared absorption

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Introduction

This talk is about images and how we look at images in a scientific context. Two concepts are important in what follows:

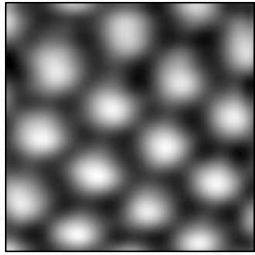
Image Processing	> > >	Interpretation
Image Analysis	> > >	Quantification

The talk will be illustrated with images from research projects old and new, from collaborators and from project students.

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A World of Atoms



On this scale, a grain of sand would be about the size of the Moon.

" To see a world in a grain of sand ... "

William Blake

850 pm

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World of Atoms

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From a World of Atoms to a World of Living Matter

A World of Atoms

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World of Atoms / Scanning Tunneling Microscope

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A World of Atoms

Working with STM images led to the development of image analysis software that supports various scanning microscopy systems:

Scanning Tunneling Microscope

Referring to any/all of these as SXM led to the unpronounceable:

Image SXM

v 1.97

February 2015

Steve Barrett

> 40,000 downloads
in the past 10 years
by universities and
research centres

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World of Atoms / STM / Software

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Image SXM

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World of Atoms / STM / Software / Image SXM

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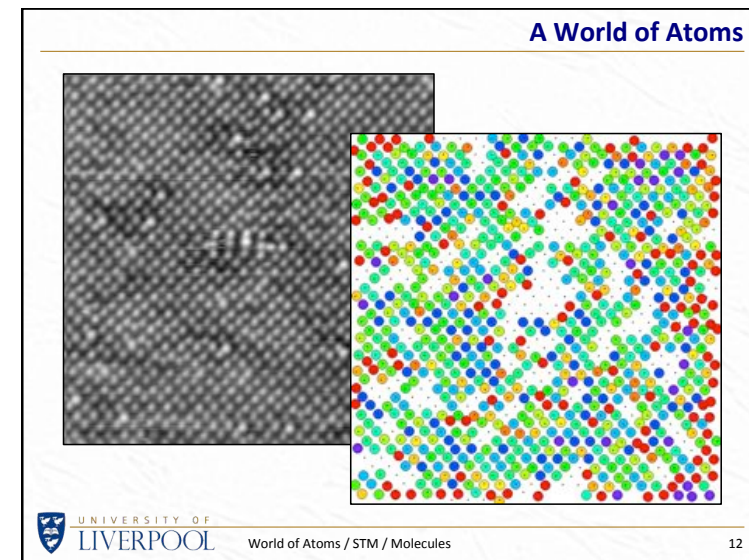
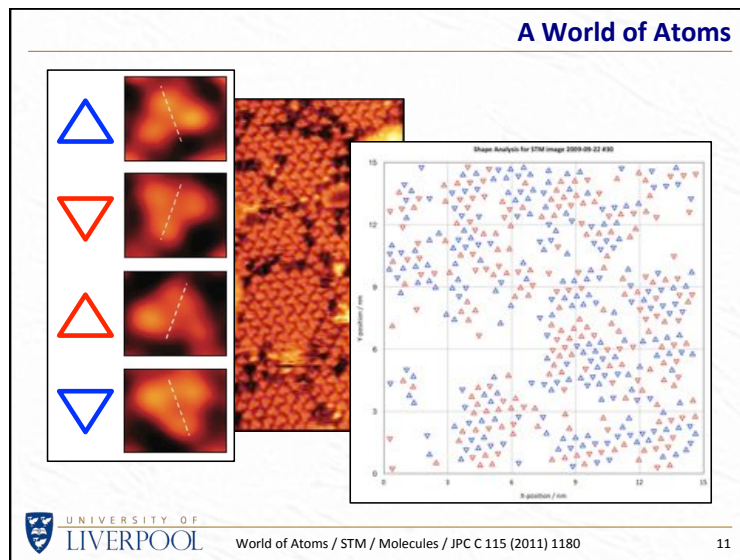
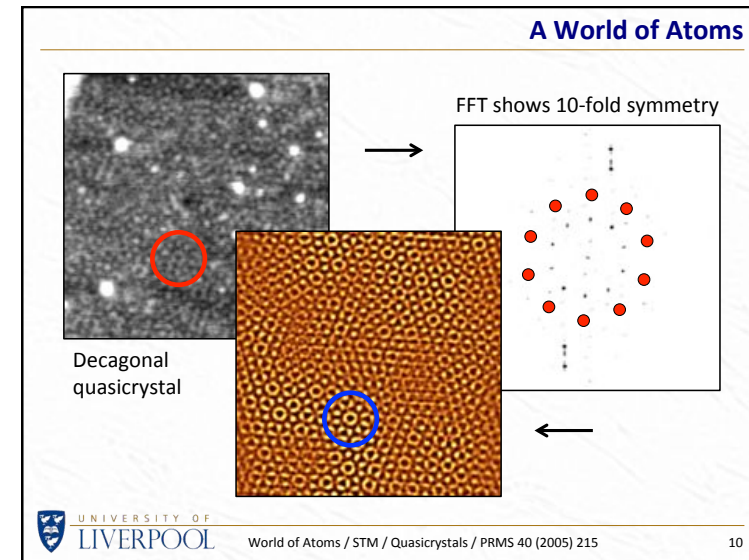
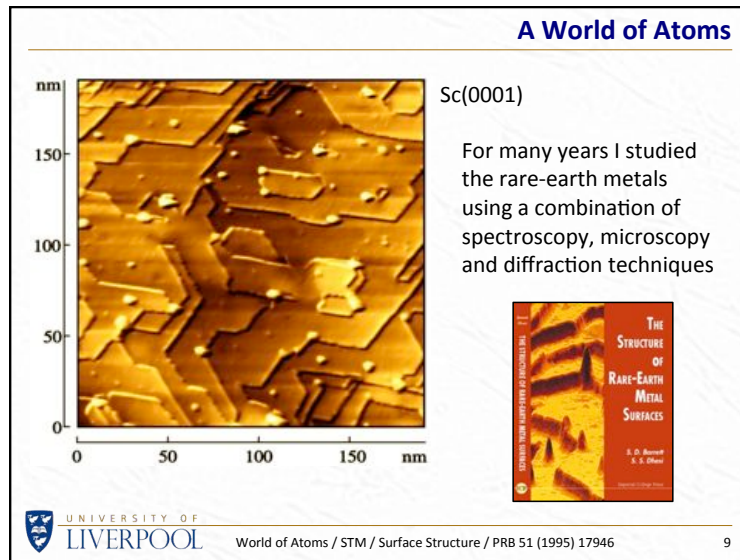
A World of Atoms

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World of Atoms / STM / Surface Structure

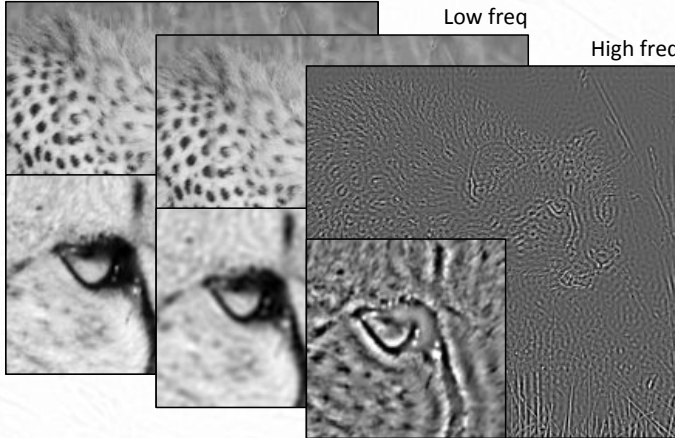
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From a World of Atoms to a World of Living Matter

Beyond Microscopy



Low freq

High freq

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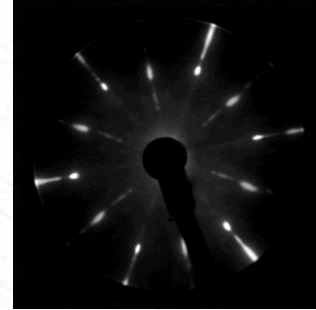
Beyond Microscopy

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Beyond Microscopy

Image SXM has also been used to analyse low-energy electron diffraction (LEED) images of surfaces.

The variation of diffraction spot intensities as a function of electron energy gives information on crystal structures.




Electron energy = 40–150 eV

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Beyond Microscopy / LEED / JCP 123 (2005) 064711

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Astrophotography



The Milky Way imaged from Teide Observatory during the UoL field trip in 2013. Due to the dark skies, very little image processing is required.


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Beyond Microscopy / Astrophotography

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Astrophotography

NGC7000 North America Nebula



Single raw image

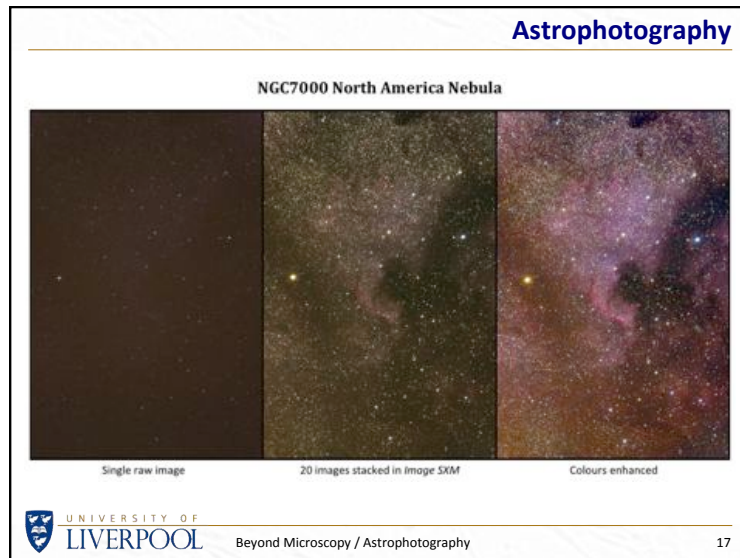
However, under the light-polluted skies of the UK, image processing can bring out hidden structures in a faint nebula.

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Beyond Microscopy / Astrophotography

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From a World of Atoms to a World of Living Matter



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Perception vs Reality

How we perceive images (what we **see**) can be VERY different from the actual information content (what is **there**). In most day-to-day situations we trust the former and don't worry about the latter.

Which is the better image processor?

Brain vs **Computer**

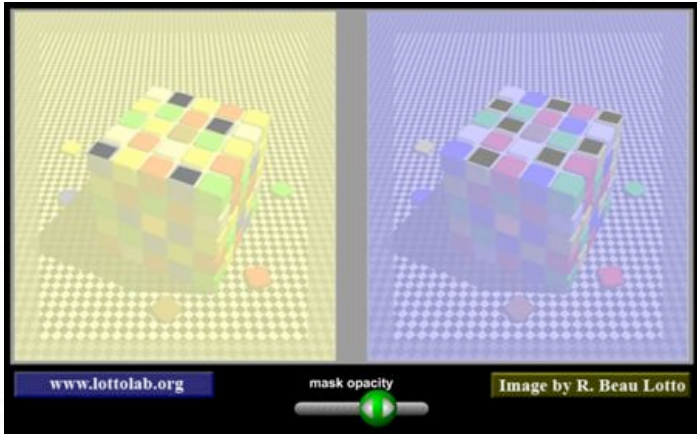
Carbon vs **Silicon**

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Perception vs Reality

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Perception vs Reality



www.lottolab.org mask opacity Image by R. Beau Lotto

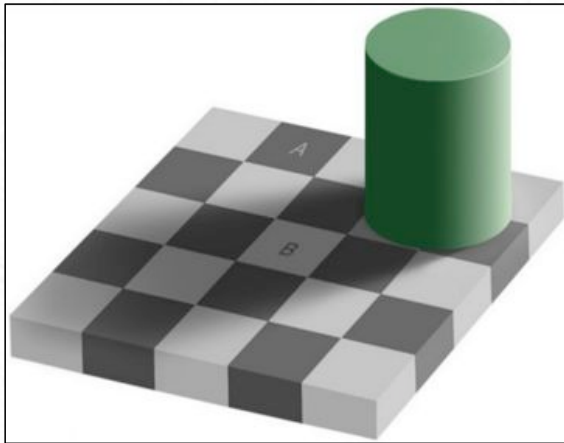
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Perception vs Reality / Colour Perception

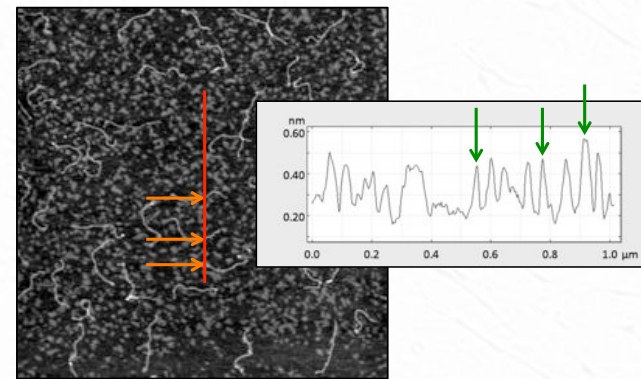
20

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Perception vs Reality

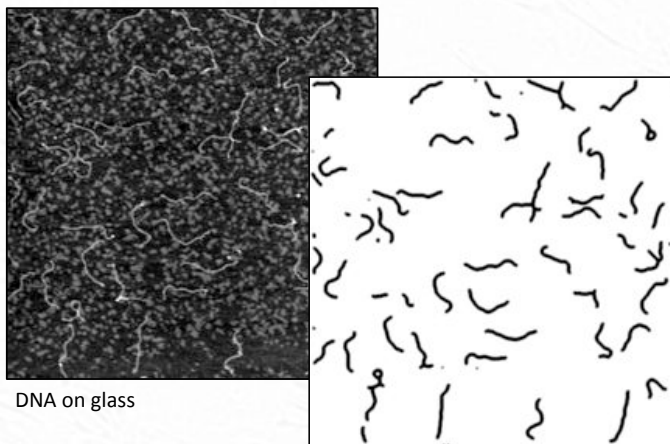


Perception vs Reality



DNA on glass

Perception vs Reality



DNA on glass

Spin-Offs

This is what I do – I find solutions to problems that have not (yet) succumbed to conventional analysis.

I do not have a strong allegiance to any particular techniques or to any algorithms that I have developed. Rather, I prefer to think of every new image as an opportunity to ask...

What techniques might be applied to this image?

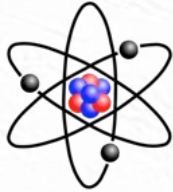
Will a combinations of existing techniques be enough?

Will a new approach, a new algorithm, be needed?


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Spin-Offs


Selecting the 'right' problem that needs addressing is part of what research is all about. The ideal problem lies somewhere between trying to understand...



Too simple




Way too complicated

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Spin-Offs

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Spin-Offs

Applications to disciplines beyond physics and chemistry were a natural consequence of the interdisciplinary nature of image analysis. In particular...

Earth Sciences

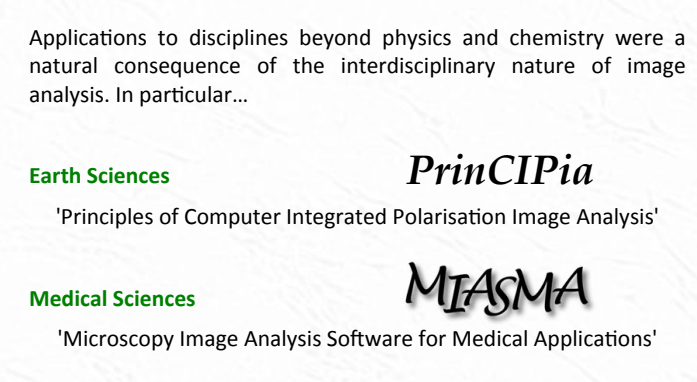
PrinCIPia


'Principles of Computer Integrated Polarisation Image Analysis'

Medical Sciences

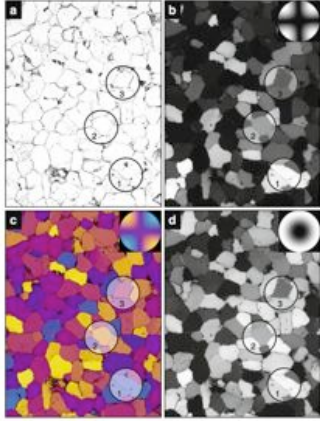
MIASMA

'Microscopy Image Analysis Software for Medical Applications'




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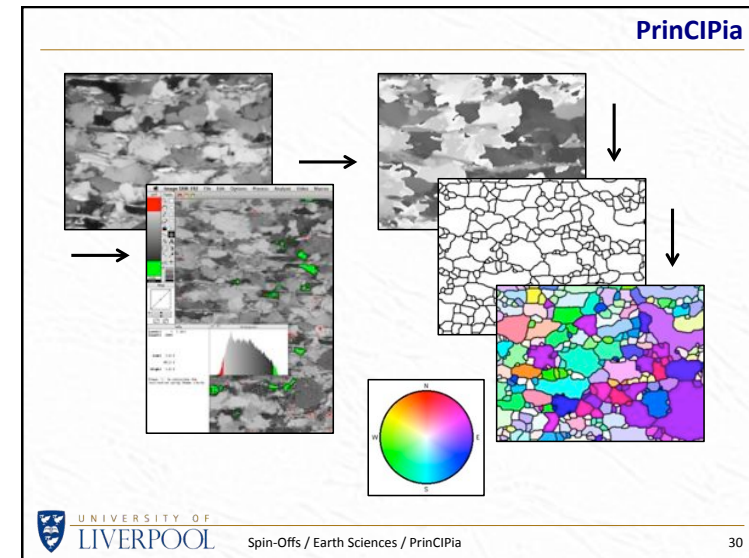
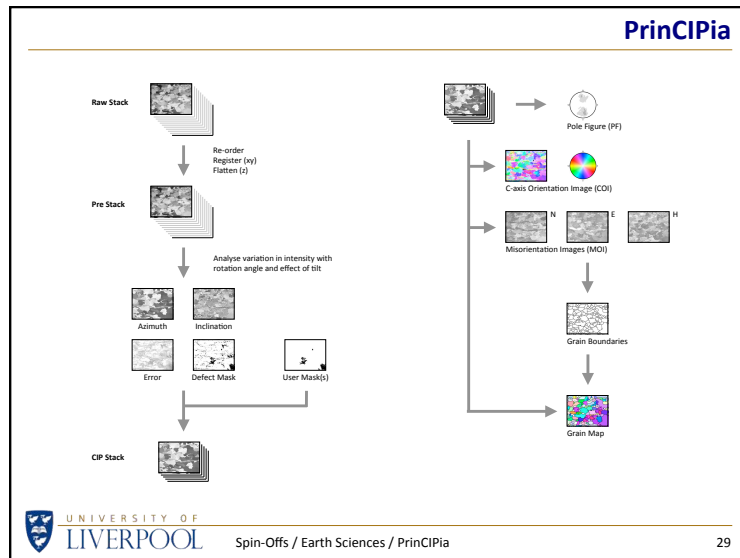
Earth Sciences



Imaging earth materials (to a physicist = 'rocks') using circularly and linearly polarised light produces colours and intensities that depend on the orientation of the crystallographic axes of the grains with respect to the optical axis of the microscope.

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Earth Sciences

Ongoing collaboration with Professor Heilbronner at the University of Basel led to a book on Image Analysis ...
... available at a reasonable price from the author.

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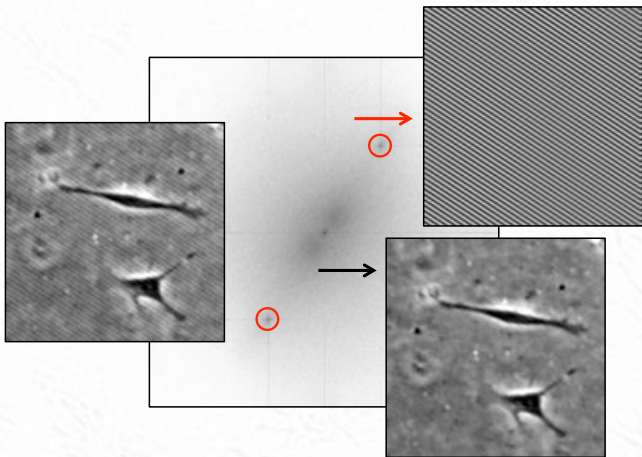
Medical Sciences

Medical spin-offs have expanded considerably in the past few years:

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From a World of Atoms to a World of Living Matter

Medical Sciences



Spin-Offs / Medical Sciences / Cell Growth / Fourier Filters

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A World of Atoms	Imaging atoms, molecules and nanostructures
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A World of Living Matter

Now very much in the world of living matter, we will take a closer look at two ongoing research projects in which image analysis is playing a key role:

- Microcirculation Analysis**
- Investigation of Cancer**

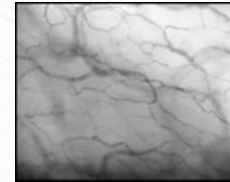
35

Microcirculation Analysis

In collaboration with consultants at Alder Hey hospital, the first trials of MIASMA software are being conducted on patients in the intensive care unit. Some of these patients suffer from meningitis, causing sepsis (aka blood poisoning).

The software quantifies the flow of blood cells through a capillary network, the *microcirculation*, as imaged by a small portable microscope placed underneath the tongue of the patient.

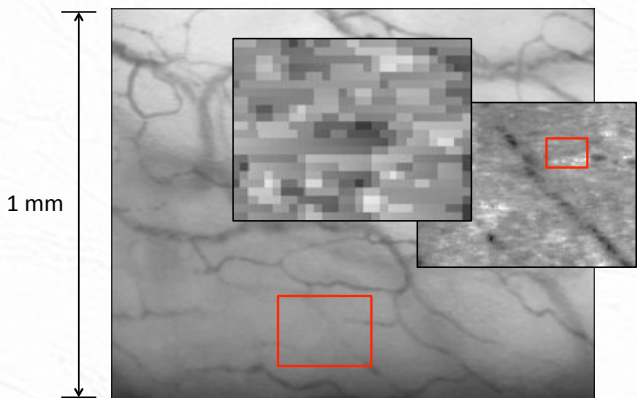
Not so much
Putting People Under the Microscope
but rather
Putting the Microscope Under People.



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Microcirculation Analysis



1 mm

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World of Living Matter / Microcirculation Analysis

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Microcirculation Analysis

Bear in mind that the blood vessels are invisible (as only the blood cells, containing haemoglobin, are imaged).

So the problem is to identify and quantify the motion of a blood cell relative to an invisible vessel in a sequence of video images that are not stable – ever tried to get a five-year old to sit still while you place a microscope under his tongue?

Any attempt at quantification will first have to deal with...

... Translation ... Magnification ... Rotation ... Distortion ...

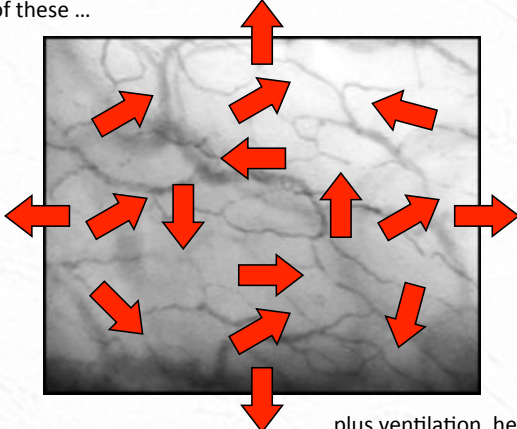
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World of Living Matter / Microcirculation Analysis

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Microcirculation Analysis

Or all of these ...



... plus ventilation, heartbeat

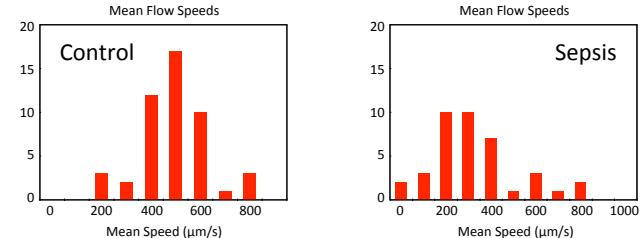
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World of Living Matter / Microcirculation Analysis / Video Stability

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Microcirculation Analysis

Through a combination of techniques, including cross-correlations (to stabilise the video images) and autocorrelations (to identify the motion of blood cells that are barely detectable) it is possible to quantify the blood flow speeds in vessels as small as $7\text{ }\mu\text{m}$ diameter.



Control

Sepsis

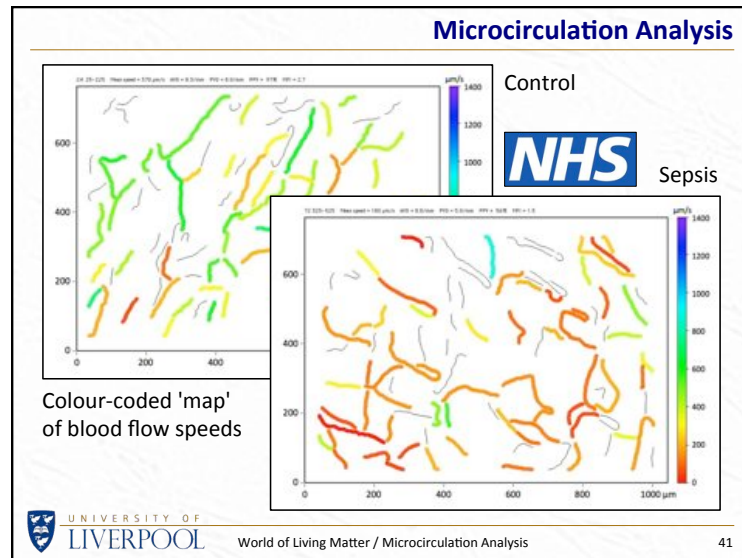
Mean Speed ($\mu\text{m/s}$)

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World of Living Matter / Microcirculation Analysis

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From a World of Atoms to a World of Living Matter



Summary

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<p>UoL staff</p> <p>David Martin, Peter Weightman, Andy Wolski</p> <p>UoL students</p> <p>Tim Craig, James Ingham, Marion Leibl, Sean Littlewood, Graham Smith</p> <p>SCAnCan Collaboration</p> <p>Paul Harrison, Yaochun Shen, Michele Siggel-King, Caroline Smith, Paul Unsworth (Liv) Mark Pritchard, Andrea Varro (ITM) Paul Bassan, Peter Gardner (Man) Oleg Kolosov, Frank Martin, Peter Tovee (Lan) Carole Tucker (Car) Antonio Cricenti, Marco Luce (Rome)</p> <p>ASTeC staff</p> <p>Mark Surman, Neil Thompson</p>	<p>MIASMA</p> <p>Riaz Akhtar, Laura Burgess, Enitan Carroll, Rebecca Clements, Liz Laird, Luning Liu, Naga Puppala, Richard Sarginson, Yalin Zheng</p> <p>PrinCIPia</p> <p>Renée Heilbronner, Rüdiger Kilian</p>
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From a World of Atoms to a World of Living Matter

<http://www.liv.ac.uk/~sdb/Talks>

Dr Steve Barrett

7 July 2015