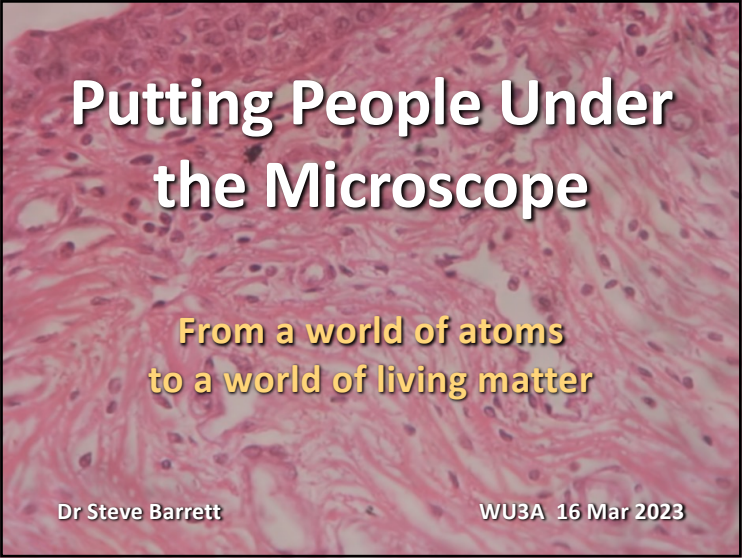


Putting People Under the Microscope



Putting People Under the Microscope

From a world of atoms
to a world of living matter

Dr Steve Barrett WU3A 16 Mar 2023

Introduction

A World of Atoms	Imaging atoms and molecules
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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2

Introduction

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

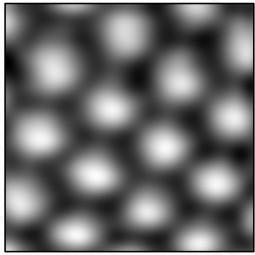
Image Processing	>>>	Interpretation
Image Analysis	>>>	Quantification

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

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3

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

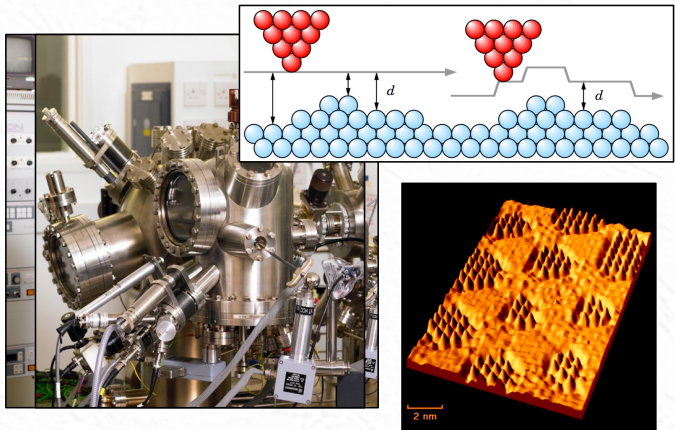
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World of Atoms

4

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A World of Atoms



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World of Atoms / Scanning Tunnelling Microscope

5


A World of Atoms

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

Scanning Tunnelling Microscope

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

Image SXM
v 2.05
September 2022
Steve Barrett



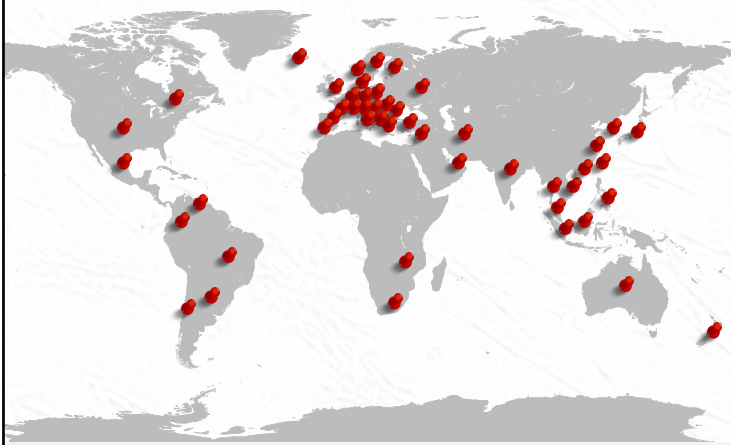
> 50,000 downloads in the past 10 years by universities and research centres

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World of Atoms / STM / Software

6

Image SXM

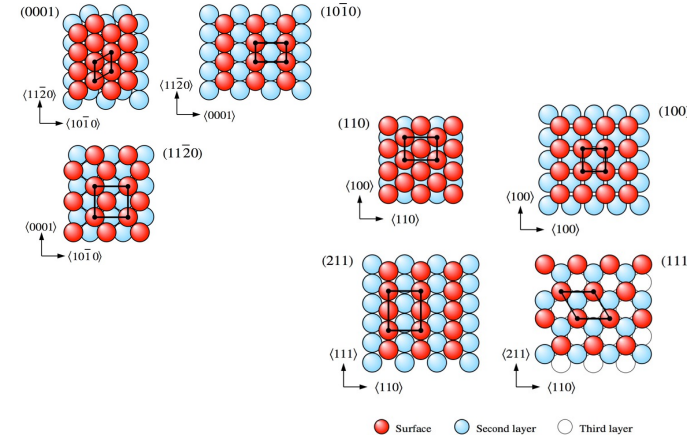


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World of Atoms / STM / Software / Image SXM

7

A World of Atoms

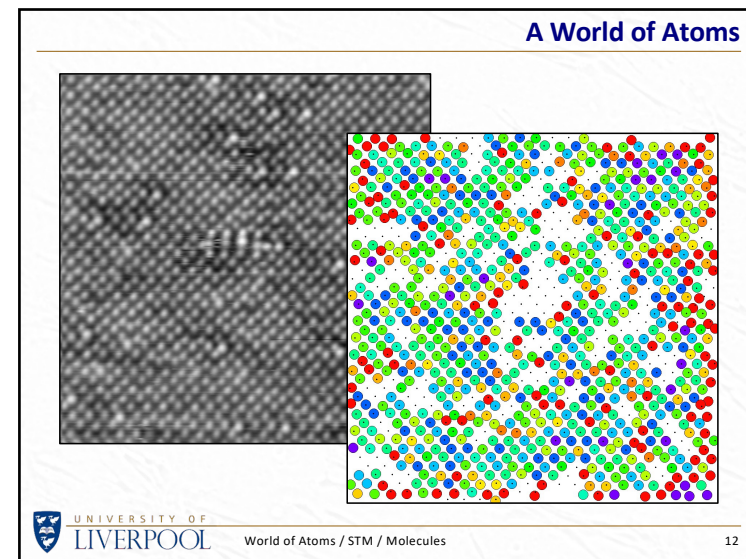
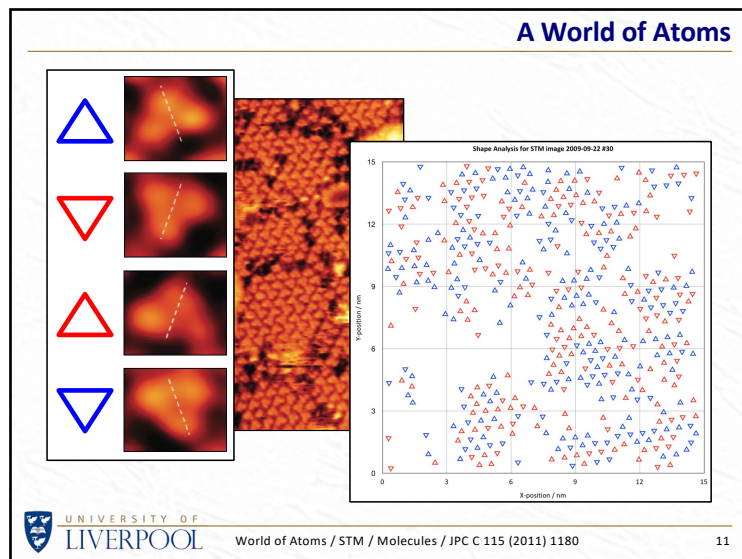
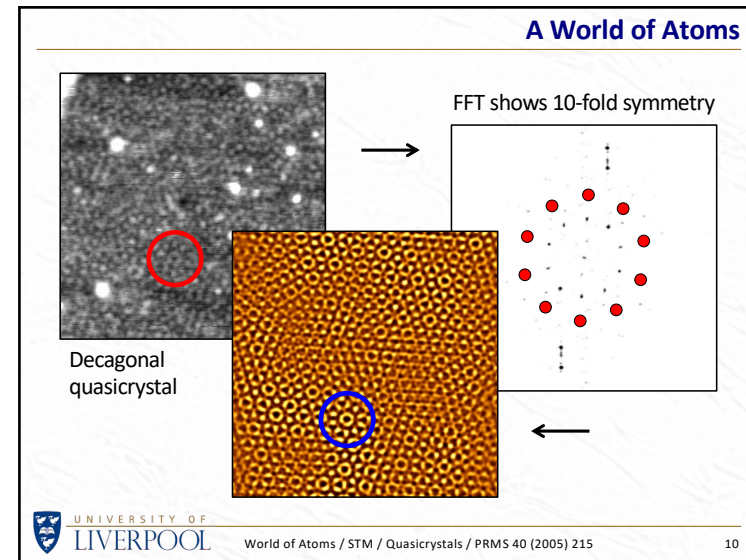
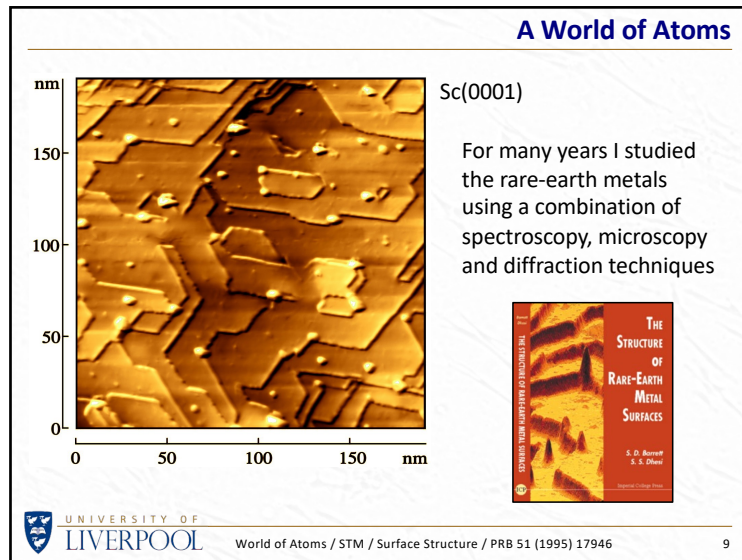


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World of Atoms / STM / Surface Structure

8

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Putting People Under the Microscope

Astrophotography



The Milky Way from Kenya.
Due to the dark skies, very
little image processing is required.



Beyond Microscopy / Astrophotography

13

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.

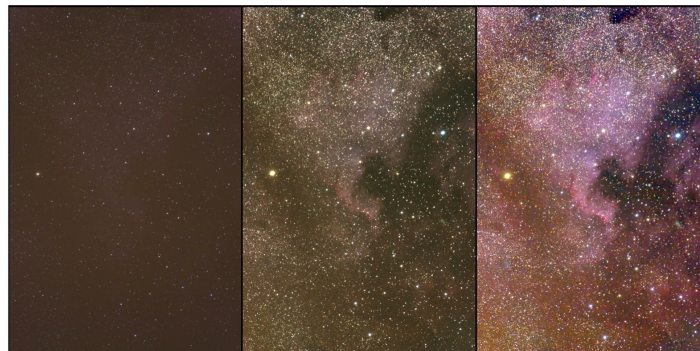


Beyond Microscopy / Astrophotography

14

Astrophotography

NGC7000 North America Nebula



Single raw image

20 images stacked in Image SXM

Colours enhanced



Beyond Microscopy / Astrophotography

15

A World of Atoms

Imaging atoms
and molecules

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



16

Putting People Under the Microscope

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*

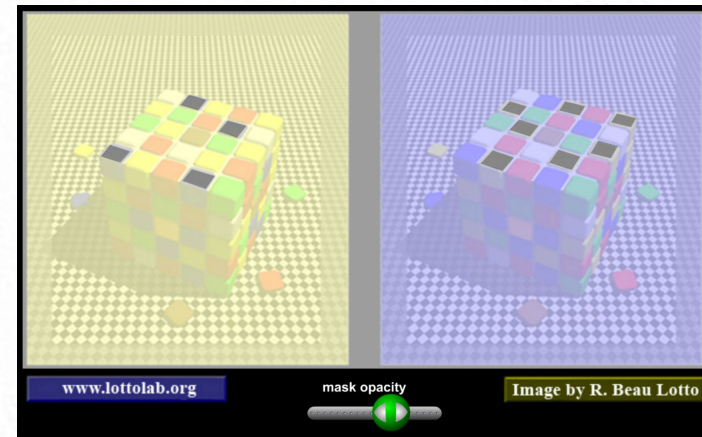
Carbon vs *Silicon*



Perception vs Reality

17

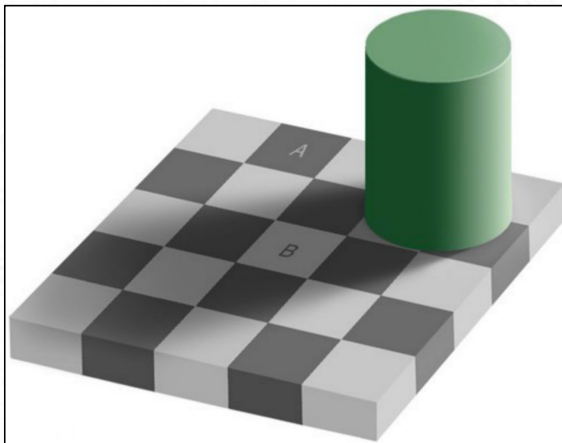
Perception vs Reality



Perception vs Reality / Colour Perception

18

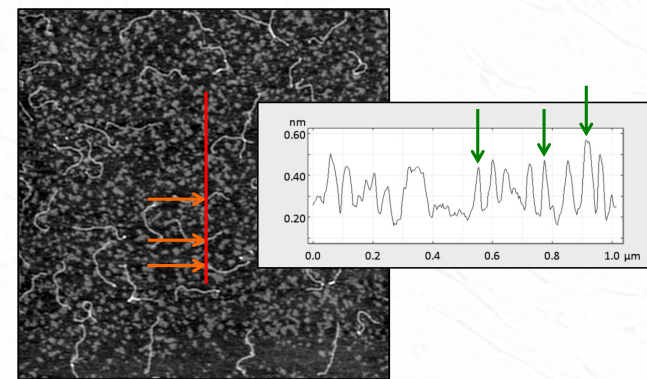
Perception vs Reality



Perception vs Reality / Grey Perception

19

Perception vs Reality



DNA on glass

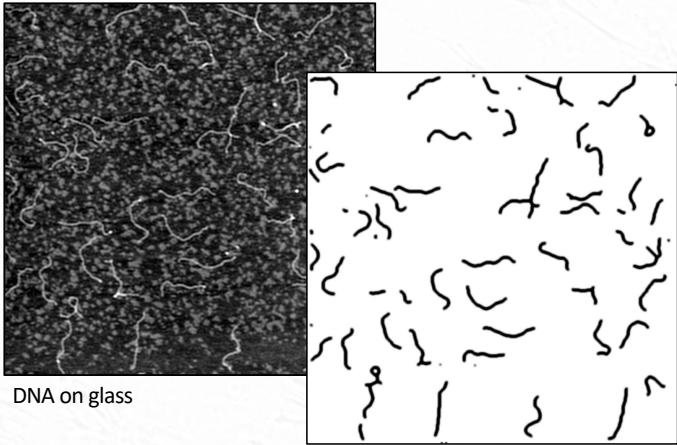


Perception vs Reality / Wood For the Trees

20

Putting People Under the Microscope

Perception vs Reality



DNA on glass

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Perception vs Reality / Wood For the Trees

21

A World of Atoms	Imaging atoms and molecules
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22

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

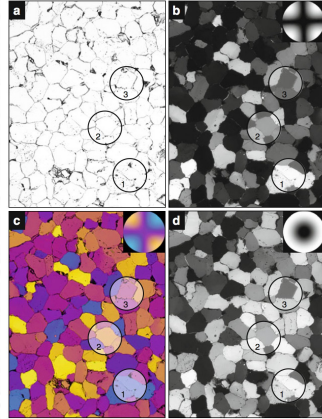
'Microscopy Image Analysis Software for Medical Applications'

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Spin-Offs

23

Earth Sciences



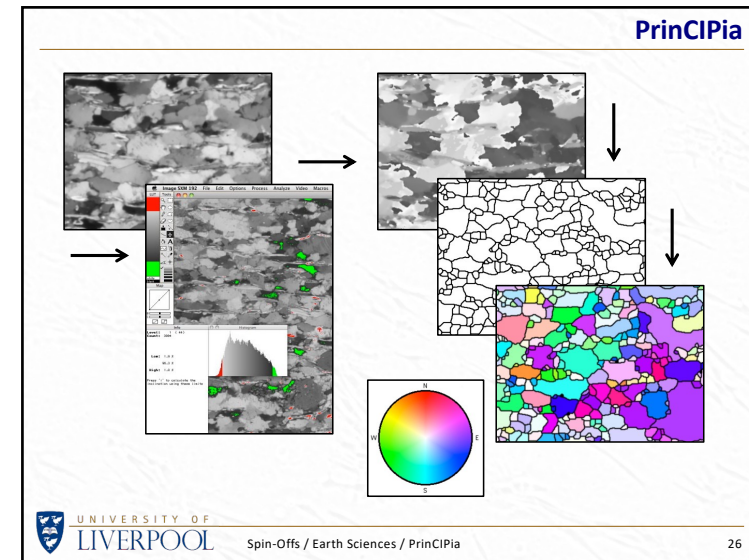
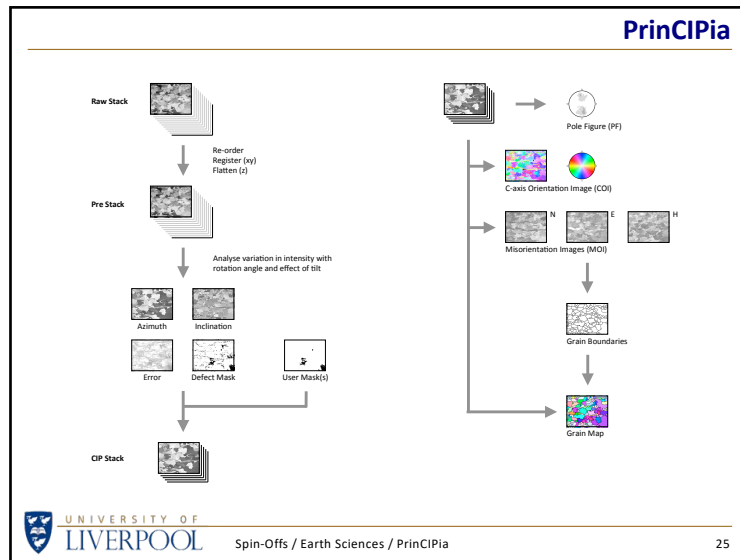
Imaging earth materials (to a physicist = 'rocks') using circularly and linearly polarised light produces colours and intensities that depend on the orientation of the crystallographic axes of the grains with respect to the optical axis of the microscope.

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Spin-Offs / Earth Sciences

24

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Earth Sciences

Renée Heilbronner
Steve Barrett

Image Analysis in Earth Sciences
Microstructures and Textures of Earth Materials

Springer

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

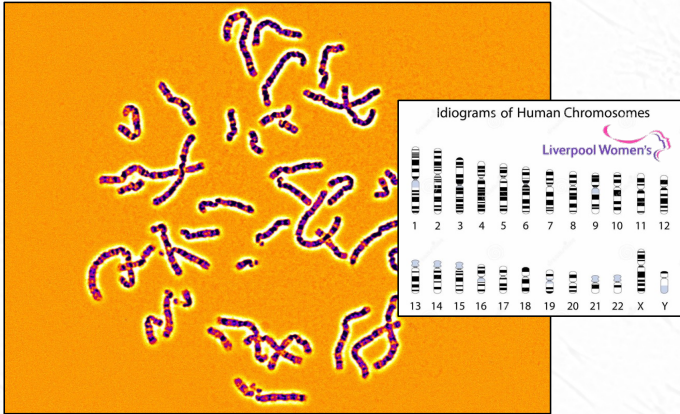
Medical spin-offs have expanded considerably in the past ten years:

MIASMA Microscopy Image Analysis Software for Medical Applications	Morphology
Particulates	Lymphocytes
Parasites	Lipid Bodies
Circulation	Microfibrils
Retinas	Bacteria

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Putting People Under the Microscope

Human Chromosomes



Idiograms of Human Chromosomes

Liverpool Women's

1 2 3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22 X Y

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Spin-Offs / Medical Sciences / Chromosomes

29

A World of Atoms

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30

A World of Living Matter

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

Microcirculation Analysis

Investigation of Cancer

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World of Living Matter

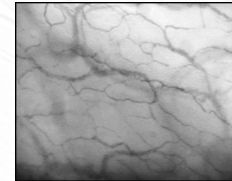
31

Microcirculation Analysis

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

The software quantified 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.

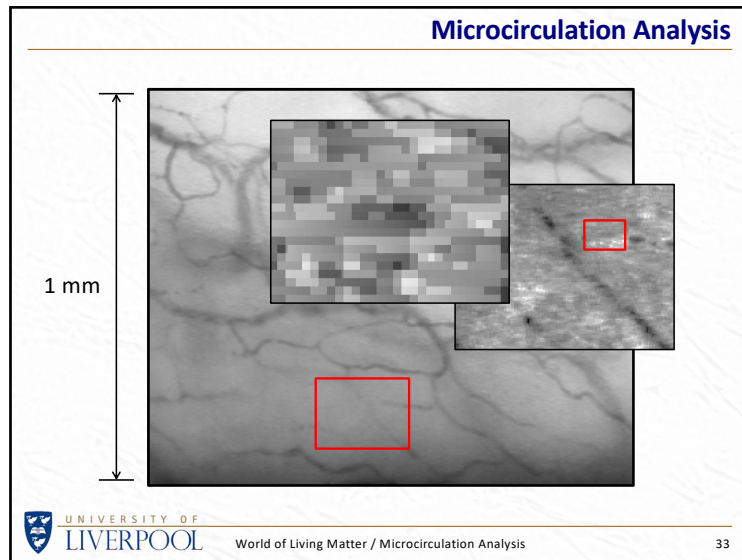


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World of Living Matter / Microcirculation Analysis

32

Putting People Under the Microscope



Microcirculation Analysis

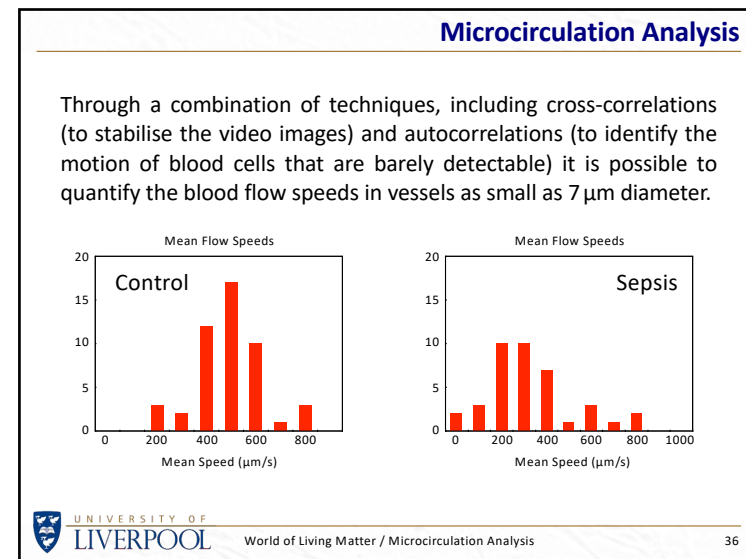
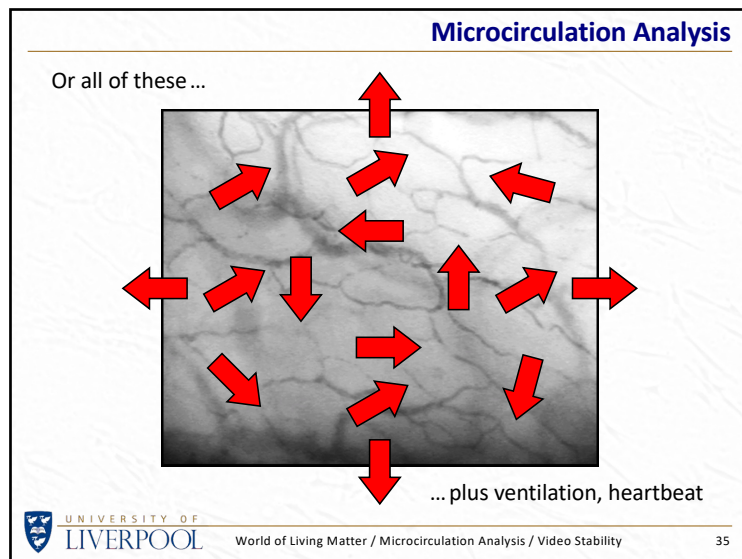
Bear in mind that the blood vessels are invisible (as only the blood cells, containing haemoglobin, are imaged).

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?

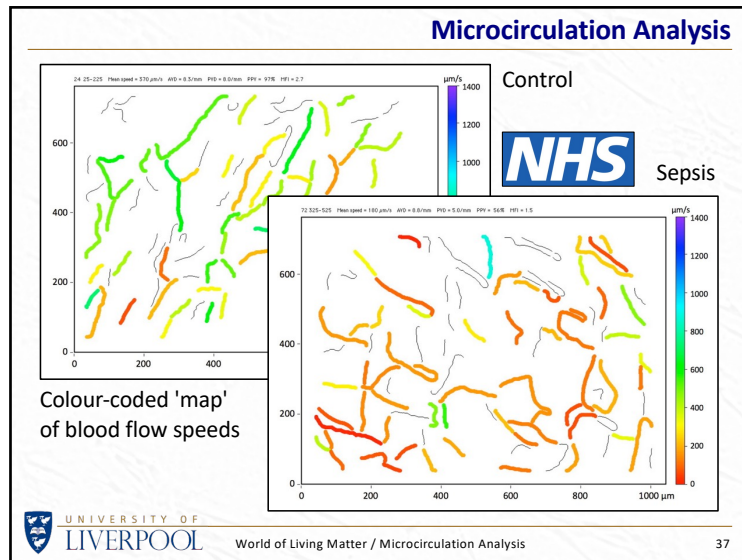
Any attempt at quantification will first have to deal with ...

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

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World of Living Matter / Microcirculation Analysis 34



Putting People Under the Microscope



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38

Investigating Cancer

This final section of the talk describes research funded through EPSRC and CRUK research grants:

- "Disease diagnosis through spectrochemical imaging of tissues"
- "Early detection of oral cancer using infrared imaging"
- "Development of a probe for the early diagnosis of cancer"

Roughly speaking, that translates to...

Can we identify an infrared absorption signature for tissue that is likely to become cancerous?

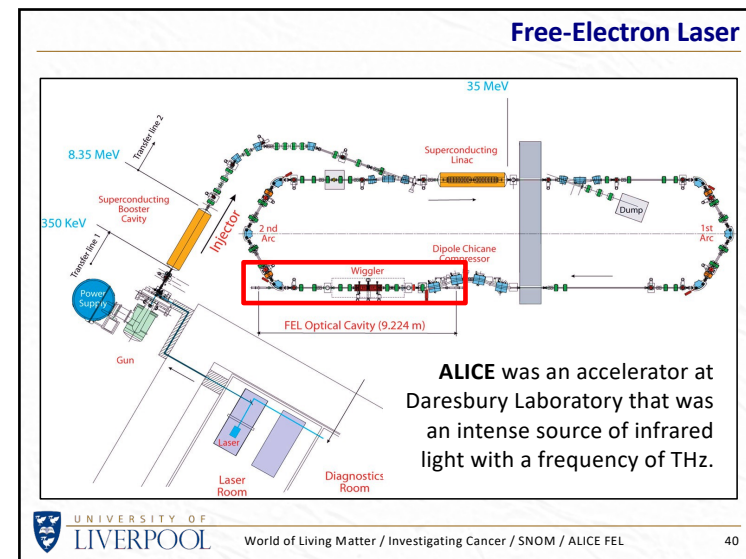
or...

Can we detect cancer before it is cancer?

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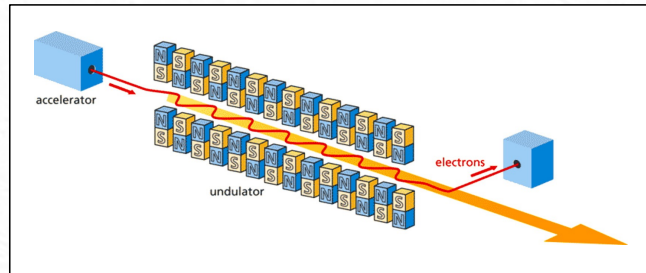
World of Living Matter / Investigating Cancer

39



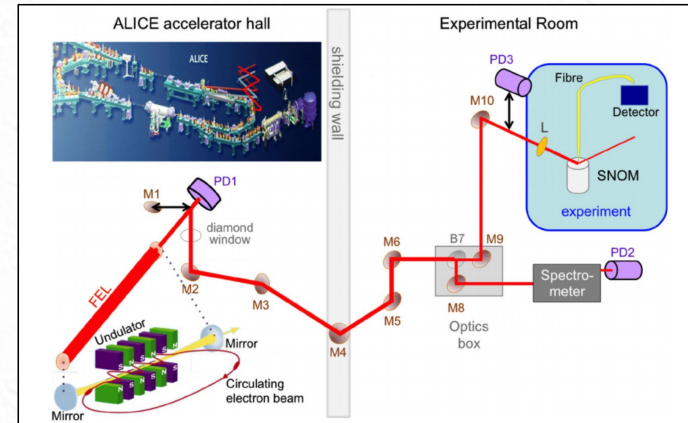
Putting People Under the Microscope

Free-Electron Laser

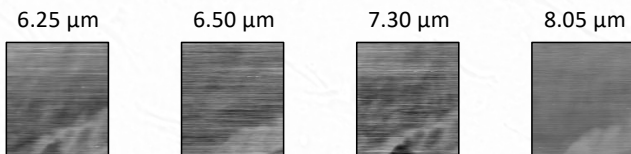


An array of magnets with alternating N-S orientation causes the electron beam to 'wobble' and emit intense beams of synchrotron radiation. The strength and period of the magnet array determines the wavelength of the emitted radiation.

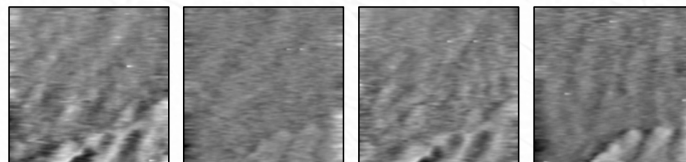
Free-Electron Laser



Scanning Near-field Optical Microscopy



Raw images as acquired by the SNOM at different IR wavelengths



Processed to remove artefacts and make features easier to see

SNOM Imaging

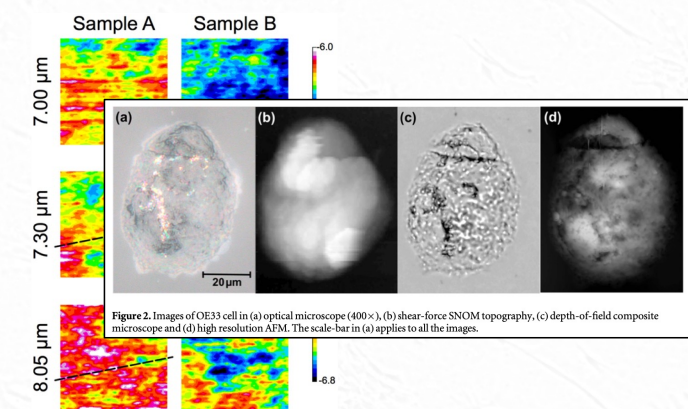
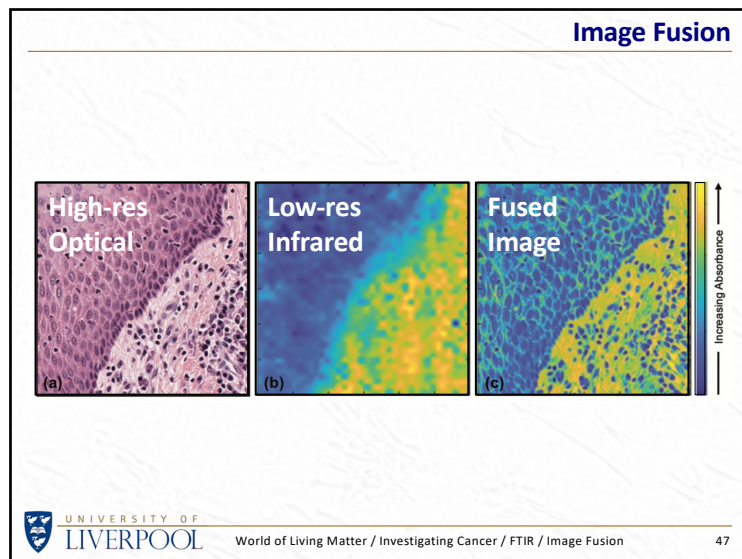
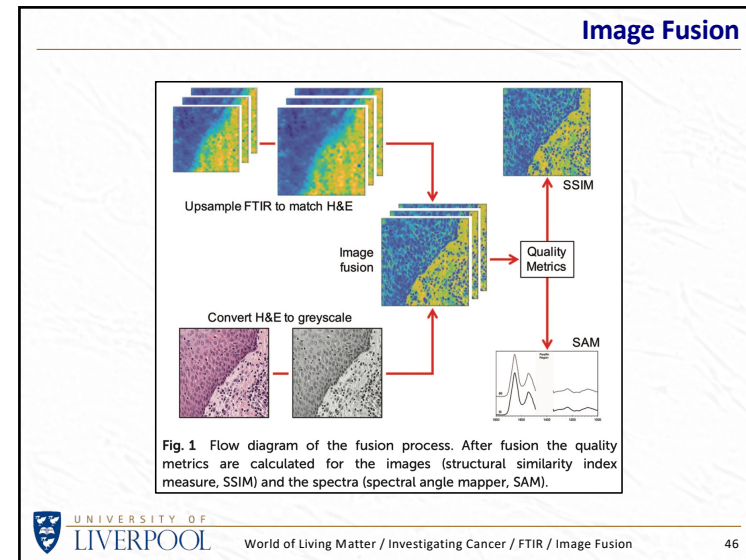
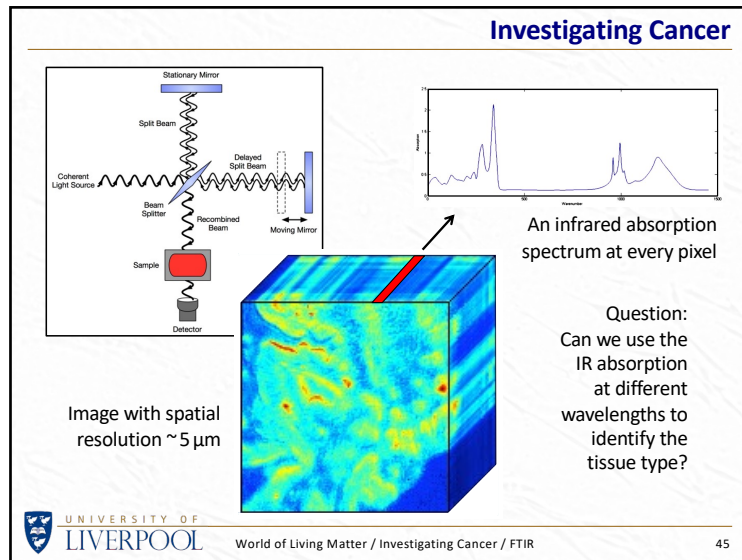


Figure 2. Images of OE33 cell in (a) optical microscope (400 \times), (b) shear-force SNOM topography, (c) depth-of-field composite microscope and (d) high resolution AFM. The scale bar in (a) applies to all the images.

Putting People Under the Microscope



Tissue Types

What type of tissue are we studying?

Epithelium tissue covers all surfaces of the human body. This means not just your skin ...

... but also the oesophagus and mouth.

Epithelial layer

After studying oesophageal cancer cells we are now focussing on oral epithelial dysplasia (OED) – changes in the cells that make up the lining of the mouth.

In particular, we want to improve the accuracy of prognosis so that we can say if a lesion found in the mouth will, or won't, progress to cancer.

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World of Living Matter / Investigating Cancer / Tissue Types 48

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LDIR Wand



SciaScan

Spectro Chemical Infrared Analysis Scan For Cancer








World of Living Matter / Investigating Cancer / LDIR Wand

49

Summary

A World of Atoms	Imaging atoms and molecules
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50

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PrinCIPIa
Renée Heilbronner, Rüdiger Kilian










51

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www.liverpool.ac.uk/~sdb/Talks

Dr Steve Barrett
WU3A 16 Mar 2023