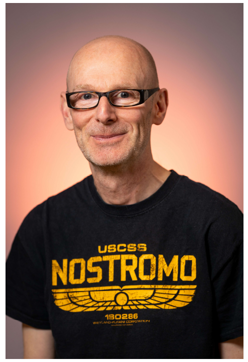
Made to be measured:

The revolutions in analytical science for the real time analysis of the human body

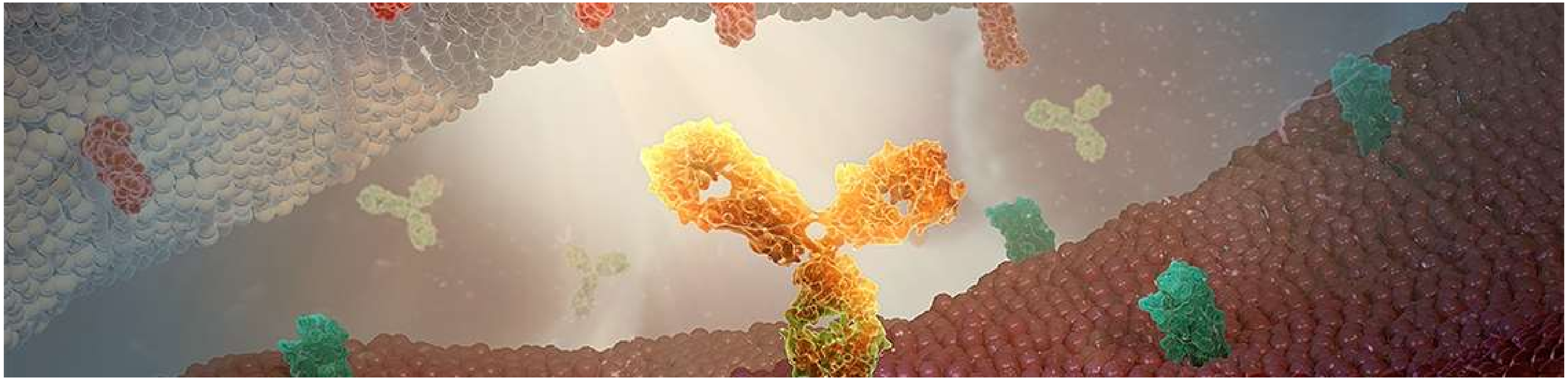


Dr Tony Bristow, Principal Scientist Measurement Science, AstraZeneca, Macclesfield

FRSC and Associate Visiting Professor, University of Warwick

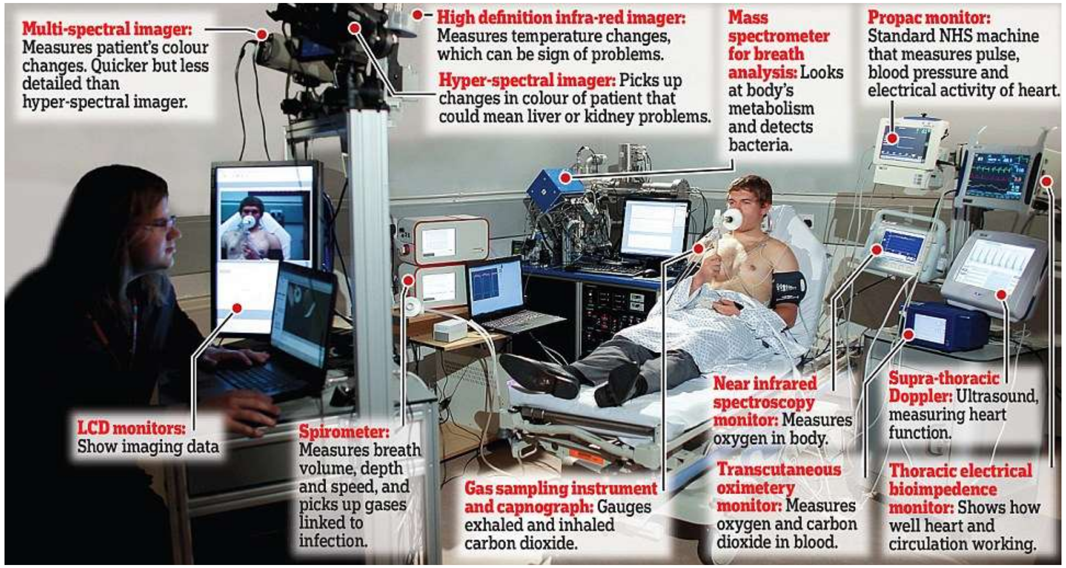
Knutsford SciBar

4 November 2019



All images in this presentation are included unambiguously for educational purposes only as part of public outreach activities

A journey through innovations in analytical science……..



Courtesy of Paul Monks – University of Leicester

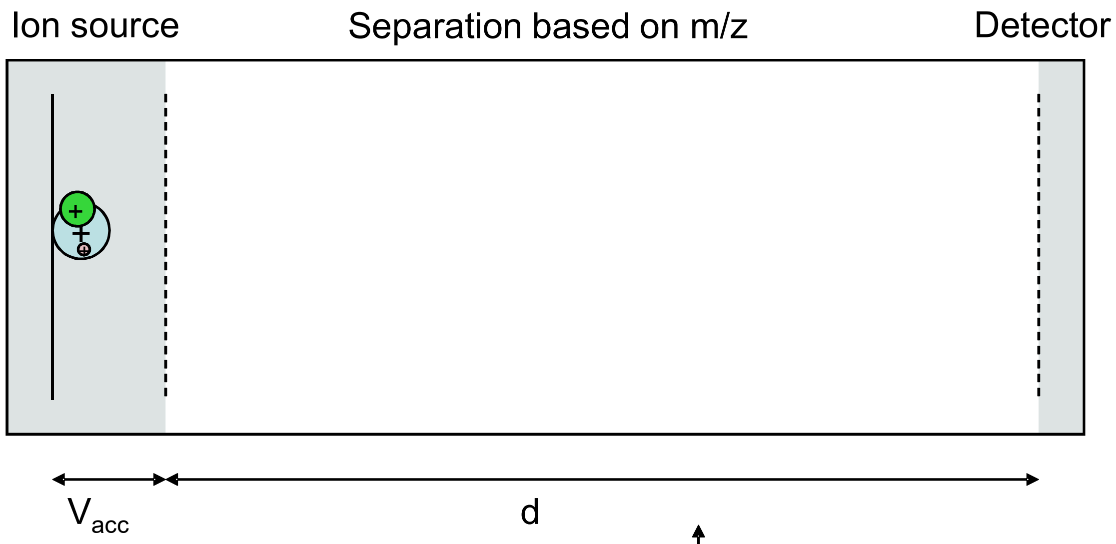
Courtesy of Abbott Diabetes Care

Lets start by thinking big and in the lab

Let’s start with mass spectrometry

- Which is a powerful technique used in analytical science that is used to:
  - elucidate the structure and chemical properties of molecules
  - quantify trace levels of compounds in large amounts of other materials (a complex matrix) - as low as one part in 10^{12}
- Detection of compounds can be accomplished with very minute quantities of sample
- A mass spectrometer measures the ***mass-to-charge ratio*** (m/z) of the ***ions*** formed from the molecules (or elements)

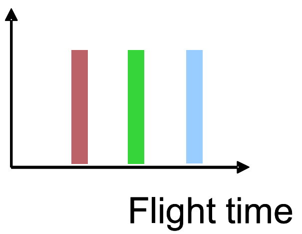
Principles of a type of mass spectrometer - Time of Flight



Ion creation

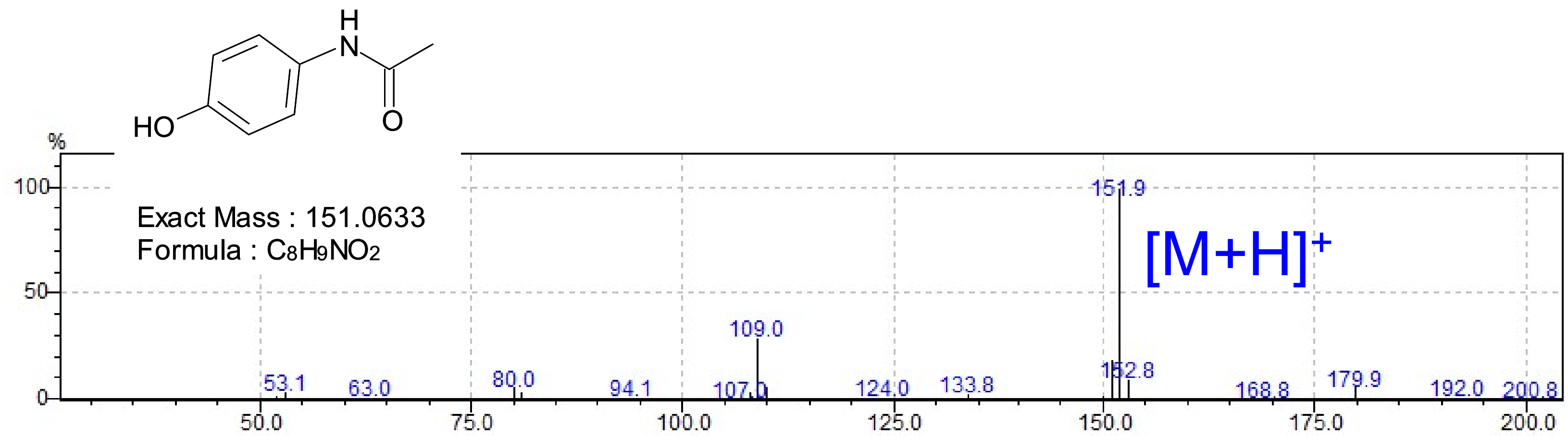
Ion separation

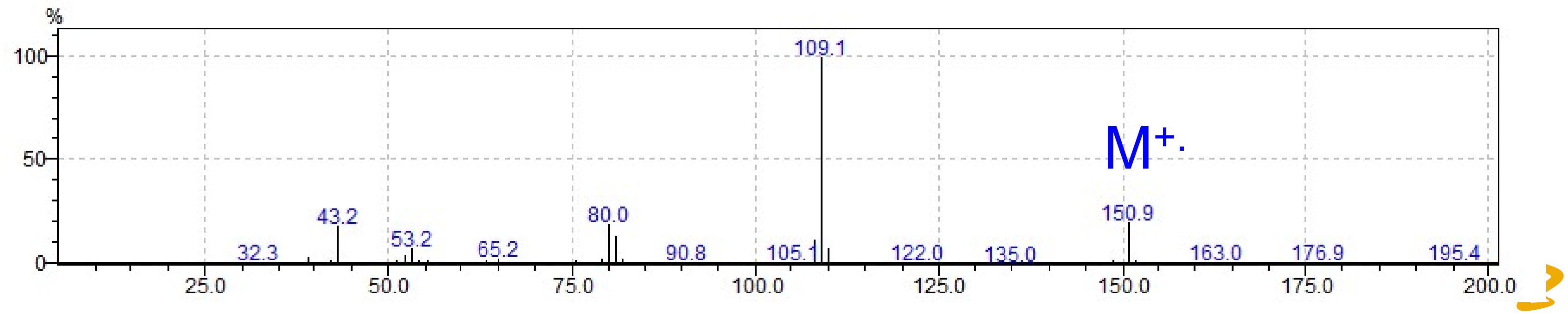
Ion detection



What does a mass spectrum tell you?

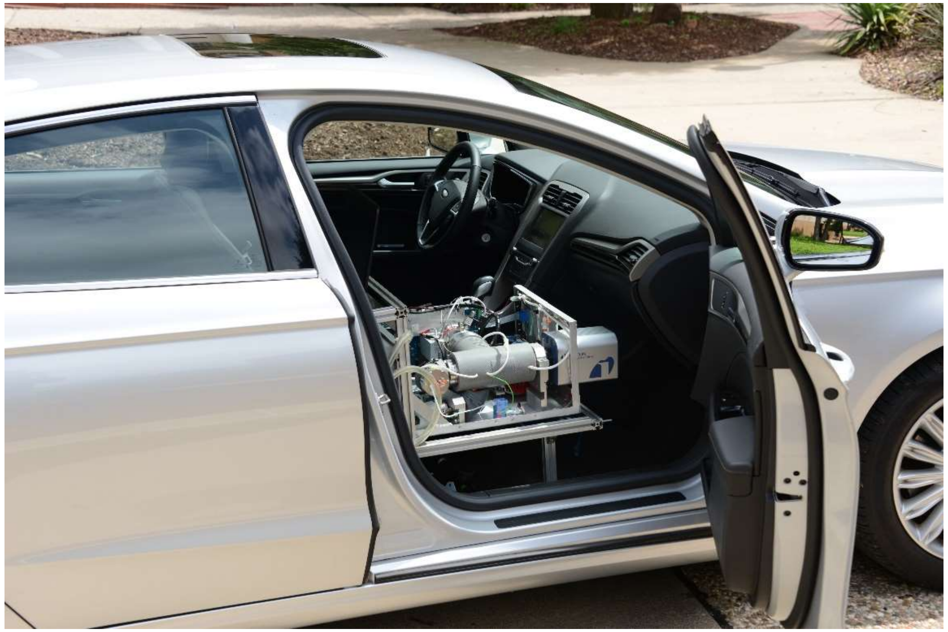
Identity – a molecular fingerprint





Fun example of MS – Mobile Environmental Analysis Rack Mounted in Front Seat

- Constant Flow sampling from front of vehicle
- Multiple inlets at different heights



Courtesy of Guido Verbeck – University of North Texas, US

Deep Well Injection - Benzene

How can mass spectrometry be used in disease diagnosis and disease understanding?

Real-time cancer diagnostics by Mass Spectrometry

Warning

The Blood and Guts Bit

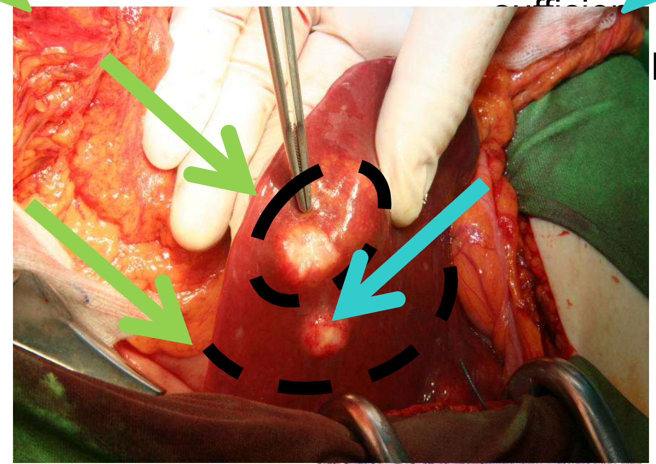
Courtesy of Zoltan Takats – Imperial College

AstraZeneca

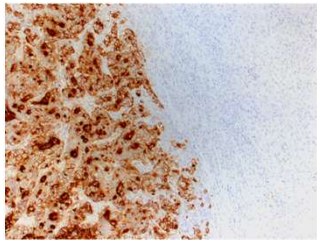
Where to dissect?

- Intraoper
identifica
  – Visua
  informati... not
  sufficie

Is it also tumor?



Frozen section

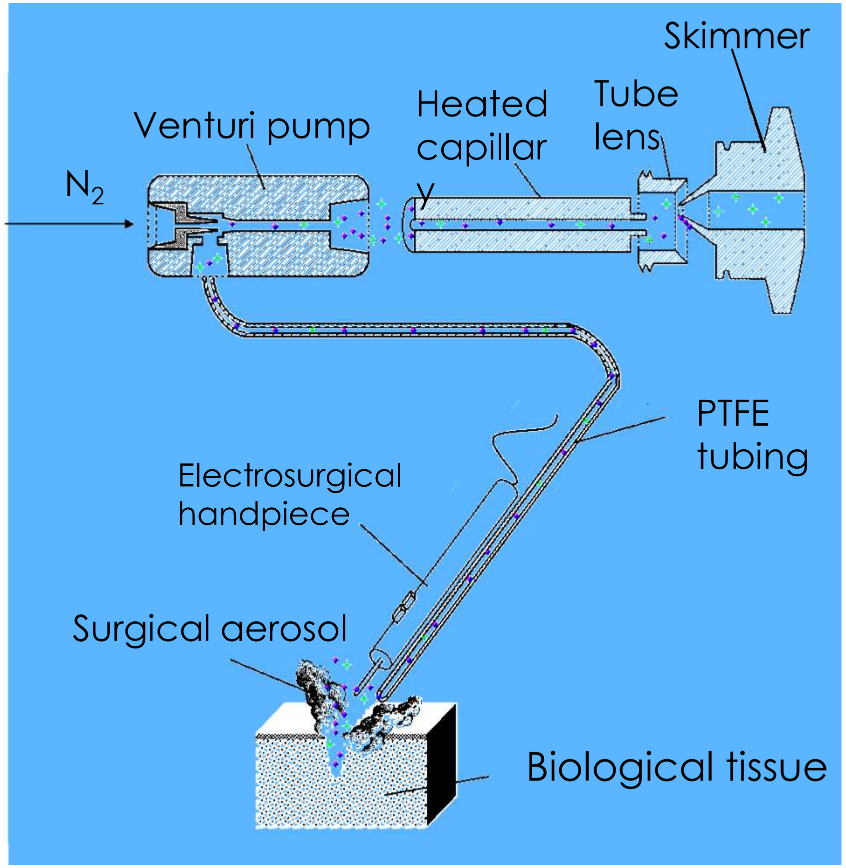


Colon adenocarcinoma liver metastasis

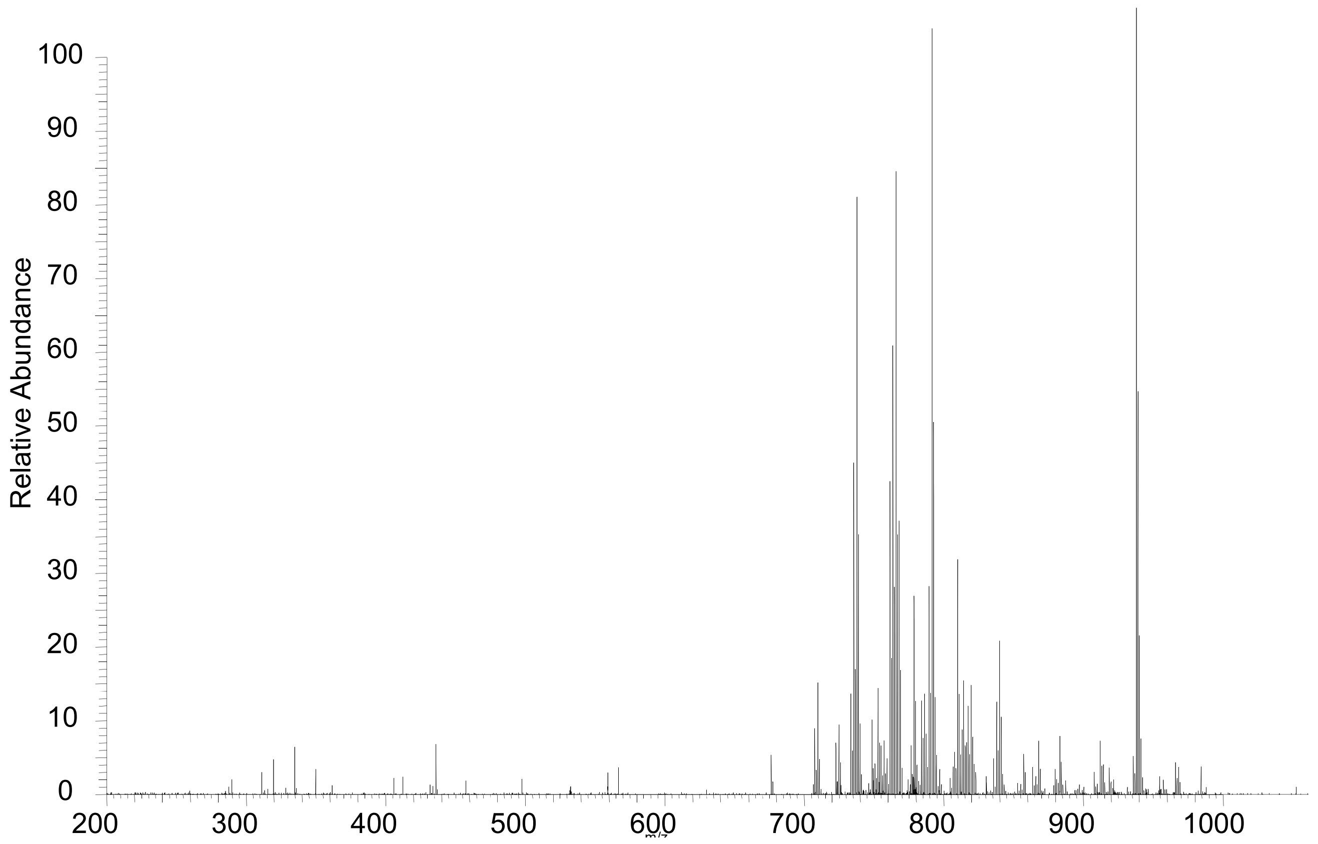
Hematoxylin-Eosin stain ~ 20-30 min

Immunohistochemistry ~ 1 hour

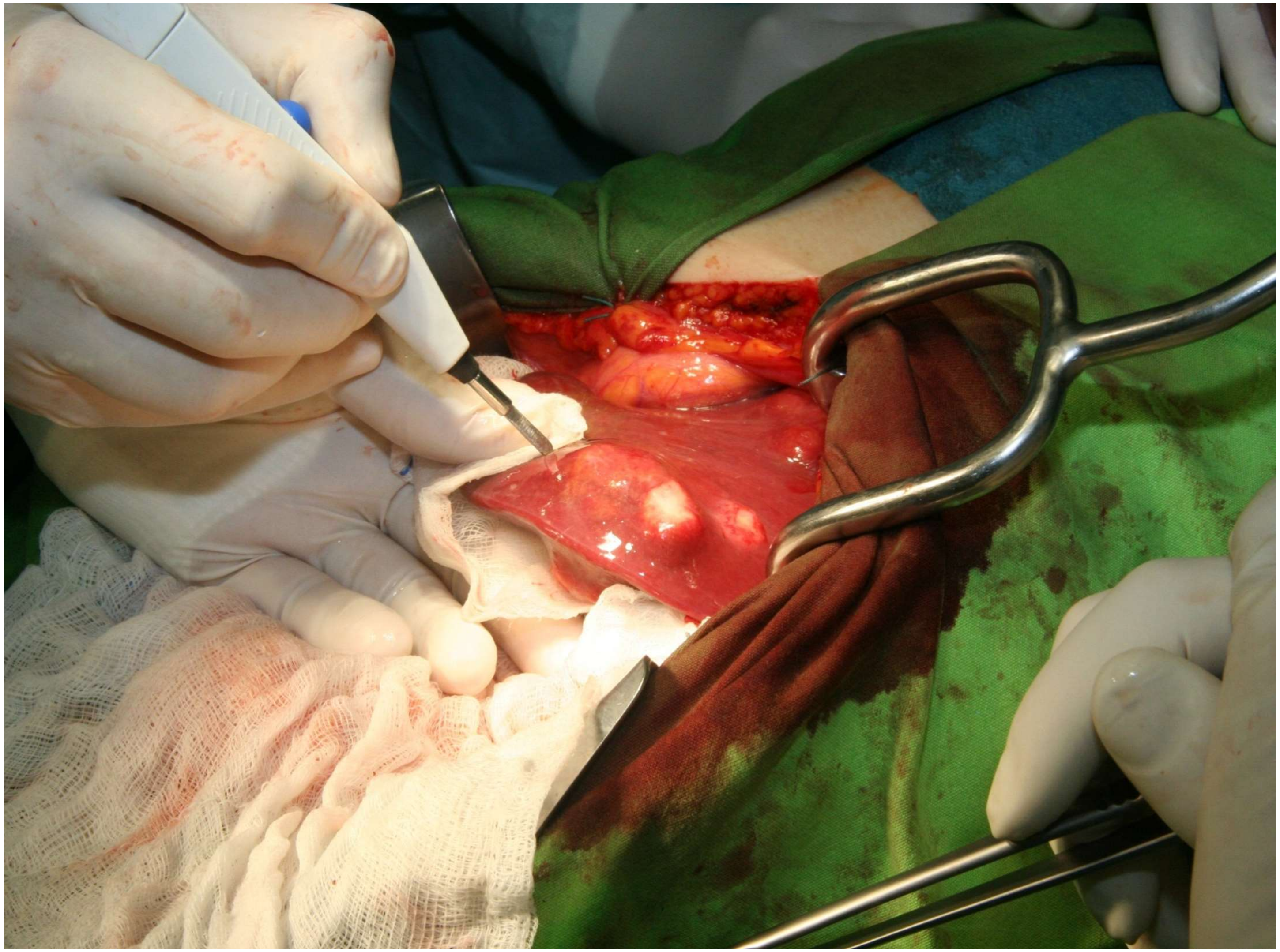
A mass spectrometer in the operating theatre in combination with Electrosurgery



The Tissue Fingerprint – a mass spectrum



A mass spectrometer in the operating theatre in combination with Electrosurgery



Breath-taking research… literally

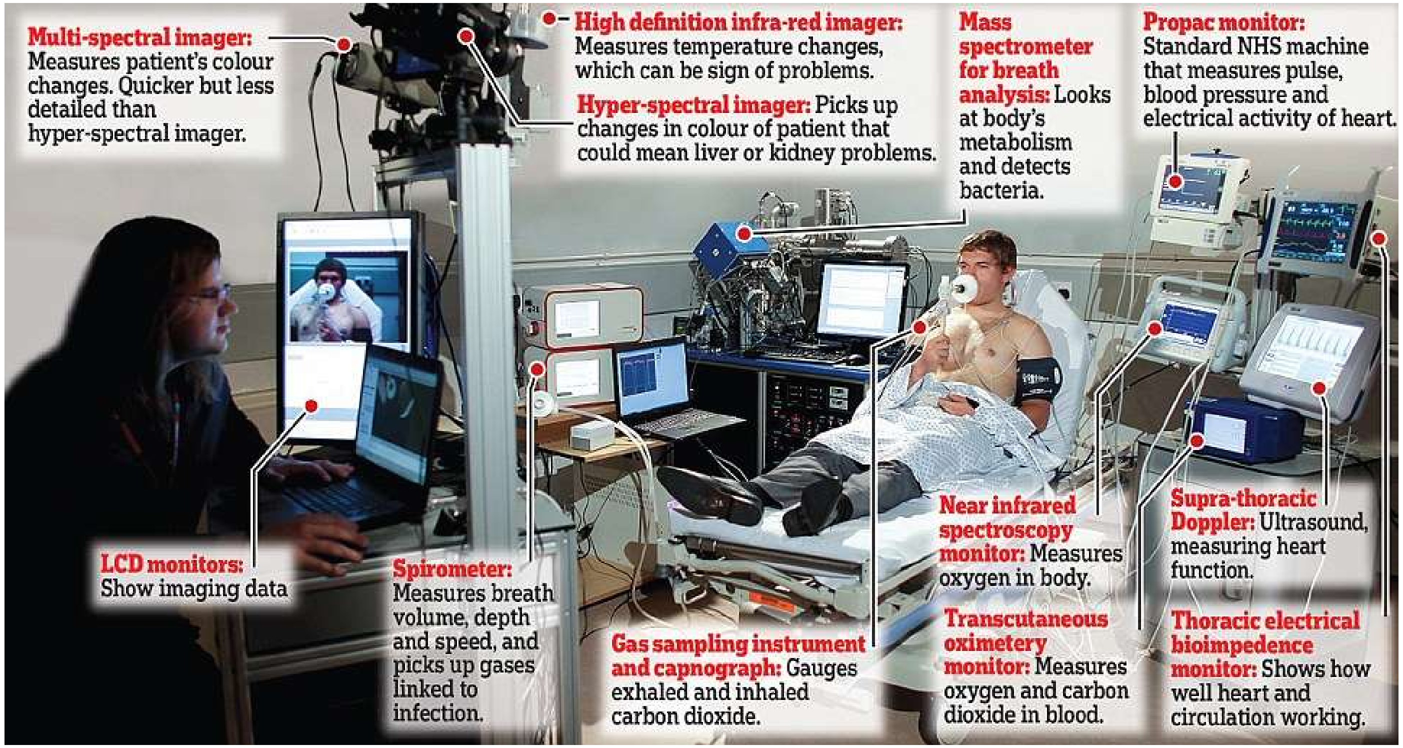
Prof. Paul S. Monks
PVC and Dept. of Chemistry
University of Leicester

Dr Michael Wilde, Dr Rebecca Cordell
and Luke Bryant,

EMBER

UNIVERSITY OF LEICESTER

Diagnostic Development Unit - DDU



(Courtesy of the Daily Mail)

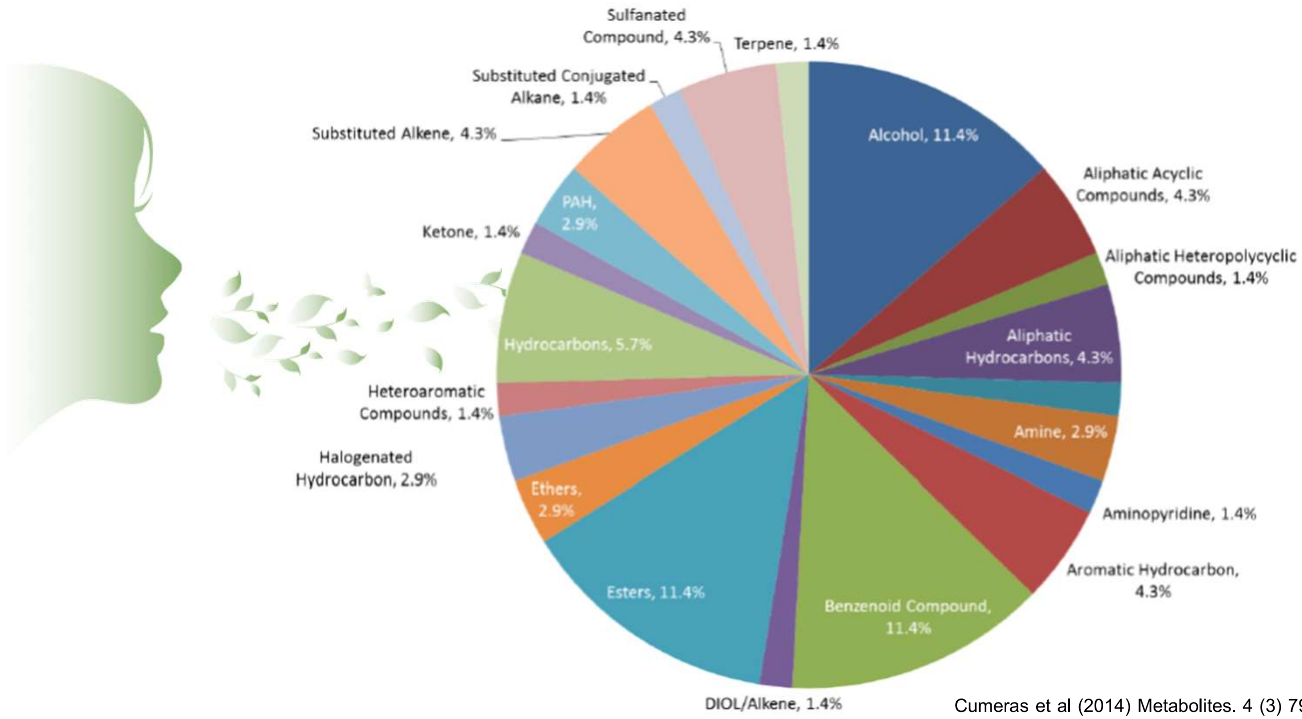
University of Leicester

Breathomics

What is breathomics and
what can we see?

WMJ1

Breathomics



Cumeras et al (2014) Metabolites. 4 (3) 790-806

The study of breath as a potential new molecular pathology

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Slide 21

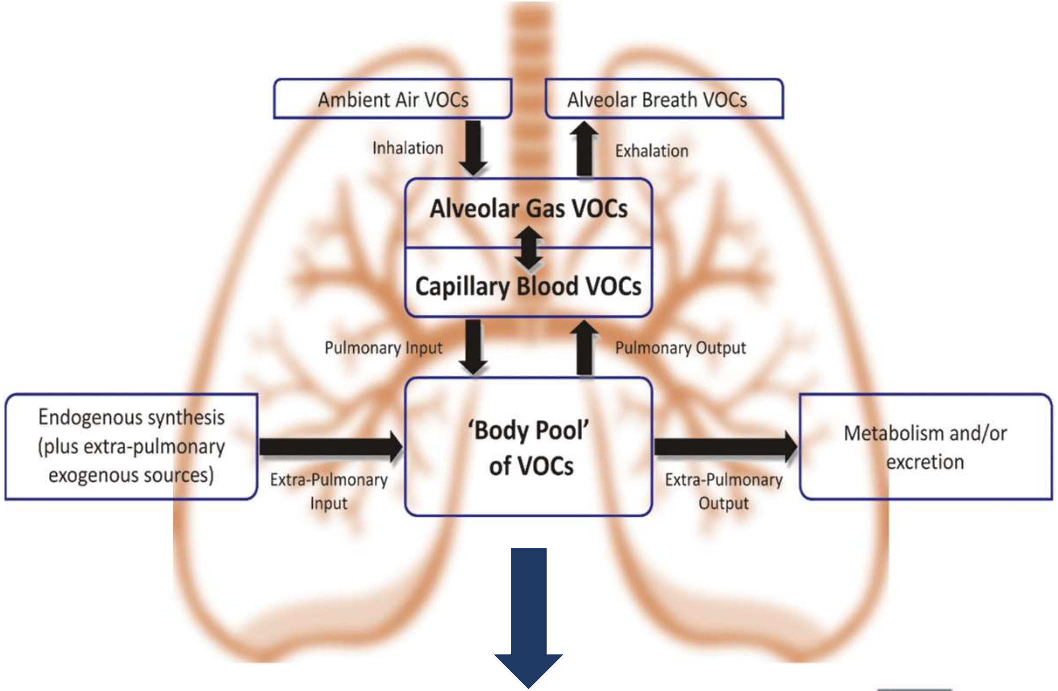
WMJ1 Breath is a wealth of chemical information, it's more than just air (comprised of N2, O2 and CO2). It contains hundreds of chemicals, referred to as volatile organic compounds (VOCs) from within the body. It's this wealth of chemical information that makes a potentially powerful new molecular pathology.

Wilde, Michael J., 02/05/2018

WMJ1

Breathomics

Breath contains hundreds of volatile organic compounds coming from the chemical processes taking place inside your body



Fingerprint disease

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Slide 22

WMJ1 Breath contains hundreds to thousands of volatile organic compounds coming from the chemical processes taking place inside your body. Cellular metabolism and reactions release metabolites/VOCs into the bloodstream. When the bloods passes via the lungs to exchange respiratory gases across the alveolar membrane, the VOCs are also exchanged. The VOCs are then exhaled in breath. Therefore, some of the exhaled VOCs represent the processes occuring inside the body.

The air we breathe in also contains exogenous VOCs.

This figure shows the input and output of VOCs in breath, showing why breath contains such a complex mixture of VOCs.

Wilde, Michael J., 02/05/2018

WMJ3

Molecular Pathology

Seeks to describe and understand the origins and mechanisms of disease using patient samples (Molecular Pathology Review 2013)

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Slide 23

WMJ3 Molecular pathology seeks to describe and understand the origins and mechanisms of disease using patient samples.

We are exploting almost every bodily fluid and cell culture the human body has to offer.

However, most traditional molecular pathologies such as blood are invasive, irreproducible (limited in volume, can't continuously take blood or urine), are biohazardous and require storage.
Wilde, Michael J., 02/05/2018

WMJ3

Molecular Pathology

Seeks to describe and understand the origins and mechanisms of disease using patient samples (Molecular Pathology Review 2013)

- ✓ Non-invasive procedure
- ✓ Suitable for people of all ages and conditions
- ✓ No risk allowing for repeated use
- ✓ Quick to perform /immediate results

Advantages of breath

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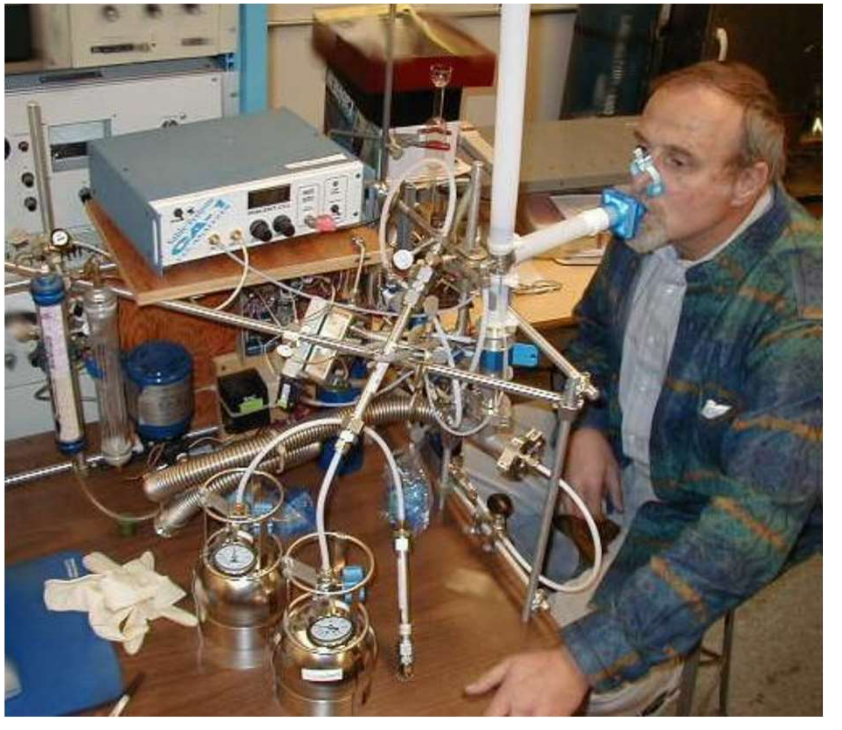
Slide 24

WMJ3 Advantages of breath compared to other molecular pathology technqiues
Wilde, Michael J., 02/05/2018

WMJ3

Analytical technologies



Advances in technology are advancing science

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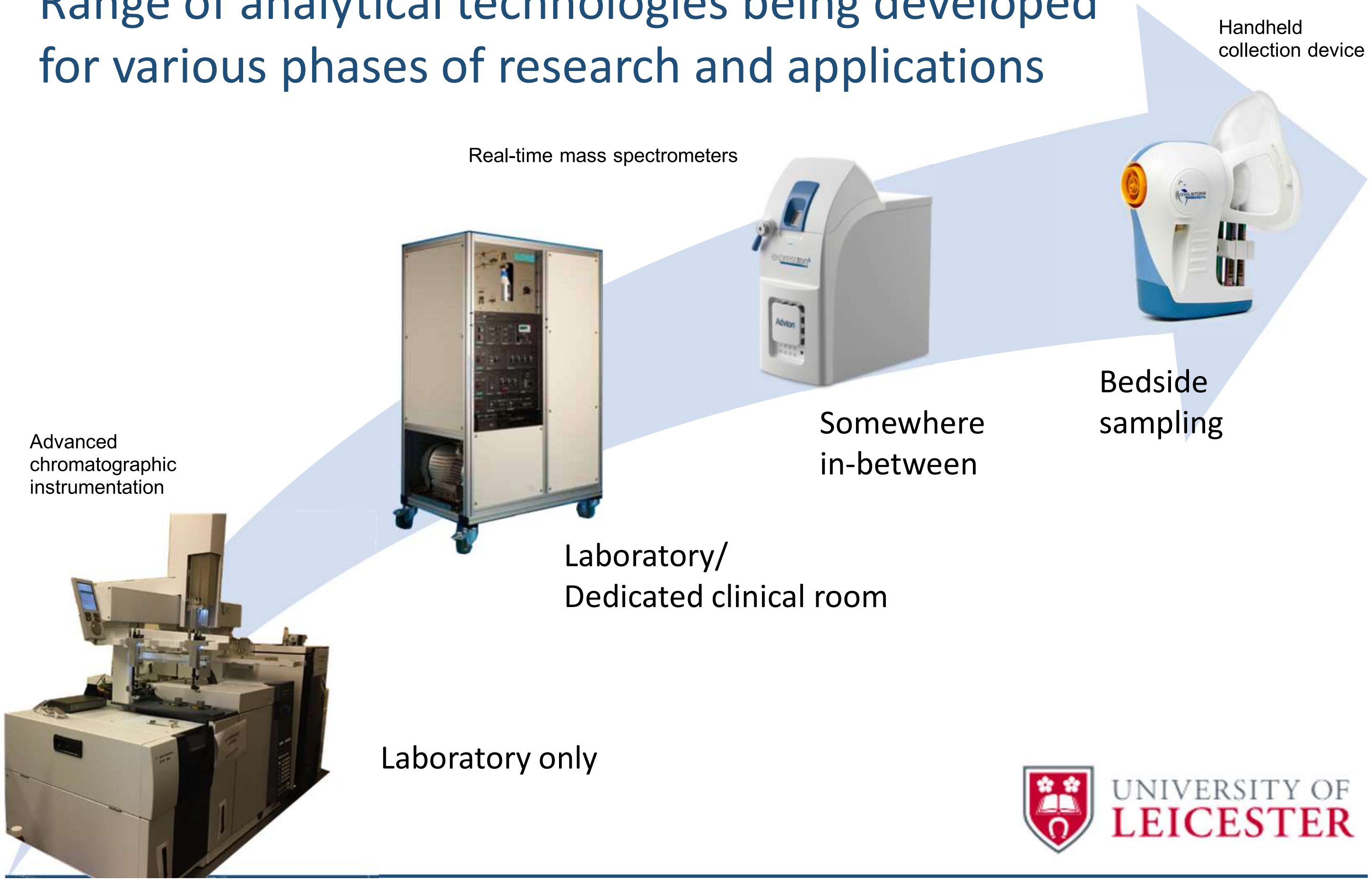
Slide 25

WMJ3 Analytical technologies are advancing
Wilde, Michael J., 02/05/2018

WMJ3

Analytical technologies

Range of analytical technologies being developed for various phases of research and applications



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Slide 26

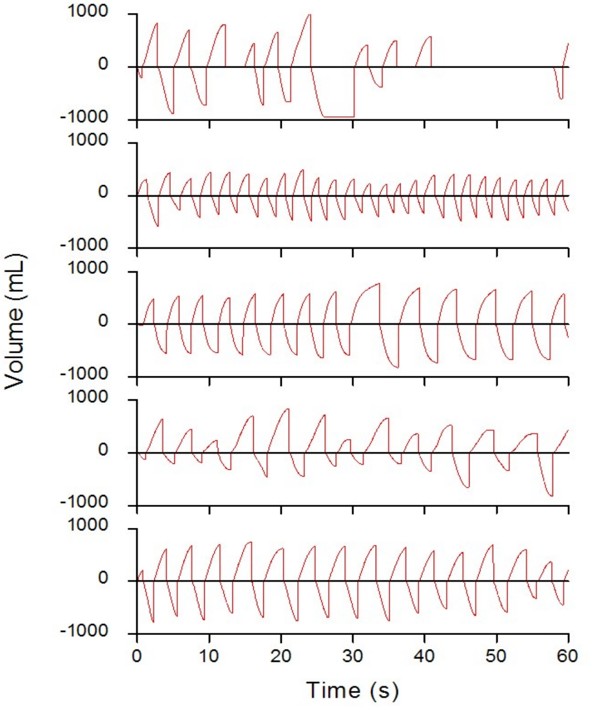
WMJ3 Technologies for analysing breath range from offline laboraotry techniques such as GC-MS and GCxGC-MS, real-time chemical ioinsation mass spectrometry such as PTR-MS and APCI-MS, online ion mobility spectrometers and handheld sampling devices for rapid collection of samples which allow bedside sampling in clinic but provide samples for more offline analysis in a laboratory.

Wilde, Michael J., 02/05/2018

WMJ3

Challenges

- Breath is transient
  - Breath cycle
  - Patient variability
- Breath is moist
- Breath composition is inhomogeneous
  - Alveolar air is target
- Breath comes through the oral (and nasal) cavity
  - Potential for contamination (e.g. toothpaste, oral bacteria)
- **Breath VOCs are at trace levels**
  - **pptV to ppbV**
  - **there are wide variety of compounds**



Five different patients undertaking tidal breathing

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WMJ3 Despite wealth of information and availability of analytical technologies, breaht analysis is challenging.
Wilde, Michael J., 02/05/2018

Real-time analysis

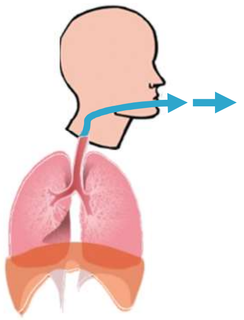
Real-time monitoring of VOCs in clinic

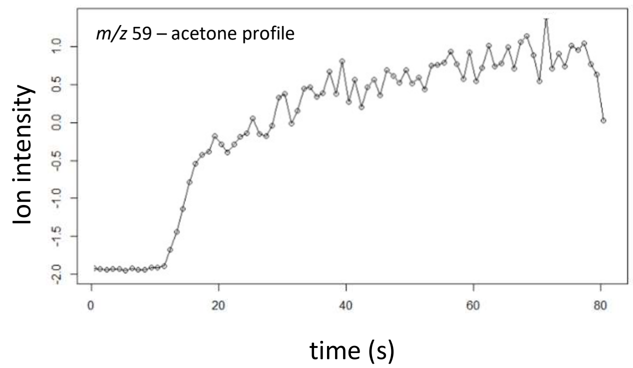
Uses a technology called proton transfer reaction-time of flight-mass spectrometry (PTR-TOF-MS)

Rapid analysis (< 1 min)

Exhaled VOCs as function of time, not just total VOCs

Individual profiles e.g. ‘breath fingerprinting’ for *precision medicine*





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Real-time analysis

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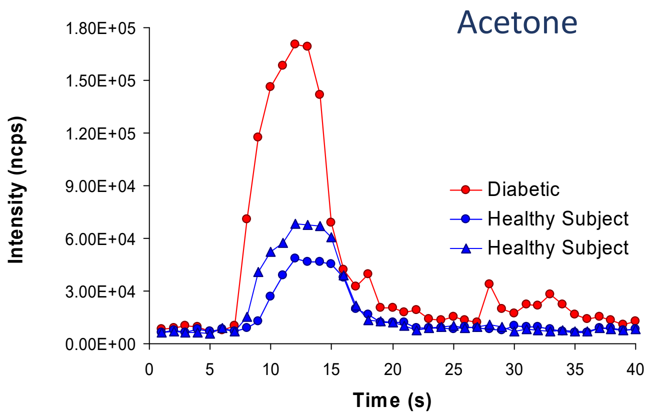
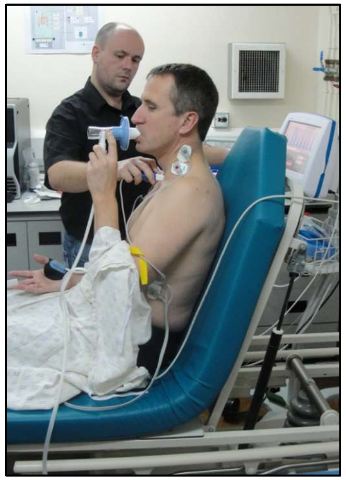
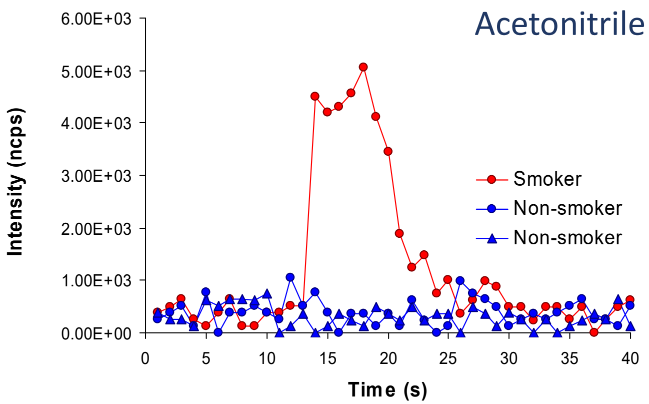
Real-time monitoring of VOCs in clinic

WMJ4

Into the clinic







Real-time measurements of breath composition

a) Acetone – simple marker for diabetes
b) Acetonitrile – marker for smokers

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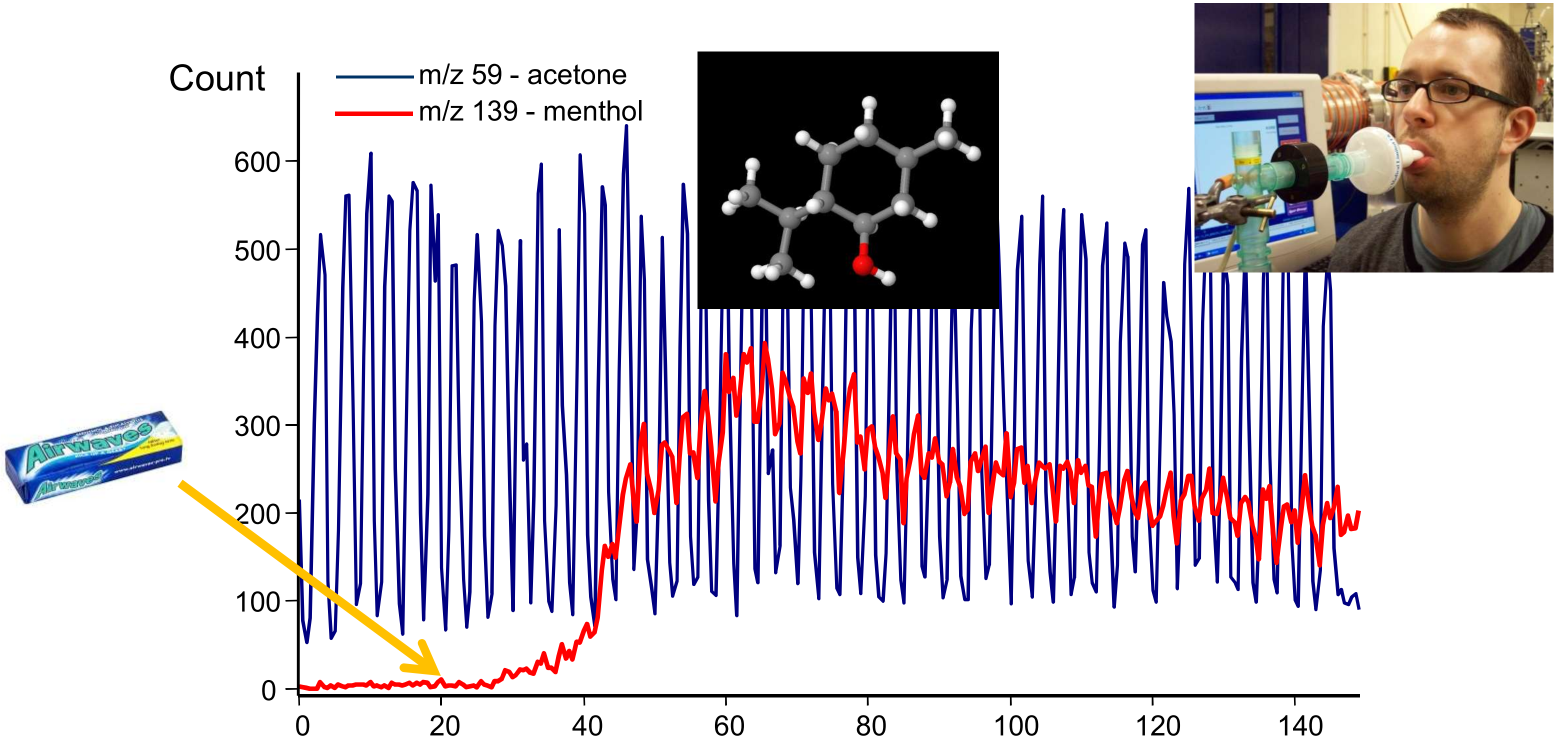
Slide 30

WMJ4 Example of real-time analysis of breath in a hospital, couple of different examples of chemicals markers in different groups of patients

Wilde, Michael J., 02/05/2018

Specific Applications:
Breath Detection of Chewing Gum



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Chromatographic separation

Offline analysis of VOCs

Uses a technology called gas chromatography-mass spectrometry (GC-MS) and two-dimensional gas chromatography (GCxGC)

Long analysis time (40+ min)

Separation of individual biomarkers

Chromatographic profile e.g. ‘breath fingerprinting’ for *precision medicine*

WMJ9

Chromatographic separation

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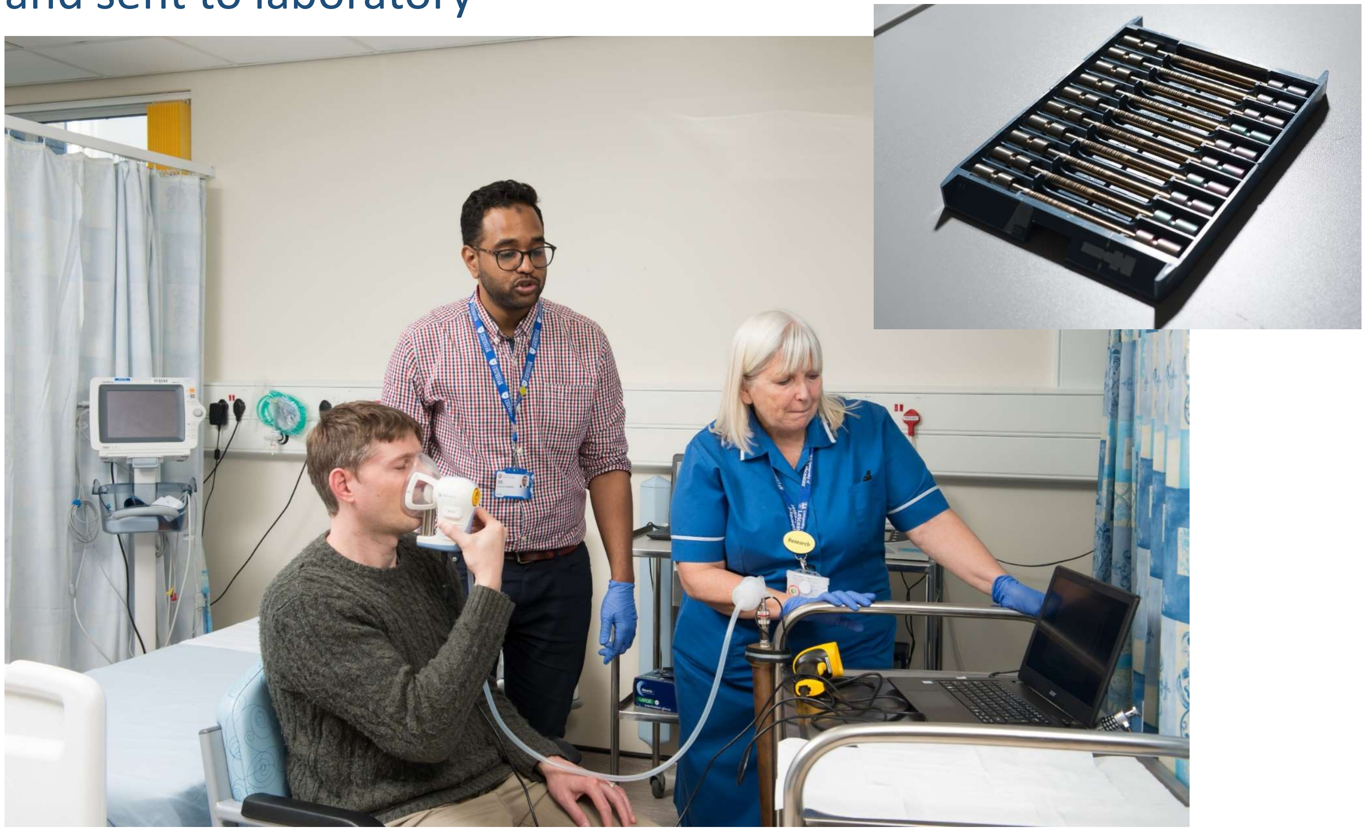
Offline analysis of VOCs – samples collected at patient bedside and sent to laboratory



WMJ9 Samples for offline analysis are collected in clinic.
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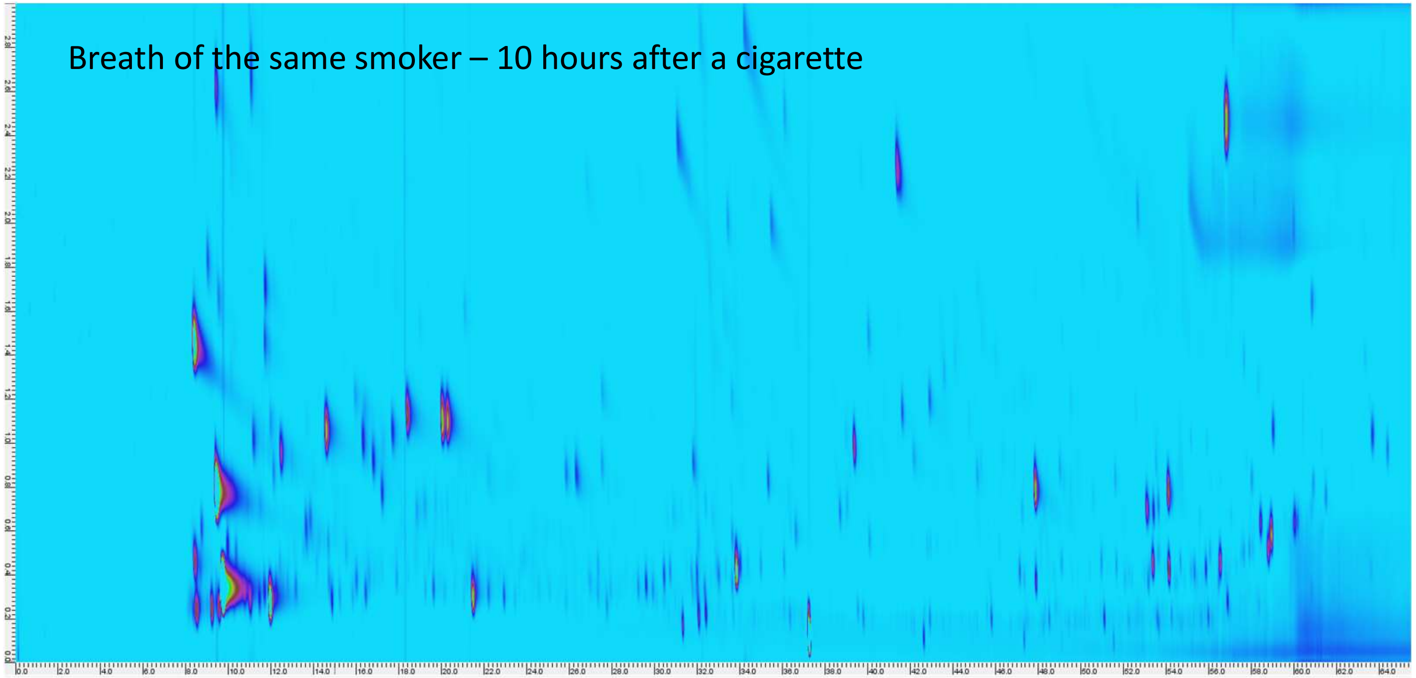
WMJ10

Into the clinic

Effects of smoking

Even after 10 hours, mouth contamination has disappeared (after eating, brushing teeth and sleeping), but additional compounds still present, coming from the body



Slide 34

WMJ10 Graphical portayal of the effects of smoking on the body. After 10 hours, increased complexity due to smoking is still observed, these compounds are in the blood and lungs and still being exhaled from the body.

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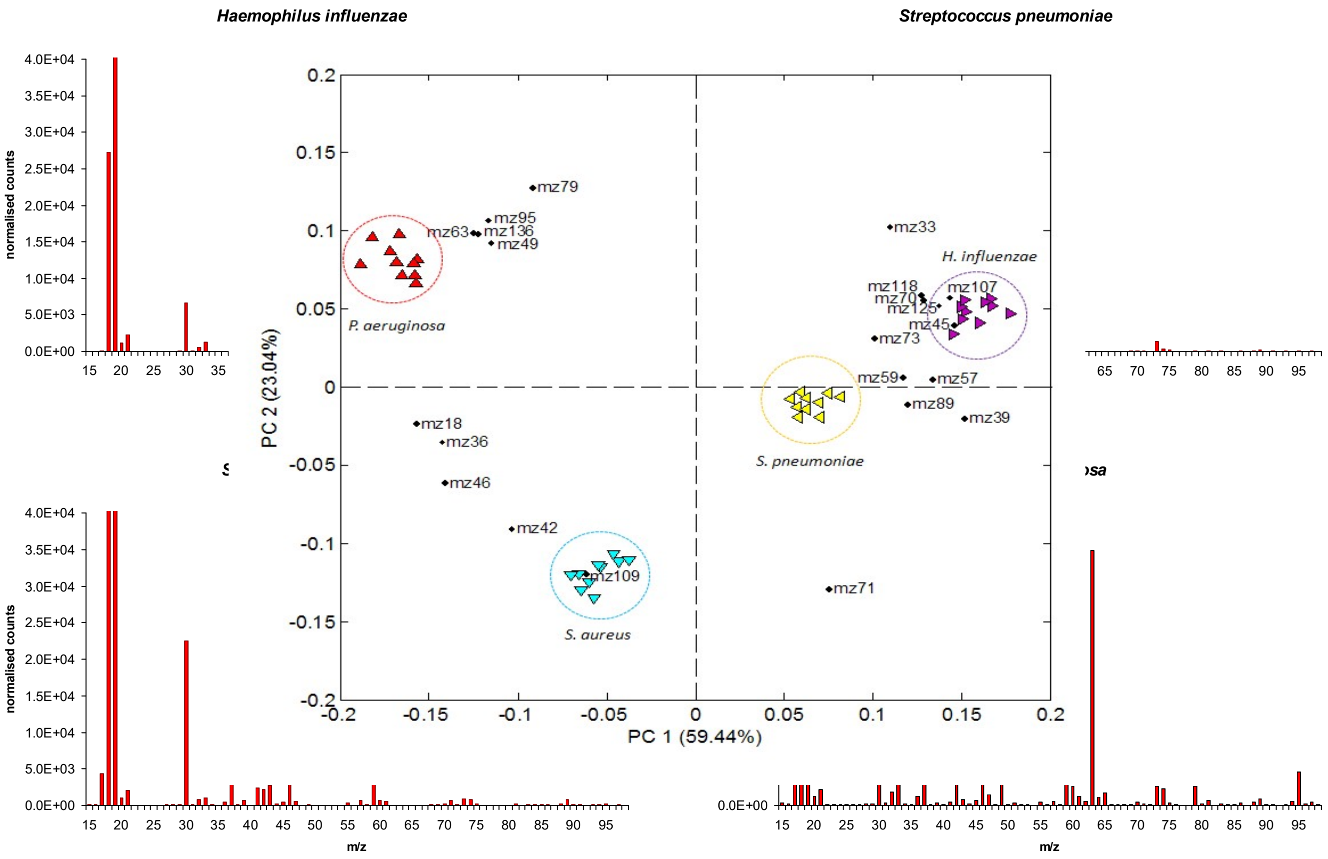
WMJ5

Bacteria headspace analysis

Bacteria release different metabolites and we can differentiate based on this profile



Slide 35

WMJ5 These are four common bacterial infections in the lungs. Analysis of the VOCs they release allows different bacteria to be characterised.
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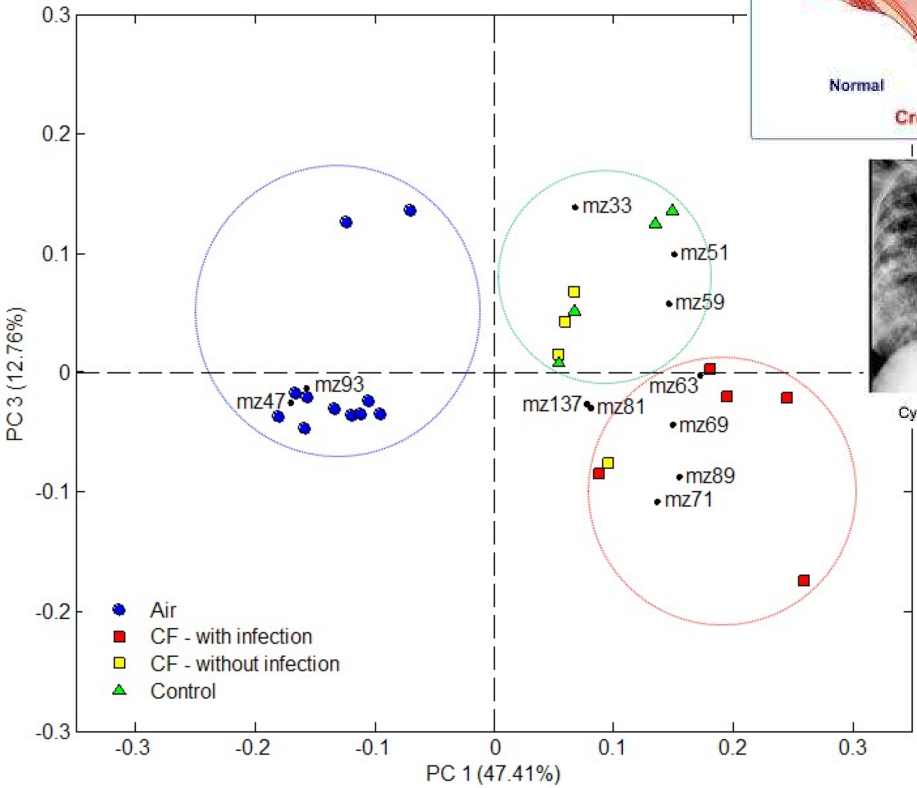
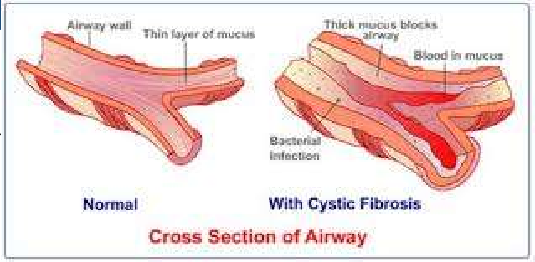
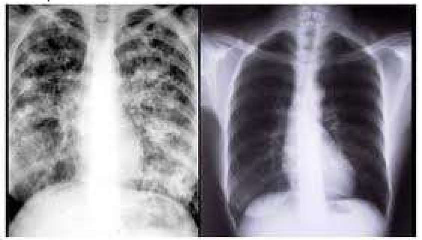
WMJ6

Cystic fibrosis

Use this to detect infection in patients







Cystic Fibrosis Lung

Healthy Lung

White et al, JBR 2013

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WMJ6 Following on the last slides, as it's possible to differentiate different bacteria, it was possible to differentiate patients suffering cystic fibrosis which had also a lung infection from their breath

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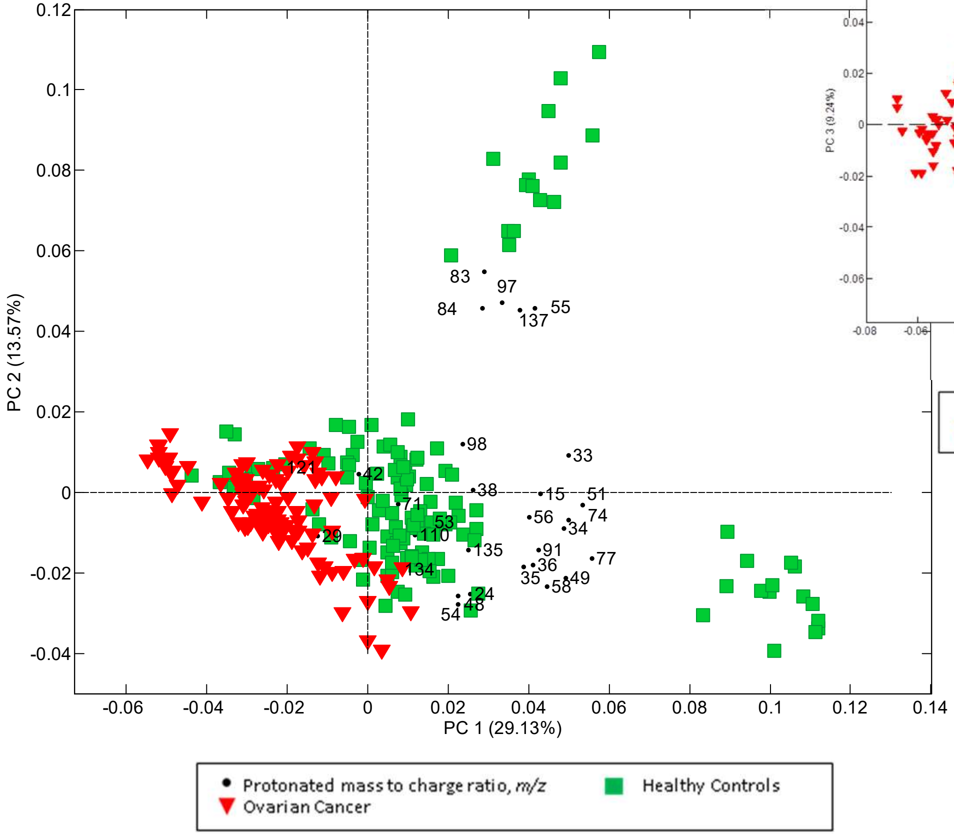
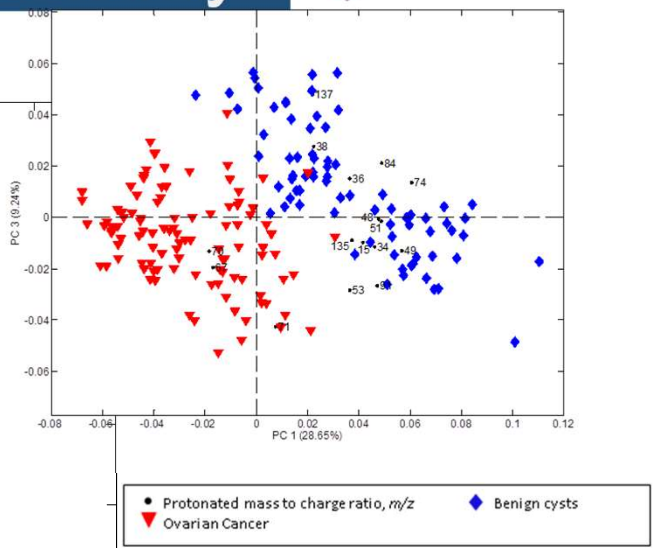
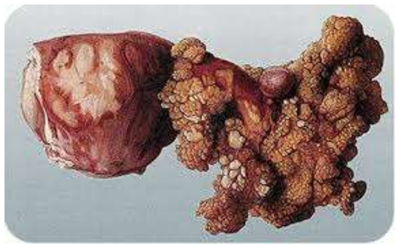
WMJ7

Ovarian cancer – pilot study





Ability to discriminate ovarian cancer from healthy controls as well as benign cysts from cancer



Slide 37

WMJ7 Analysis of different biopsy samples showed it was possible to differentiate cancer cells and healthy cells, if these chemical differences can be detected in breath then it would be a valuable diagnostic tool for clincians.

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Future outcomes

1) **Clinicians-** with improved diagnostics and biomarkers

2) **Patients-** by improved clinical decision making with near-patient, non-invasive technologies that are widely applicable

3) **Health care providers-** decision making for optimising allocation of resources

4) **Pharmaceutical industry-** 'breathomics' as an outcome in early phase development, stratification, companion diagnostic in the clinic

5) **Platform technology industries-** improvements in the development of novel devices with clinical applications and the embedding this new molecular pathology in health care.

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Fresh — Bloated — Active — Advanced Active

Decomposition begins approximately 4 minutes after death.

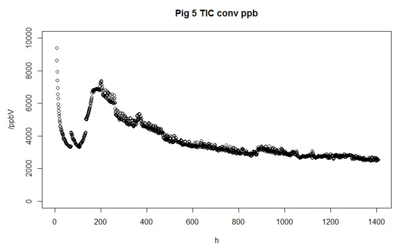
Accumulation of gases causes body to swell.

Body deflates, protein is broken down into fatty acids.

Corpse dries. Only remains are skin, hair and bones.

Fingerprinting Air - Applications

Whiff of Death



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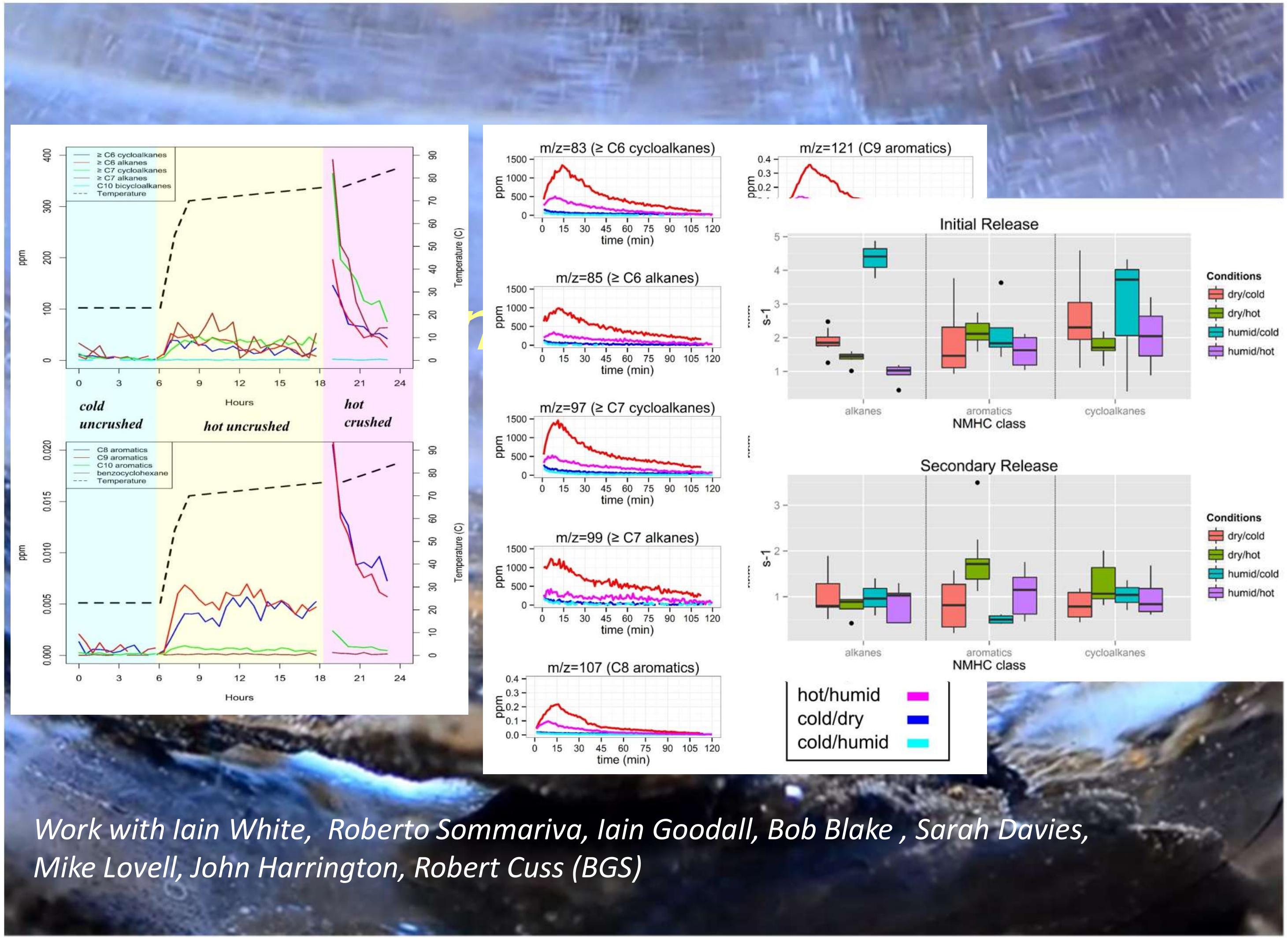
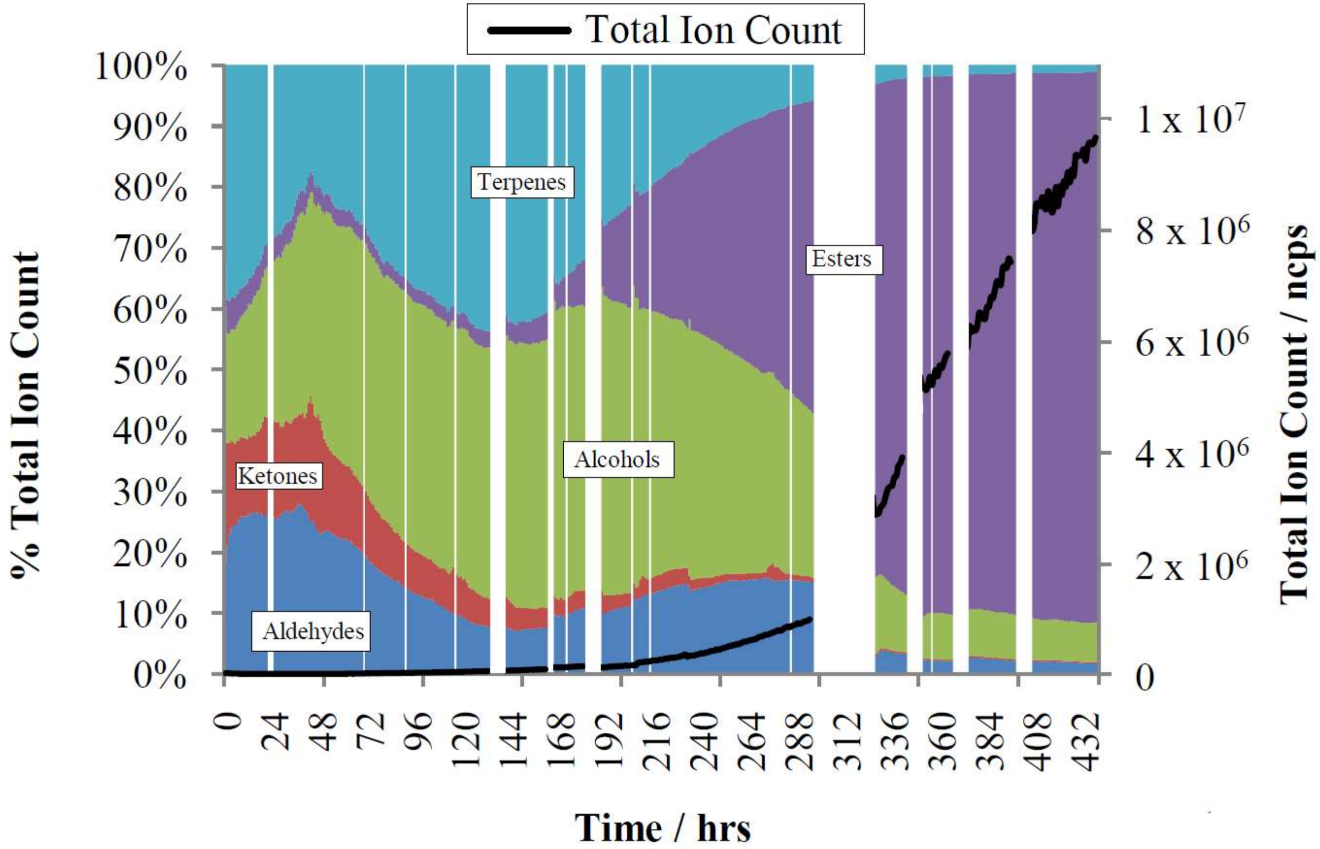

≥ C6 cycloalkanes
≥ C6 alkanes
≥ C7 cycloalkanes
≥ C7 alkanes
C10 bicycloalkanes
Temperature
ppm
Temperature (C)
Hours
cold uncrushed
hot uncrushed
hot crushed
C8 aromatics
C9 aromatics
C10 aromatics
benzocyclohexane
m/z=83 (≥ C6 cycloalkanes)
m/z=85 (≥ C6 alkanes)
m/z=97 (≥ C7 cycloalkanes)
m/z=99 (≥ C7 alkanes)
m/z=107 (C8 aromatics)
m/z=121 (C9 aromatics)
time (min)
Initial Release
Secondary Release
alkanes
aromatics
cycloalkanes
NMHC class
Conditions
dry/cold
dry/hot
humid/cold
humid/hot
hot/humid
cold/dry
cold/humid
Work with Iain White, Roberto Sommariva, Iain Goodall, Bob Blake , Sarah Davies,
Mike Lovell, John Harrington, Robert Cuss (BGS)



Work with Iain White, Bob Blake, Andy Taylor (UNott, MARS)

What have Uni Leicester looked at …

- Security – Chemical Warfare Agents
- Food analysis – Is a single malt better?
- Automotive emissions – H_2S quantification
- Medical diagnostic or prognostic
  - Breath analysis
- Process monitoring – engine emissions
- Consumer Product testing – ***'Watching Paint Dry'***
- Environmental monitoring or measurement
  - Atmospheric Composition, Isobaric Compounds, Secondary Organic Aerosol
- Forensic Science
  - Arson, Bodily fluids, Dead Bodies, DoA

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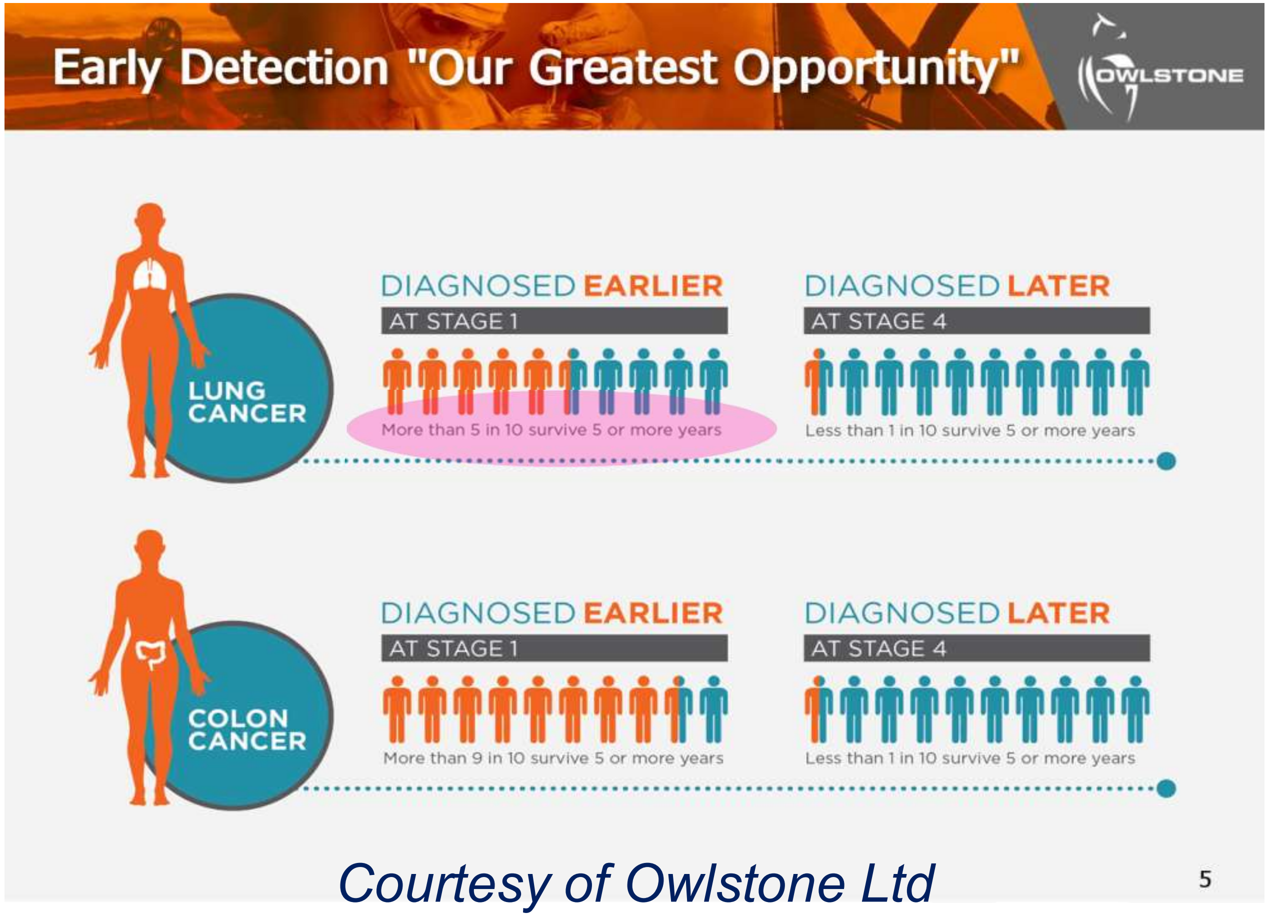
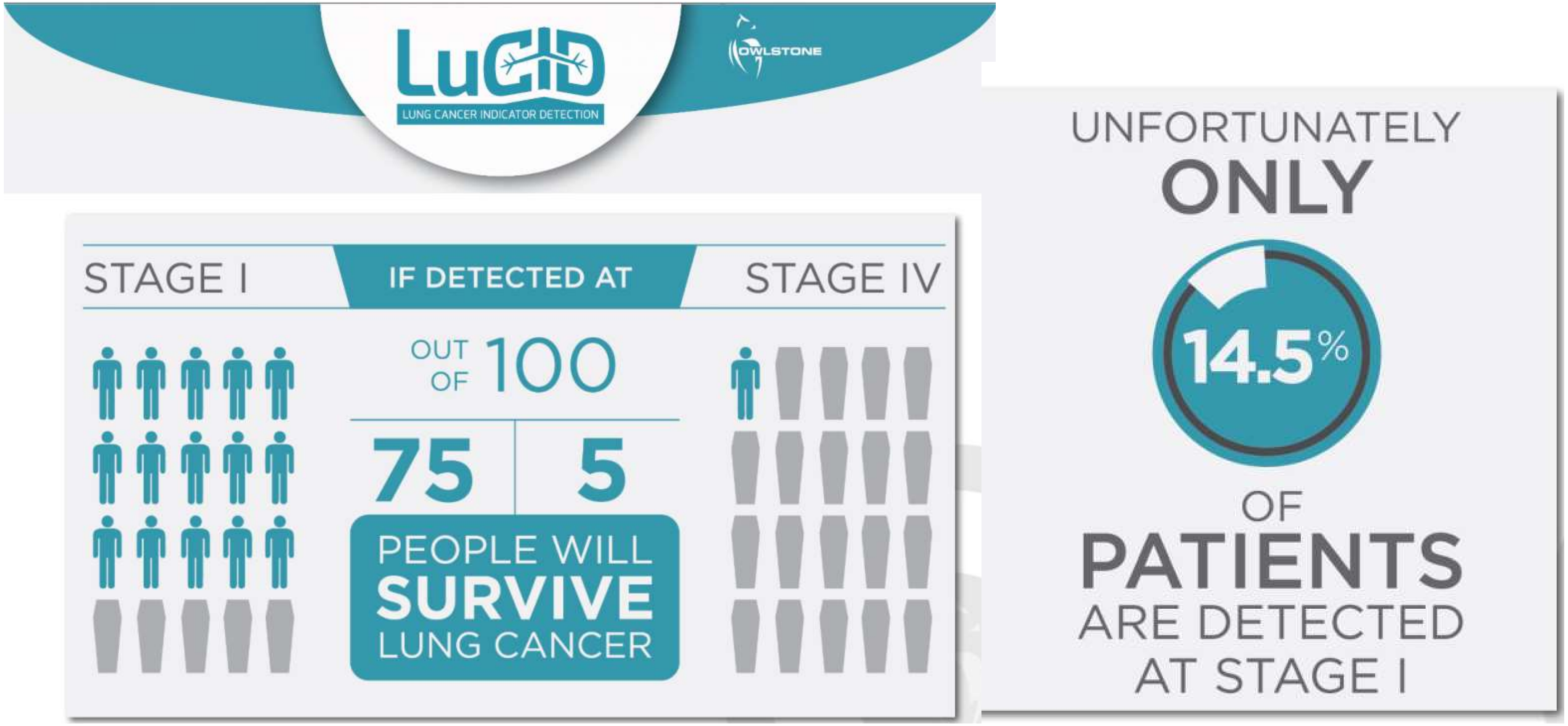
Sampling the patient remotely for disease diagnosis

Early detection for cancer diagnosis



Courtesy of Owlstone Ltd



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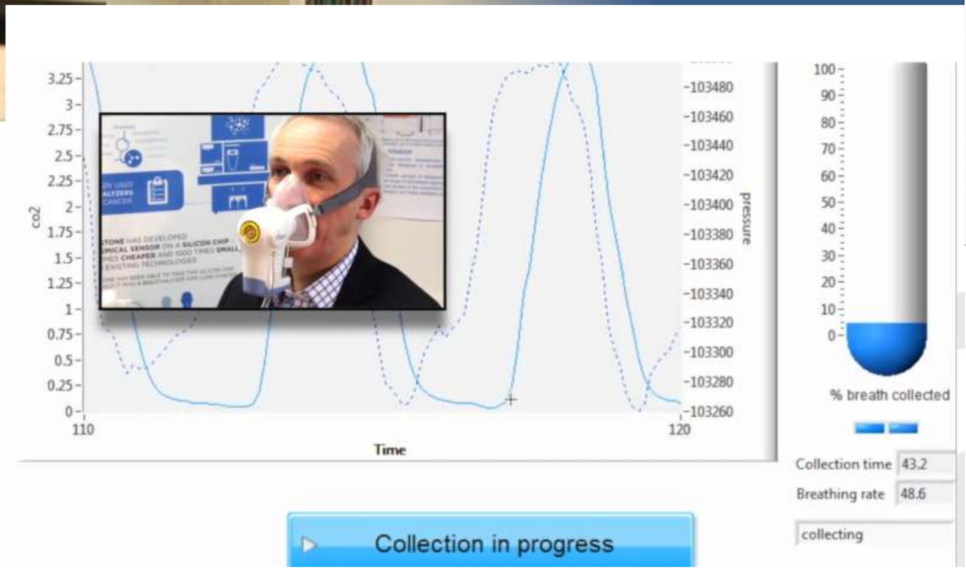
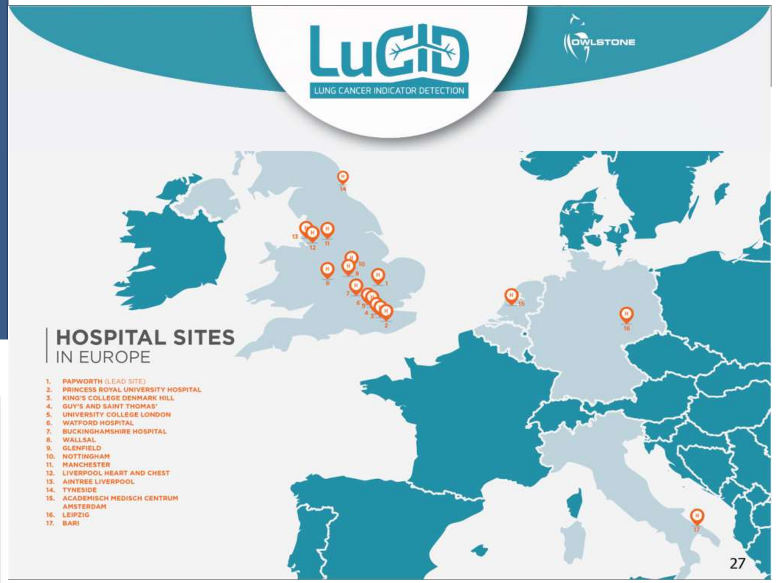
LuCID
LUNG CANCER INDICATOR DETECTION

OWLSTONE

- £1.1M NHS contract
- Largest breath biomarker trial ever undertaken in the world
- Multi-centre across UK, Europe.
- Initial target recruitment 600; ~300 lung cancer patients and 300 controls. Extended to 2,500 to 3,000 for early stage detection.
- NIHR portfolio approved (UKCRN ID: 19914)
- Chief Investigator: Dr Robert Rintoul

Courtesy of Owlstone Ltd





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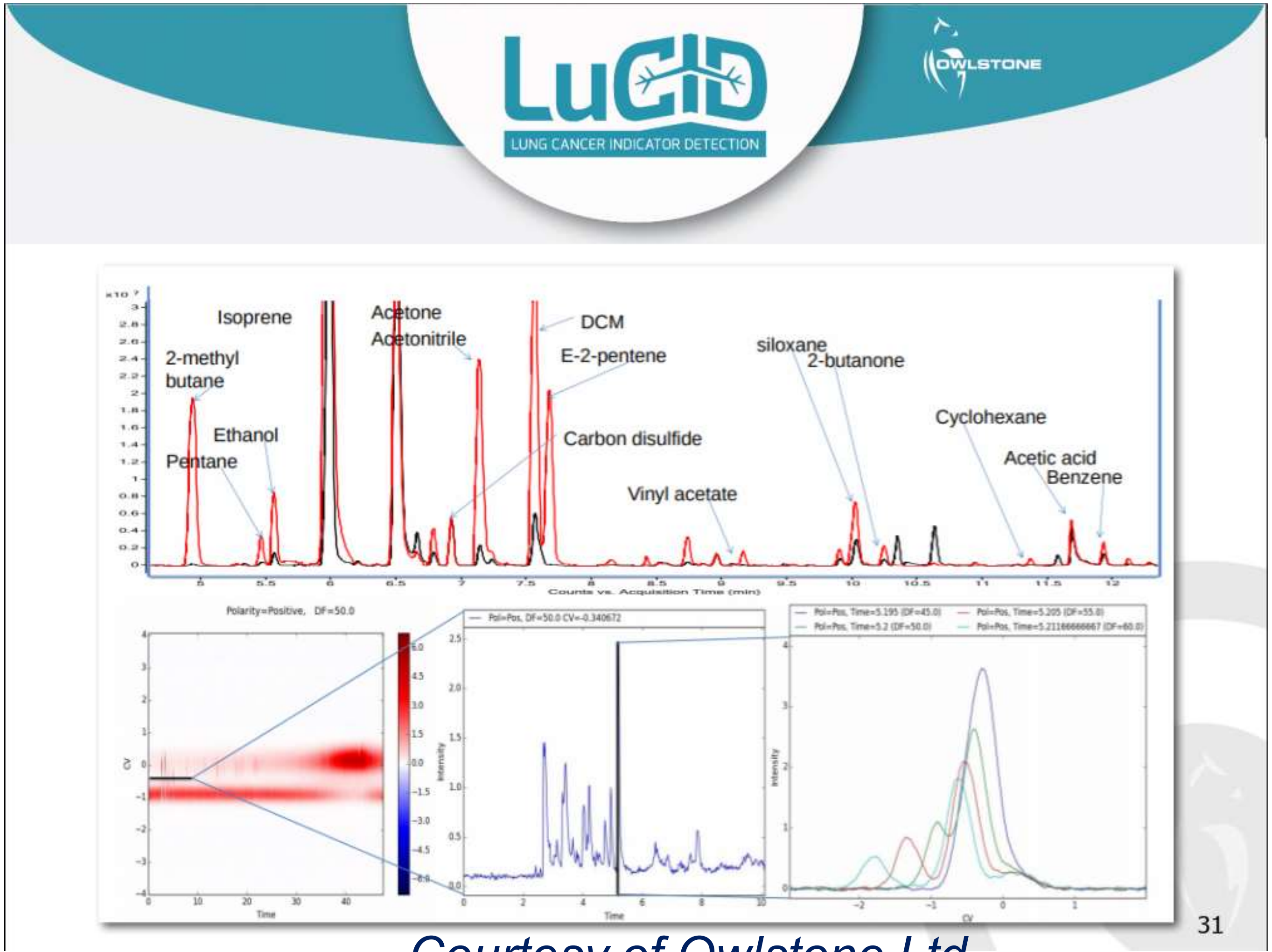

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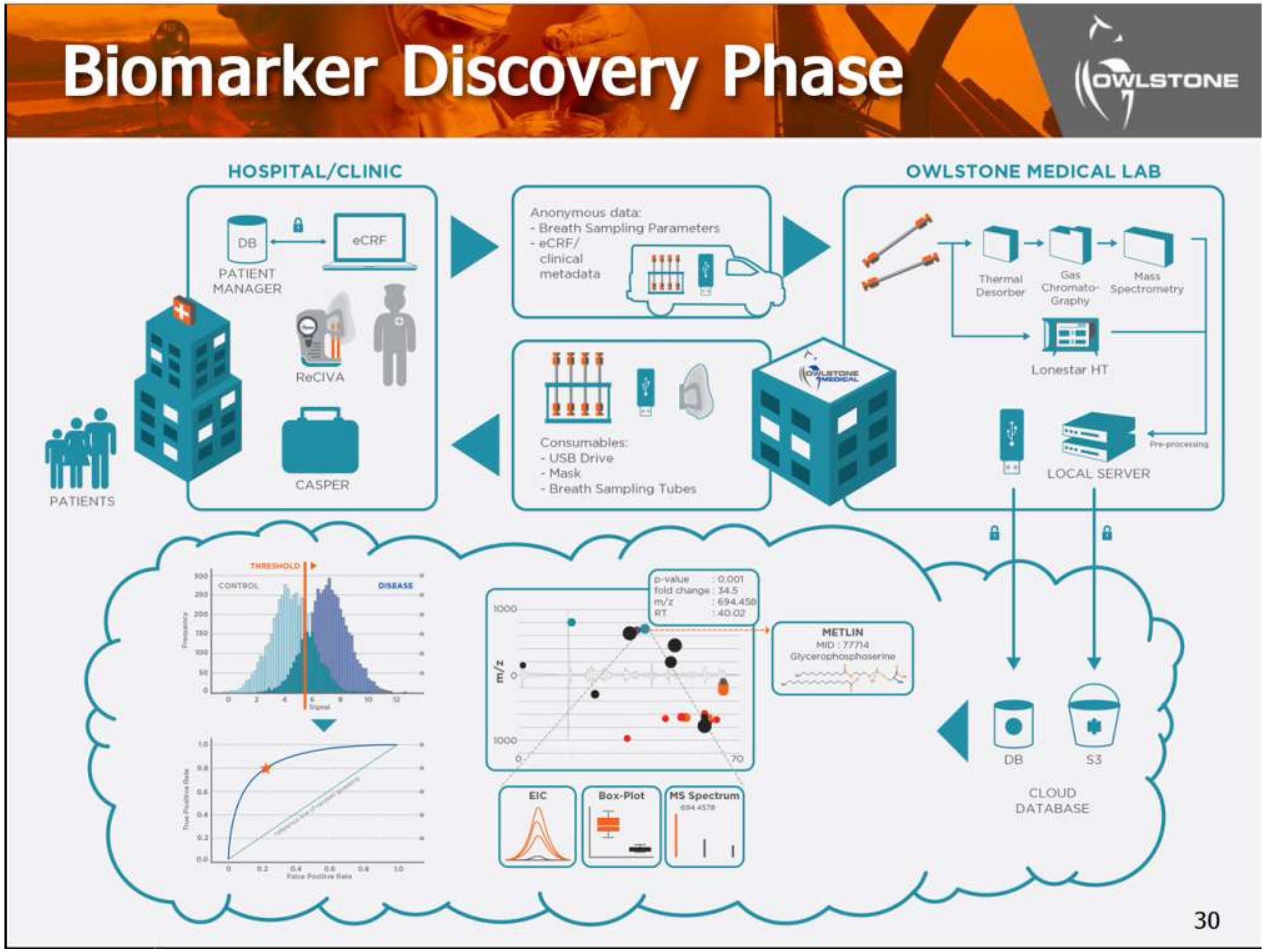

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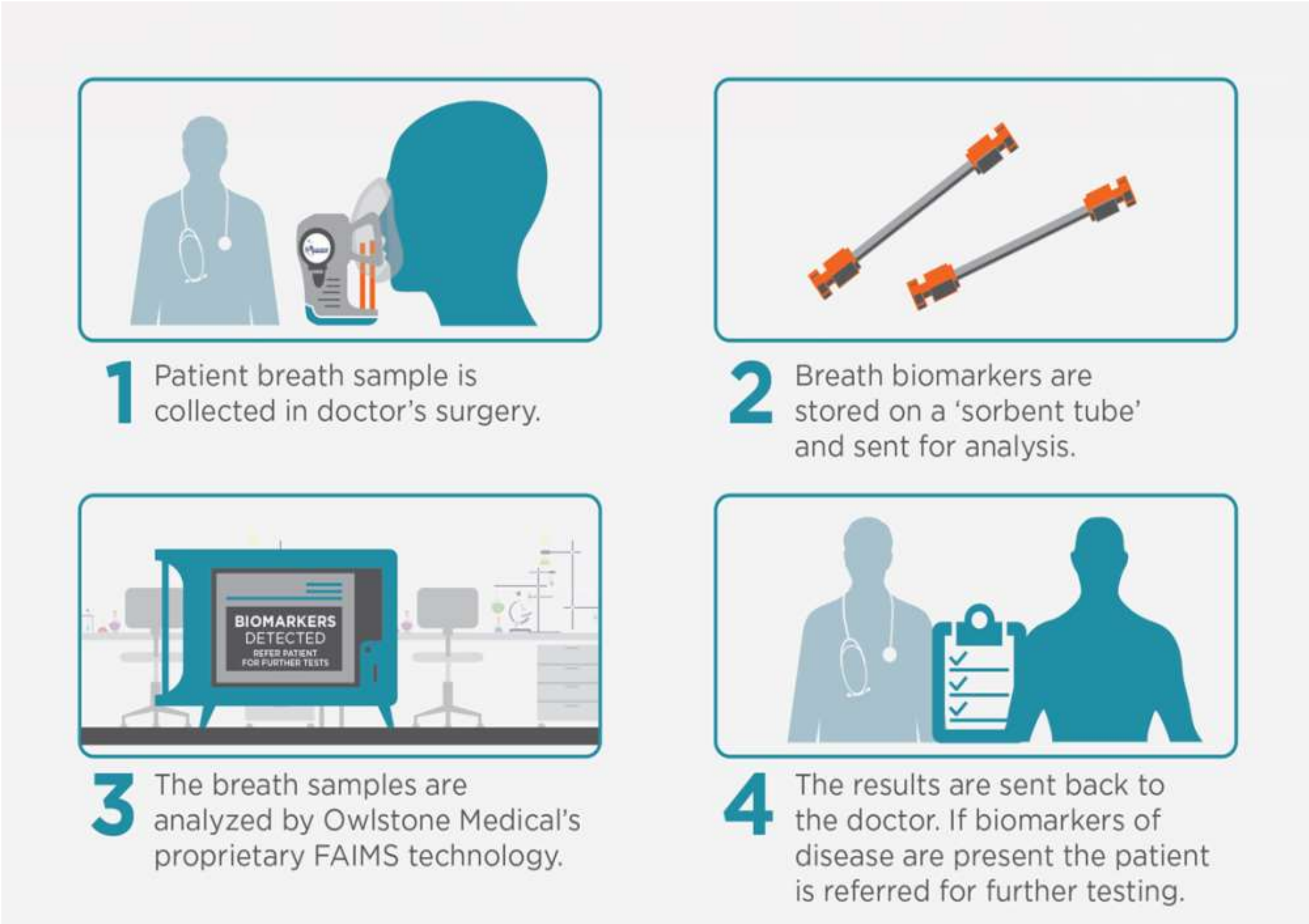

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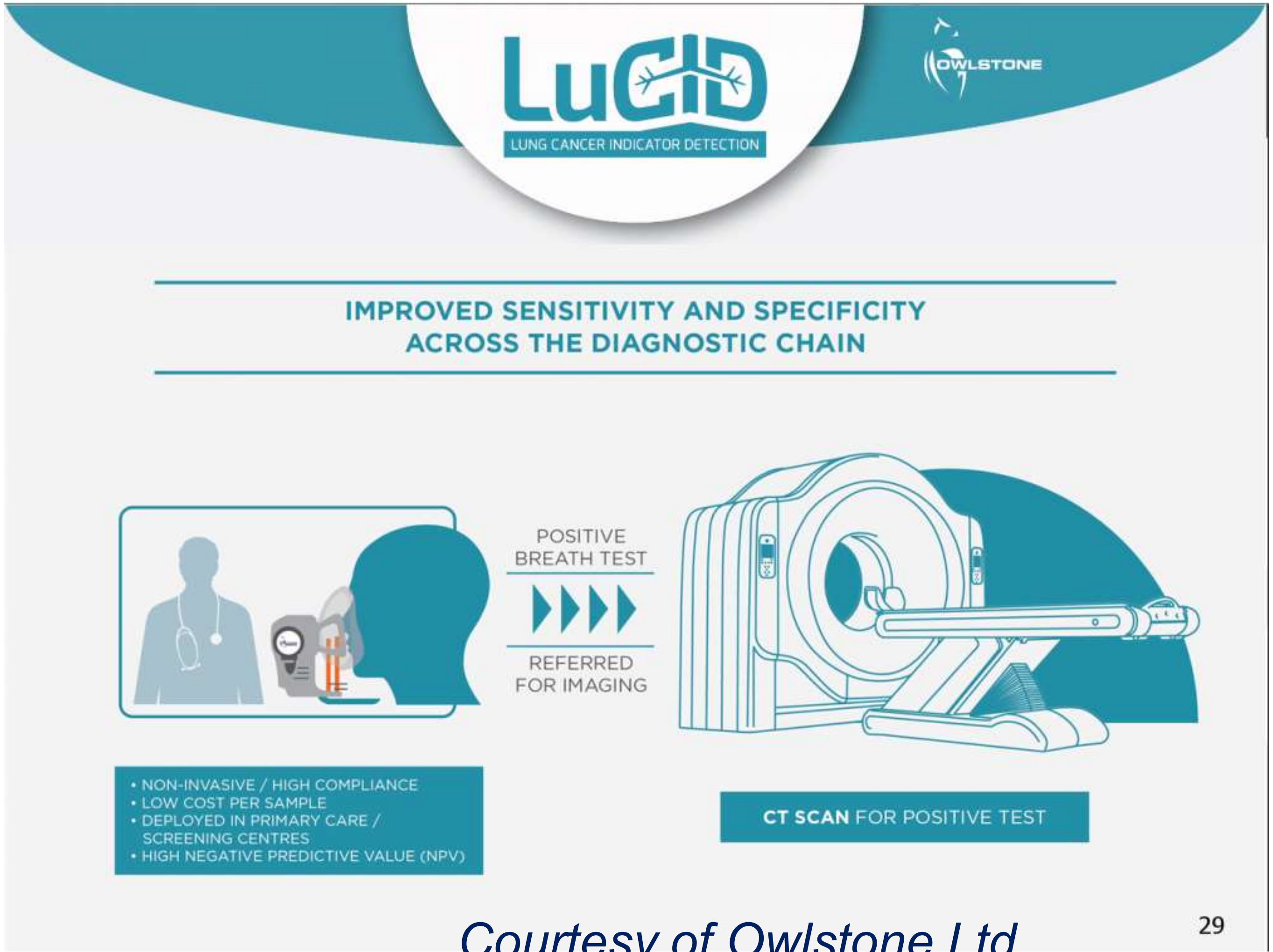


Courtesy of Owlstone Ltd

Analytical science and Parkinson's diagnosis

The woman who can smell Parkinson's disease

By Elizabeth Quigley
BBC Scotland news

22 October 2015

Share

Joy Milne was tested by researchers to see if she could detect people with Parkinson's through a tell-tale odour

Dr Tilo Kunath, a Parkinson's UK fellow at Edinburgh University, was one of the first scientists Joy spoke to.

Early study - tested Joy with six people with Parkinson's and six without.

Each wore a t-shirt for a day, then the t-shirts retrieved, bagged and coded.

"Her accuracy was 11 out of 12. We were quite impressed."

Joy identified six Parkinson's and was adamant one of the 'control' subjects had Parkinson's.

Eight months later the control individual informed the research team that he had been diagnosed with Parkinson's.

Joy wasn't correct for 11 out of 12, she was actually 12 out of 12.

Inspired a much bigger study

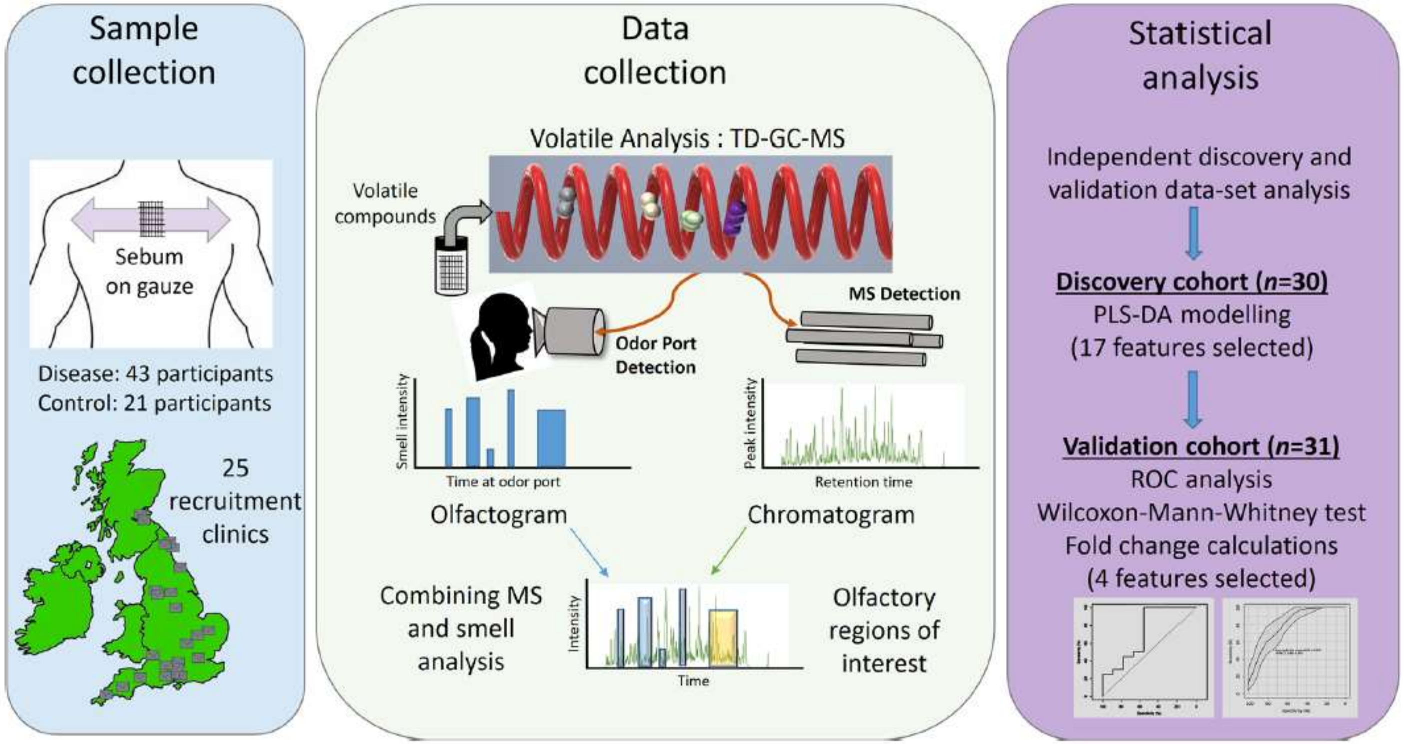
Analytical science and Parkinson’s diagnosis

- Professor Perdita Barran’s research group at the University of Manchester are collaborating with Joy to characterise the specific chemical odours associated with Parkinson’s

- Testing t-shirt samples from patients

- Applying Gas Chromatography-Mass Spectrometry to characterise the many components of the odours captured on the t-shirts
  - Laboratory based analytical science for fundamental understanding

- Overall goal is to create a clinical test for the early diagnosis of the disease
  - Simple test and/or device

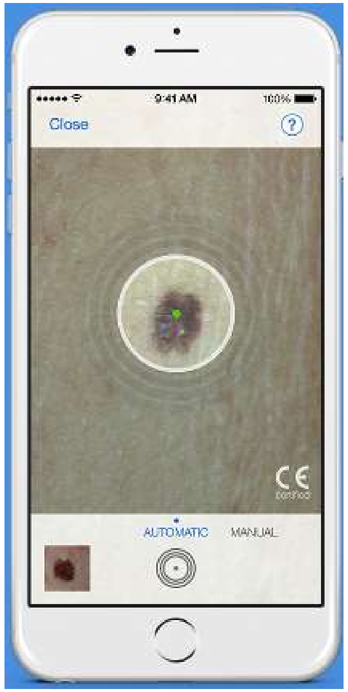


Reference: Barran et al, ACS Cent. Sci. 2019, 5, 599−606

Comprehensive analysis of sebum from patients raises the possibility that individuals can be screened noninvasively based on targeted analysis of volatile biomarkers

The universal analytical scientist…..coming to a home near you soon?

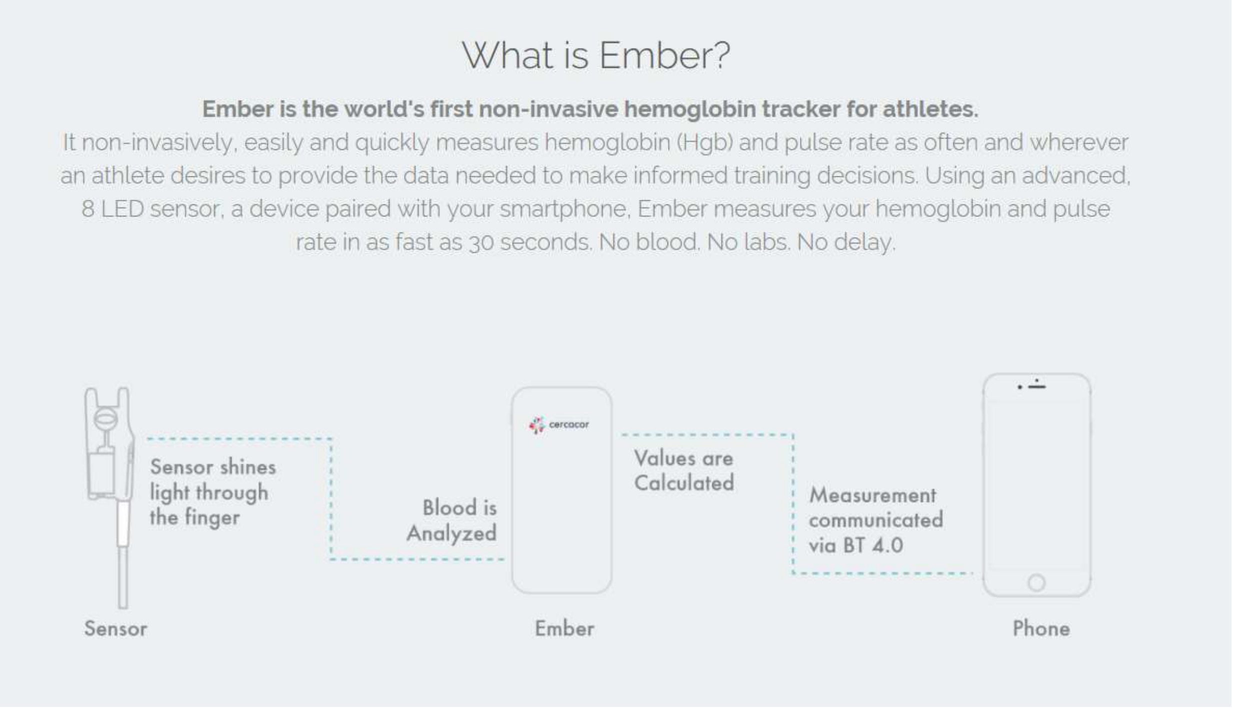
Examples of the roving analytical scientist

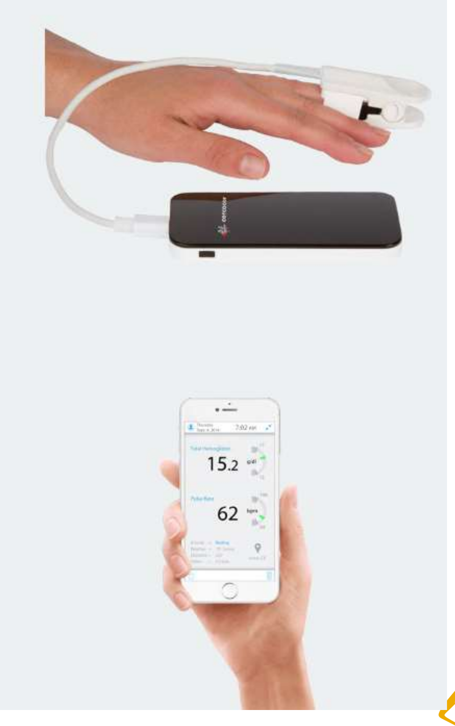


References: http://www.drinkdriving.org, https://skinvision.com, http://uk.clearblue.com

Ceracor Ember

Non-invasive Hemoglobin monitoring sports training

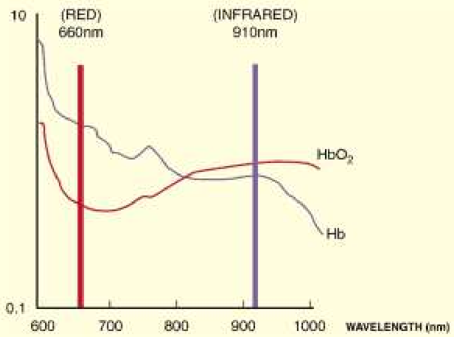




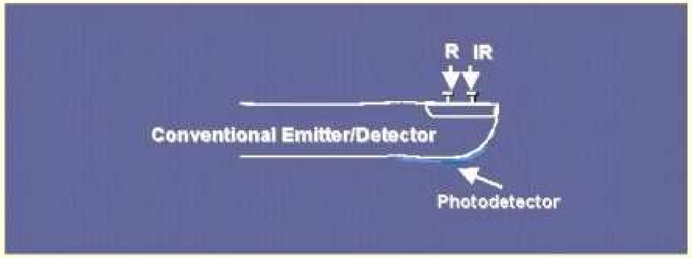
Reference: http://www.cercacor.com/#what-is-ember

The Science of Hemoglobin Measurement

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band.



Pulse oximetry uses a light emitter with red and infrared LEDs that shines through a reasonably translucent site with good blood flow. Typical adult/pediatric sites are the finger, toe, pinna (top) or lobe of the ear. Infant sites are the foot or palm of the hand and the big toe or thumb. Opposite the emitter is a photodetector that receives the light that passes through the measuring site.



Pulse oximetry is a noninvasive method for monitoring a person's oxygen saturation (SO_2).

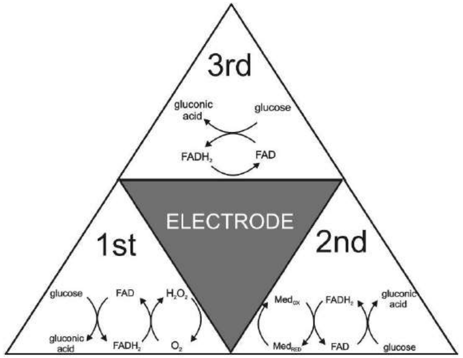
A blood-oxygen monitor displays the percentage of blood that is loaded with oxygen.

More specifically, it measures what percentage of hemoglobin, the protein in blood that carries oxygen, is loaded

Reference: http://www.oximetry.org/pulseox/principles.htm

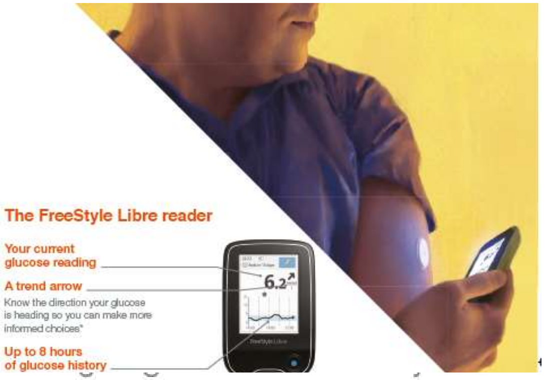
Sensors – an evolving area providing new opportunities
Real world example of advances in patient home monitoring
Glucose and Diabetes

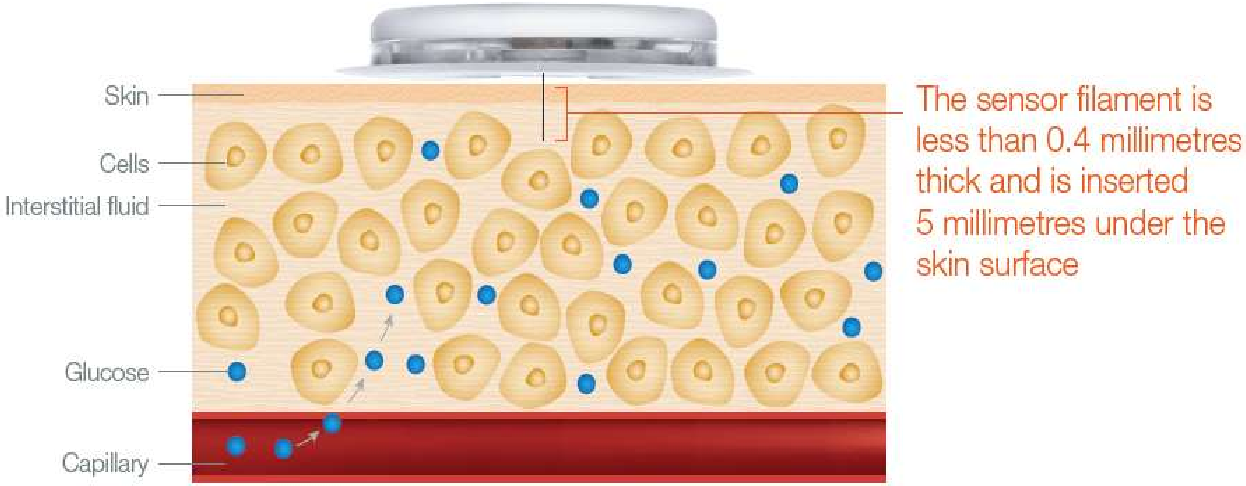
$$\mathrm{GOx(FAD)} + \mathrm{glucose} \longrightarrow \mathrm{GO_x(FADH_2)} + \mathrm{glucolactone} \qquad (1)$$



Courtesy of Abbott Diabetes Care

Abbott Freestyle Libre





Courtesy of Abbott Diabetes Care

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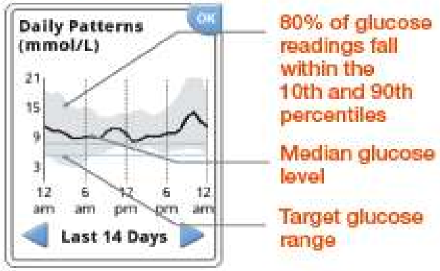
Daily Patterns

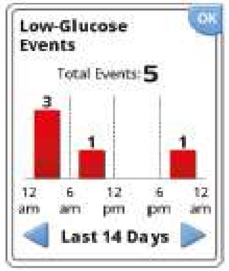


Shows the variability of glucose levels over multiple days to give a quick snapshot of glycaemic control.

Time In Target

Shows the percentage of time glucose readings were above, below and within the target glucose range, helping motivate patients to get more of their readings within the target range.

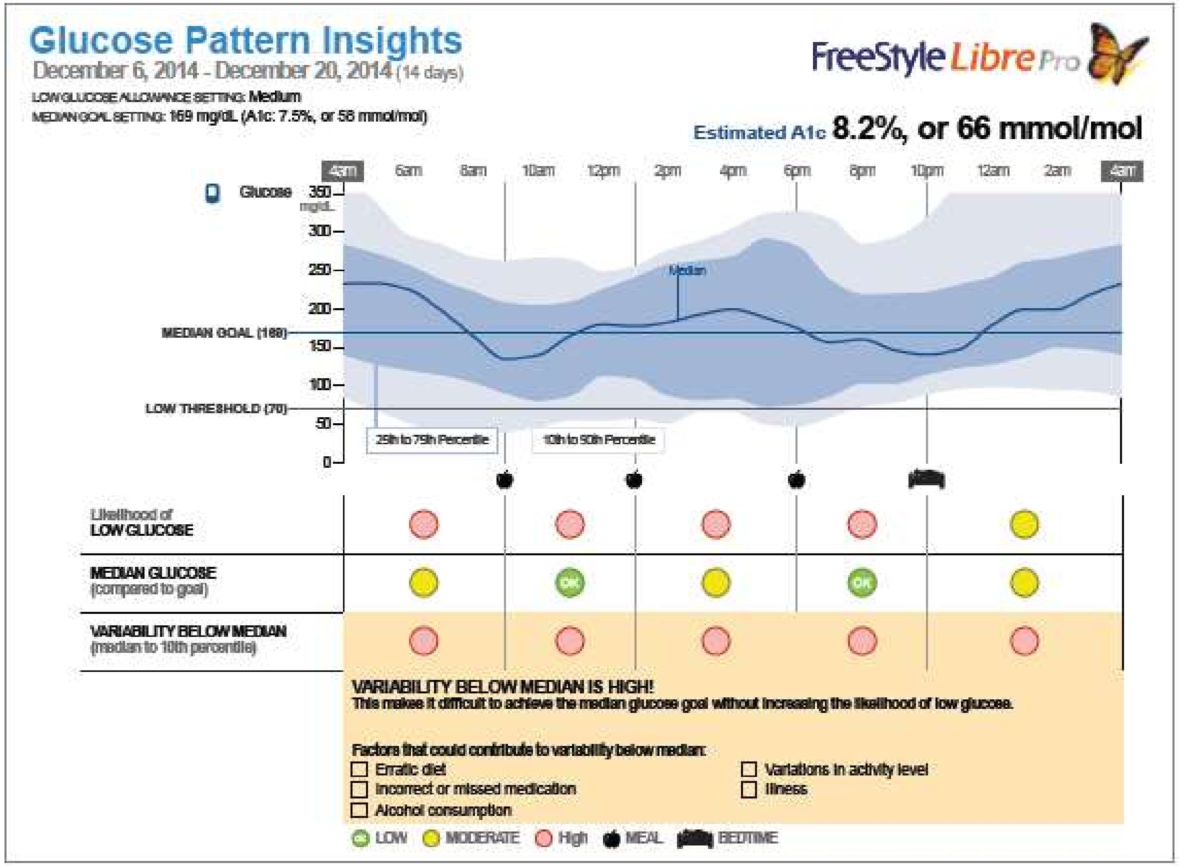
Low Glucose Events



Shows the total number of low glucose events at 4 different times of day. Low glucose events are recorded when glucose readings are lower than 3.9mmol/L for longer than 15 minutes.

Courtesy of Abbott Diabetes Care

Abbott Freestyle Libre



Courtesy of Abbott Diabetes Care

60 million real-world glucose tests reviewed

DIABETES RESEARCH AND CLINICAL PRACTICE 137 (2018) 37–46

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journal homepage: www.elsevier.com/locate/diabres

International Diabetes Federation

Real-world flash glucose monitoring patterns and associations between self-monitoring frequency and glycaemic measures: A European analysis of over 60 million glucose tests

Timothy C. Dunn [a,*], *Yongjin Xu* [a], *Gary Hayter* [a], *Ramzi A. Ajjan* [b]

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Glycaemic measures

ABSTRACT

Aims: Randomised controlled trials demonstrate that using flash glucose monitoring improves glycaemic control but it is unclear whether this applies outside trial conditions. We investigated glucose testing patterns in users worldwide under real life settings to establish testing frequency and association with glycaemic parameters.

Methods: Glucose results were de-identified and uploaded onto a dedicated database once readers were connected to an internet-ready computer. Data between September 2014 and May 2016, comprising 50,831 readers and 279,446 sensors worldwide, were analysed. Scan rate per reader was determined and each reader was sorted into twenty equally-sized rank-ordered groups, categorised by scan frequency. Glucose parameters were calculated for each group, including estimated HbA_{1c}, time above, below and within range identified as 3.9–10.0 mmol/L.

Results: Users performed a mean of 16.3 scans/day [median (IQR): 14 (10–20)] with 86.4 million hours of readings and 63.8 million scans. Estimated HbA_{1c} gradually reduced from 8.0% to 6.7% (64 to 50 mmol/mol) as scan rate increased from lowest to highest scan groups (4.4 and 48.1 scans/day, respectively; $p < .001$). Simultaneously, time below 3.9, 3.1 and 2.5 mmol/L decreased by 15%, 40% and 49%, respectively (all $p < .001$). Time above 10.0 mmol/L decreased from 10.4 to 5.7 h/day (44%, $p < .001$) while time in range increased from 12.0 to 16.8 h/day (40%, $p < .001$). These patterns were consistent across different countries.

Conclusions: In real-world conditions, flash glucose monitoring allows frequent glucose checks with higher rates of scanning linked to improved glycaemic markers, including increased time in range and reduced time in hyper and hypoglycaemia.

AstraZeneca

Innovations and a vision of the future

Science fiction
becoming science fact

Portable analytical instruments for detection of drugs and explosives – **Have you been tested?**

From lab based analysis to remote continuous monitoring

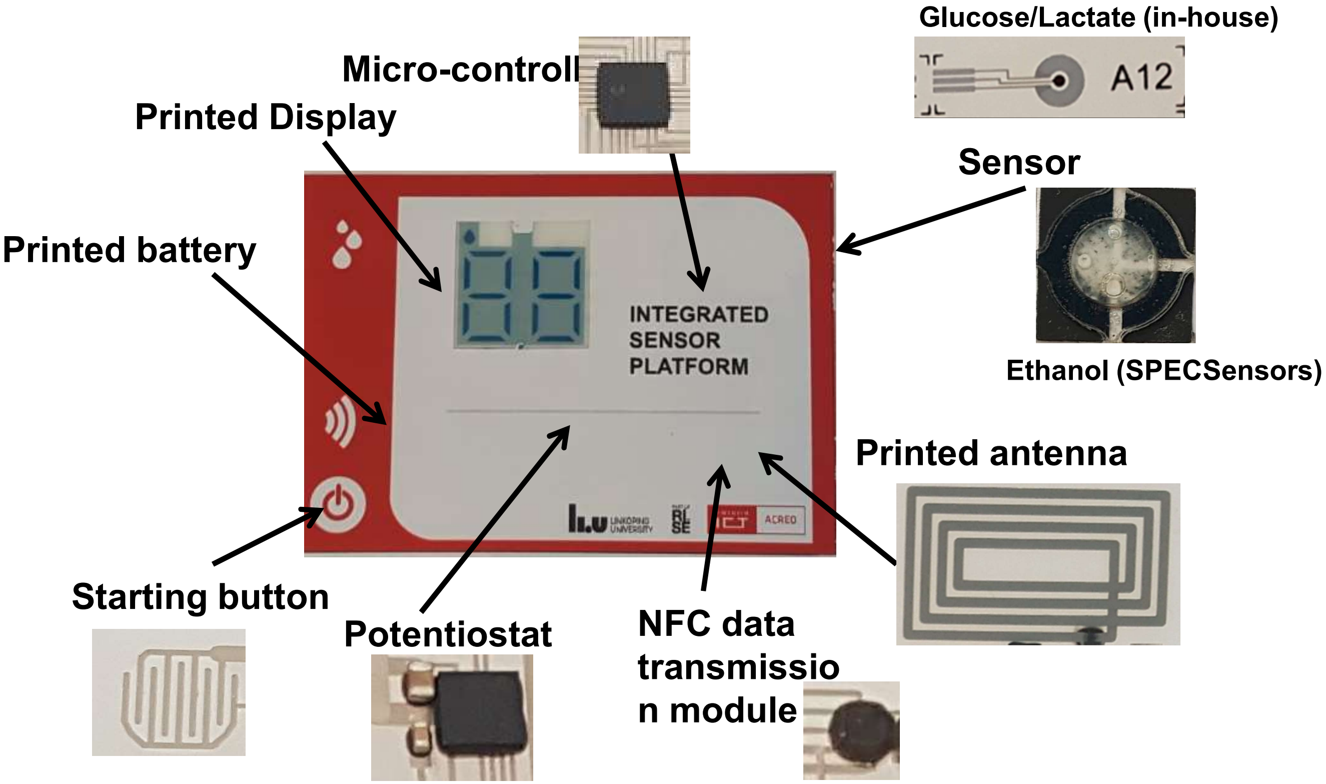
Today

Key drivers:

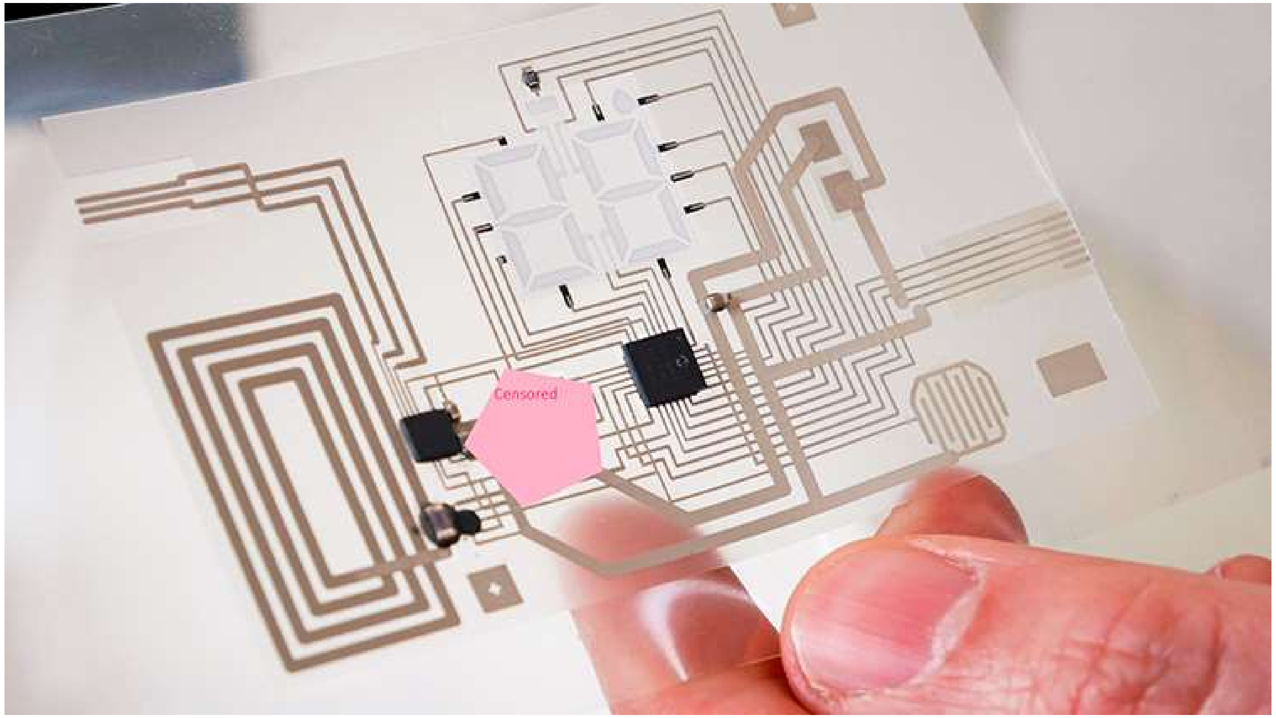
- Individual choice and ownership of data
- Decentralization
- Personalized Medicine
- Mobility !

Central lab ***Doctor´s office*** ***Home*** ***Full mobility Continous monitoring***

The miniaturised integrated platform



Courtesy of ACREO


Censored

Targets for detection, our know-how portfolio

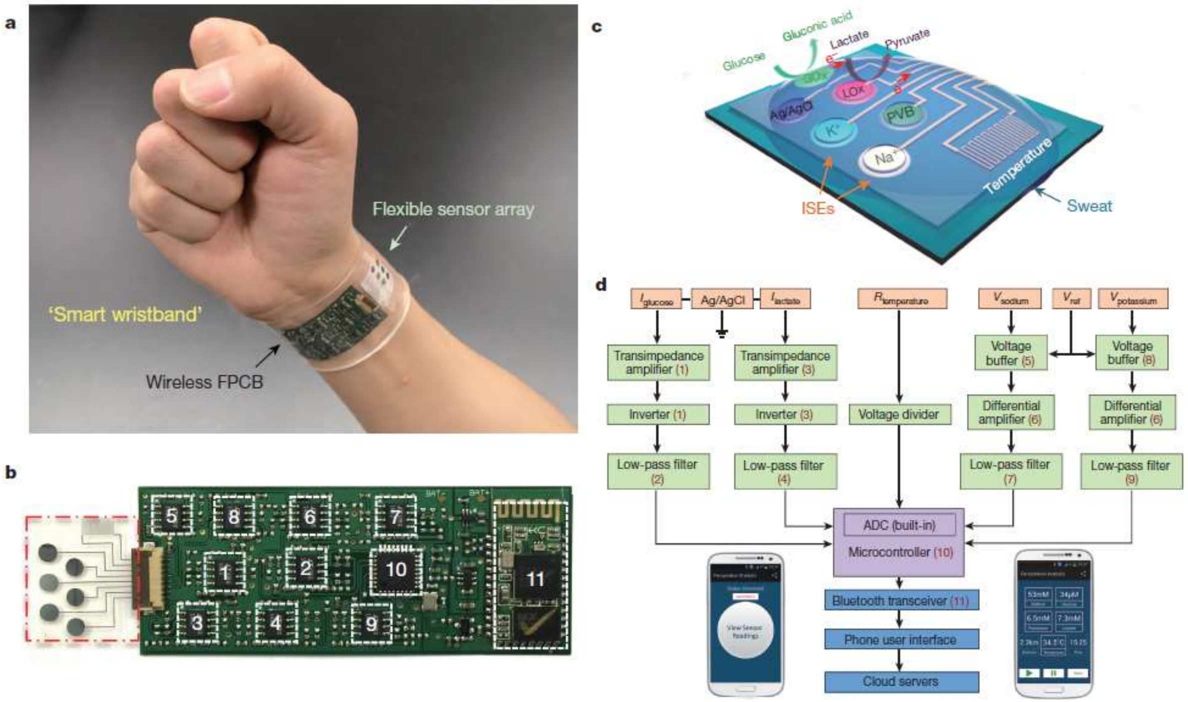
Parameter	Invasive	Where to measure	Important for
Oxygen	yes	Body fluids(blood or Interstitial fluids)	General assessment of hospitalised patient conditions
pH	both	Sweat or body fluids (blood or interstitial fluids)	Patient hydration and maybe wound healing
Na	both	Sweat or body fluids (blood or interstitial fluids)	Patient hydration and other diseases
Cl	yes	Body fluids (blood or interstitial fluids)	Patient hydration and other diseases
Lactate	both	Sweat or body fluids (blood or interstitial fluids)	Diabetes or physical activity or poor oxigenation
glucose	yes	Body fluids	Diabetes
Creatinine	yes	Body fluids (blood or interstitial fluids	Renal function
Conductivity**	both	Body fluids (blood or interstitial fluids) or skin (non-invasive)	Evaluation of stress or patient hydration.
Ammonium	yes	Body fluids (blood or interstitial fluids	Renal and liver function
Phenylalanine	yes	blood	Phenylketonuria in newborn
β-hydroxybutyrate	yes	blood	diabetes
Amylase	no	saliva	Stress
Affinity based sensors	yes	Blood, interstitial fluids, saliva	

Courtesy of ACREO

Acreo have a proprietary technology for microneedle sampling

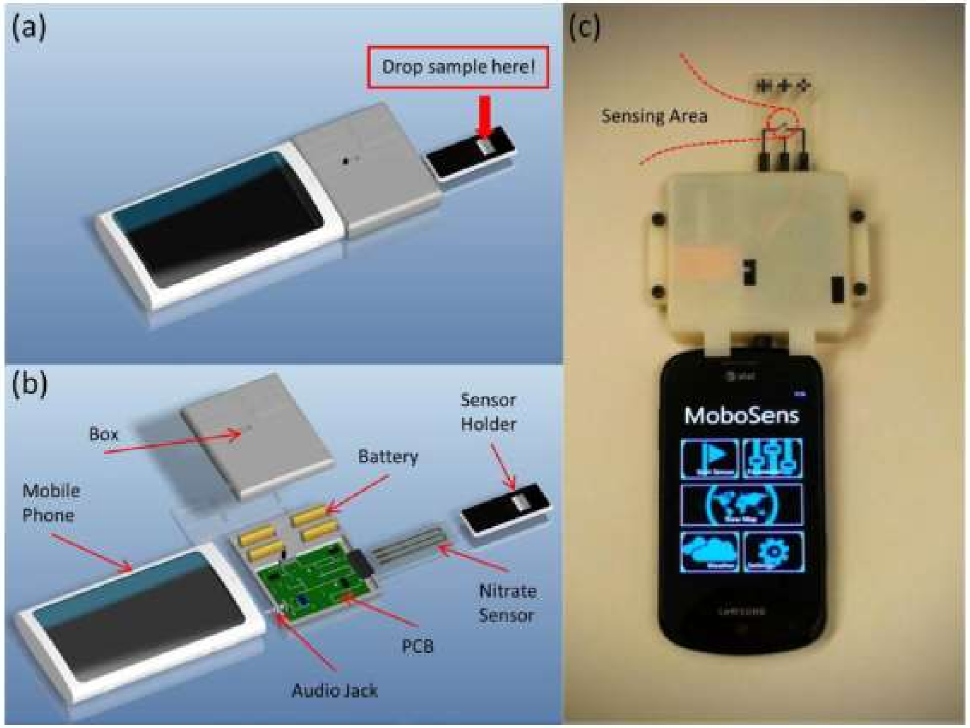
Minimally invasive sampling

More analytical chemistry laboratories you wear
Getting a sweat on……………



Reference: Nature, Volume 529, January 2016.
Gao et al, University Of California, Berkeley

The analytical chemistry laboratory in your mobile phone
Environmental analysis



Reference: Sensors and Actuators B 209 (2015) 677–685. X. Wang et al, *University Of Illinois*

There is big challenge for the technology development

- Specificity
- Validation of measurement
- Cost for end user
- Cost for health service
- Cost/health benefits
- Time to develop
- Ease of use
- Ease of understanding and interpretation
- Very few examples available commercially when you consider the thousands of publications in the area

Data, data and ever more data…………….
What does it all mean?????

AI is also transforming healthcare….

AI early diagnosis could save heart and cancer patients

By Pallab Ghosh
Science correspondent, BBC News

2 January 2018

Share

Sir John Bell believes that artificial intelligence can save the NHS

Researchers at an Oxford hospital have developed artificial intelligence (AI) that can diagnose scans for heart disease and lung cancer.

AI early diagnosis could save heart and cancer patients

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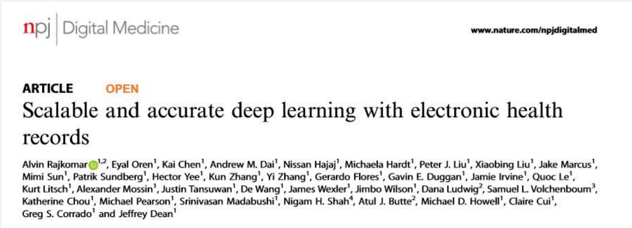


npj | Digital Medicine

www.nature.com/npjdigitalmed

ARTICLE OPEN

Scalable and accurate deep learning with electronic health records

Alvin Rajkomar[1,2], Eyal Oren[1], Kai Chen[1], Andrew M. Dai[1], Nissan Hajaj[1], Michaela Hardt[1], Peter J. Liu[1], Xiaobing Liu[1], Jake Marcus[1], Mimi Sun[1], Patrik Sundberg[1], Hector Yee[1], Kun Zhang[1], Yi Zhang[1], Gerardo Flores[1], Gavin E. Duggan[1], Jamie Irvine[1], Quoc Le[1], Kurt Litsch[1], Alexander Mossin[1], Justin Tansuwan[1], De Wang[1], James Wexler[1], Jimbo Wilson[1], Dana Ludwig[2], Samuel L. Volchenboum[3], Katherine Chou[1], Michael Pearson[1], Srinivasan Madabushi[1], Nigam H. Shah[4], Atul J. Butte[2], Michael D. Howell[1], Claire Cui[1], Greg S. Corrado[1] and Jeffrey Dean[1]

Google AI

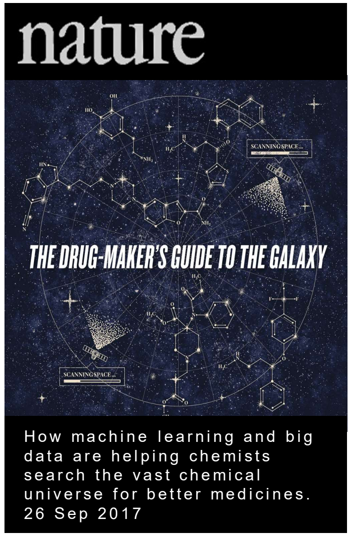
ARTICLES

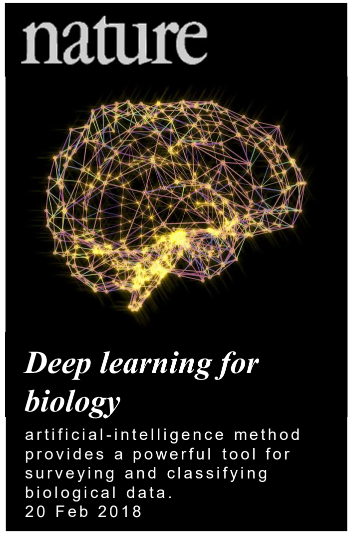
https://doi.org/10.1038/s41551-018-0195-0

nature biomedical engineering

Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning

Ryan Poplin[1,4], Avinash V. Varadarajan[1,4], Katy Blumer[1], Yun Liu[1], Michael V. McConnell[2,3], Greg S. Corrado[1], Lily Peng[1,4*] and Dale R. Webster[1,4]





…diagnosis and prediction of disease progression… and now R&D

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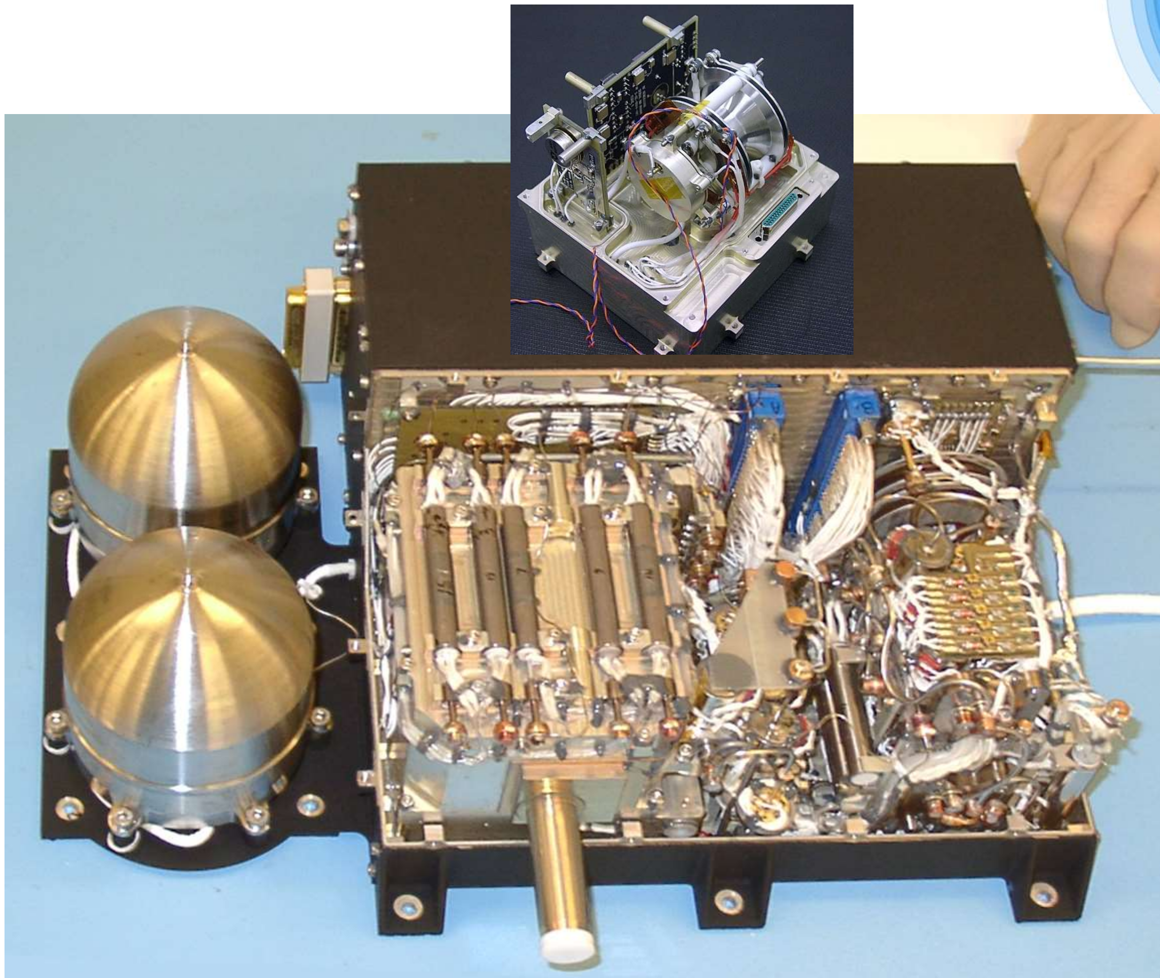
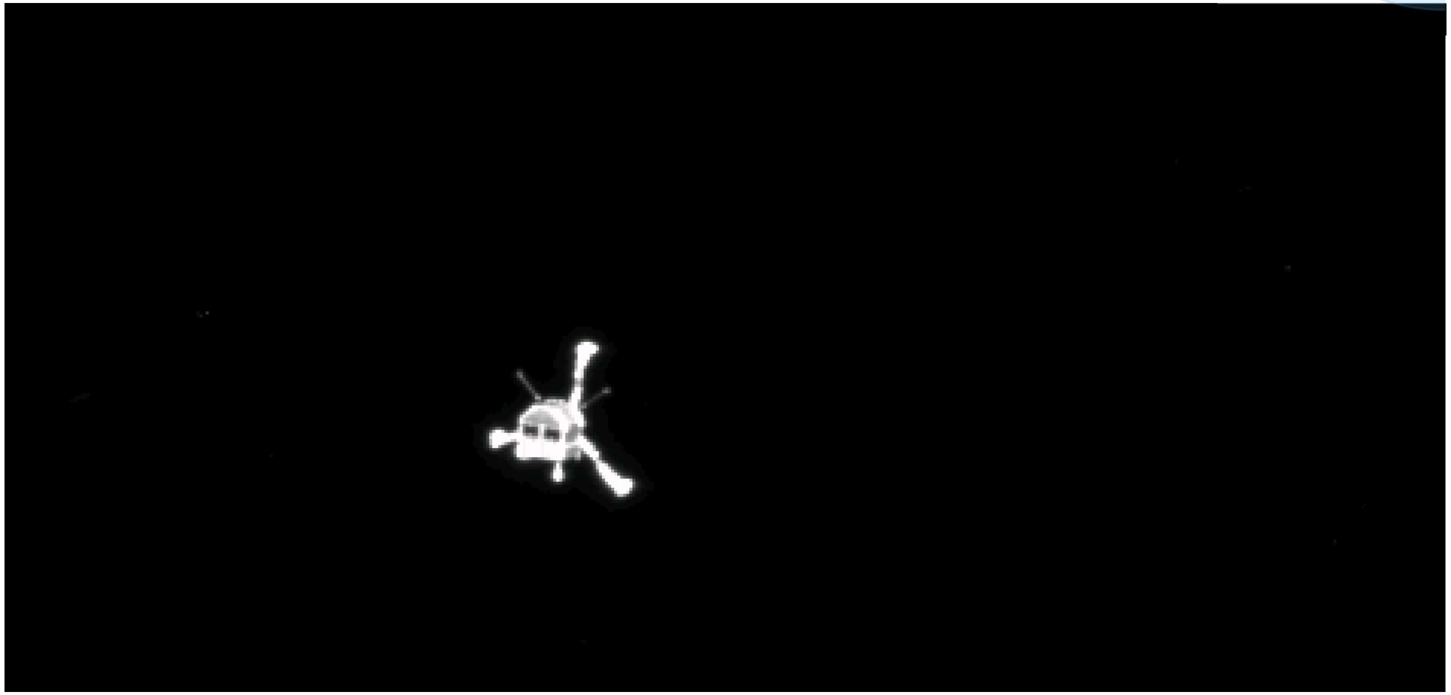
If you can record the mass spectrum of a comet anything is possible…….

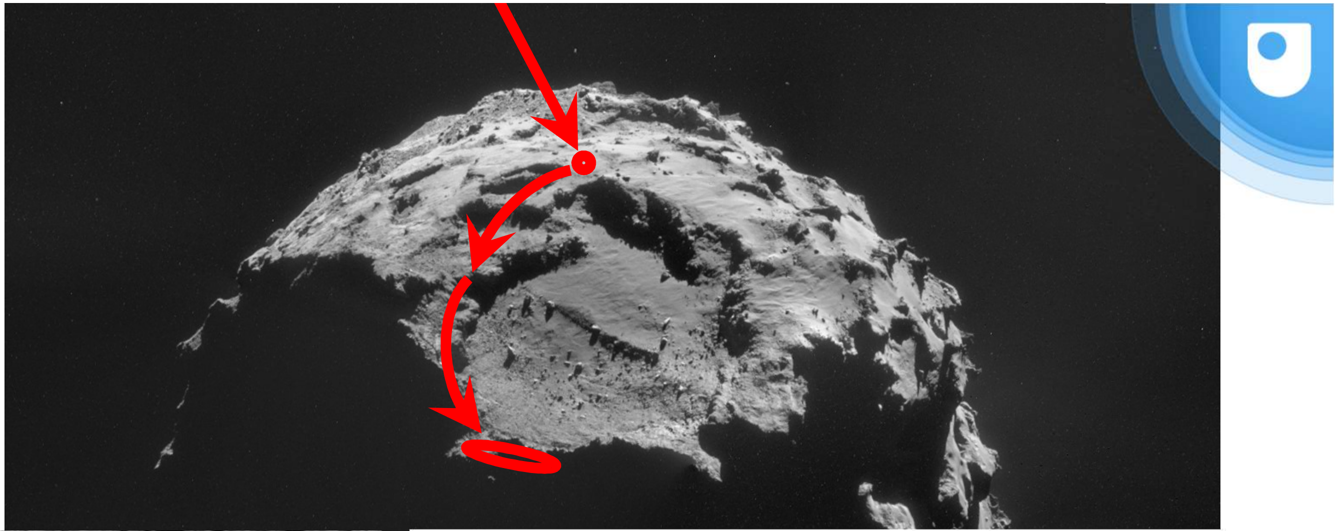
A bit more fun with analytical science in space

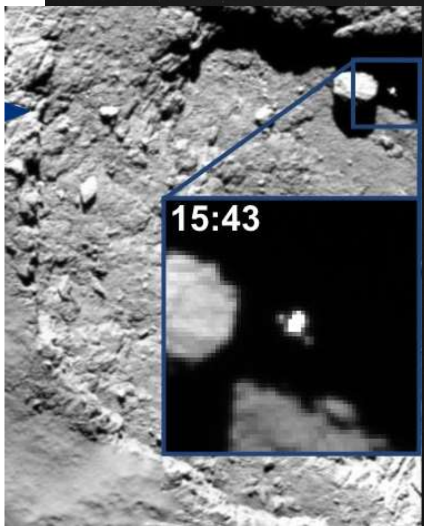


Courtesy of Professor Ian Wright

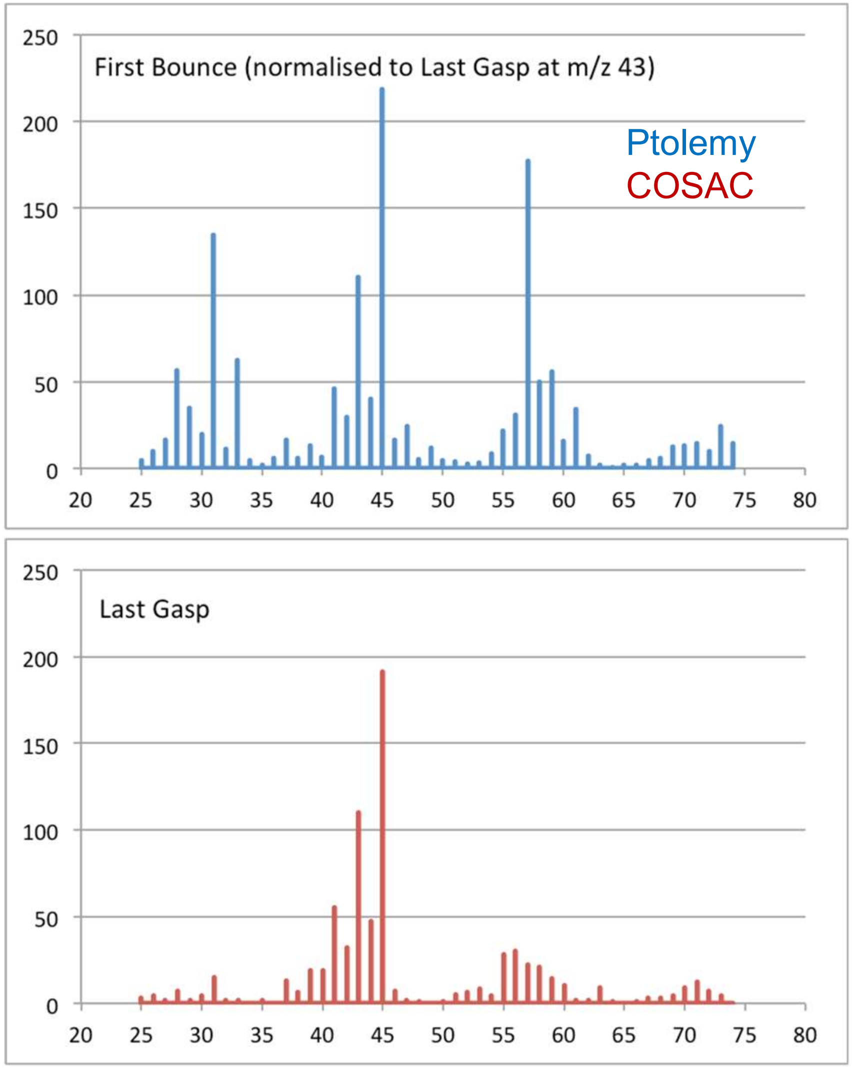


Courtesy of Professor Ian Wright

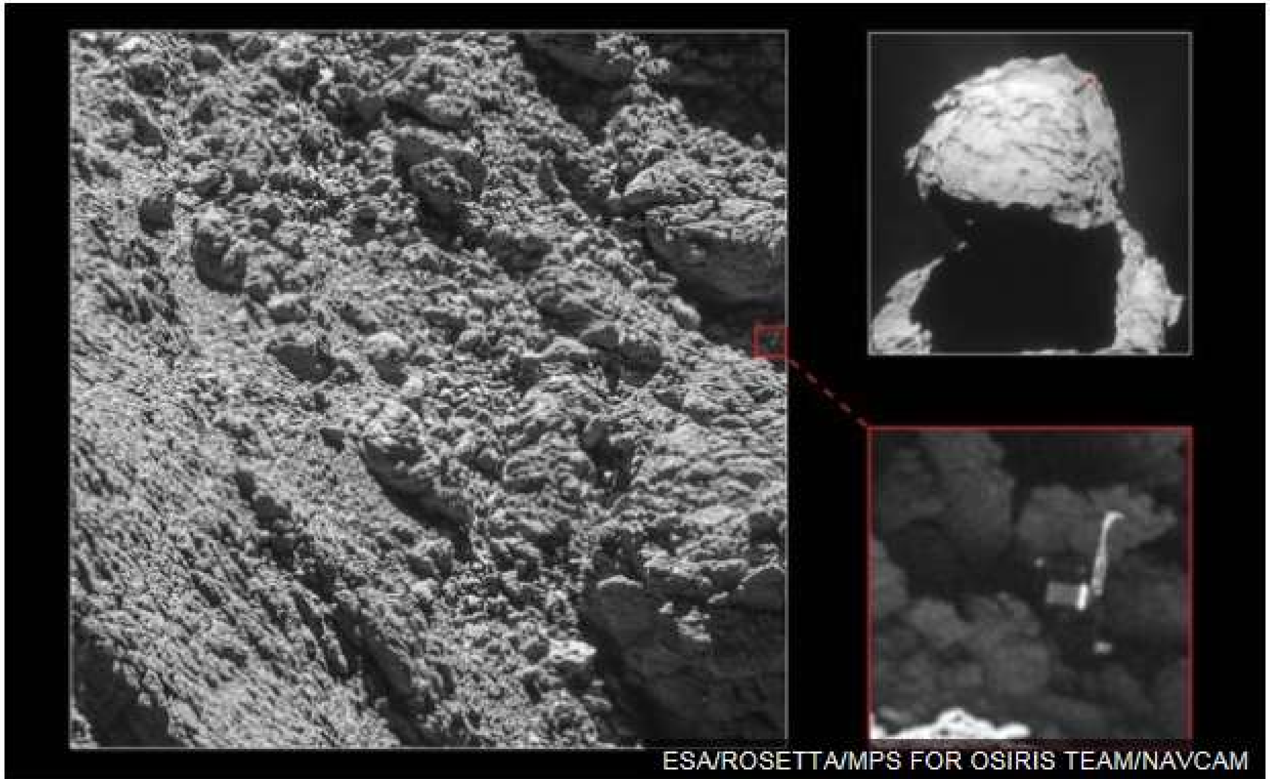




Date and Time (UTC)	Ptolemy measurement	Results	Comments
12 – Nov 15:43:46	MS sniff (13 minutes)	6 Mass spectra	9 minutes after landing. Water and rich in organics
13 – Nov 06:35:15	MS sniff (10 minutes)	6 Mass spectra	comet day. Mainly water, very low organics
13 – Nov 08:37:18	MS sniff (10 minutes)	6 Mass spectra	comet dusk. Philae in shadow
13 – Nov 10:39:20	MS sniff (10 minutes)	6 Mass spectra	comet night
13 – Nov 12:41:21	MS sniff (10 minutes)	6 Mass spectra	comet night.
14 – Nov 02:54:36	MS sniff (2 minutes)	6 Mass spectra	comet late night
14 – Nov 12:36:52	MS sniff (2 minutes)	6 Mass spectra	comet early night. Mainly water, very low organics
14 – Nov 22:38:19	HTO/CASE (40 minutes)	275 Mass spectra	Attempt to analyse material collected in CASE oven during landing and any concentrated coma.



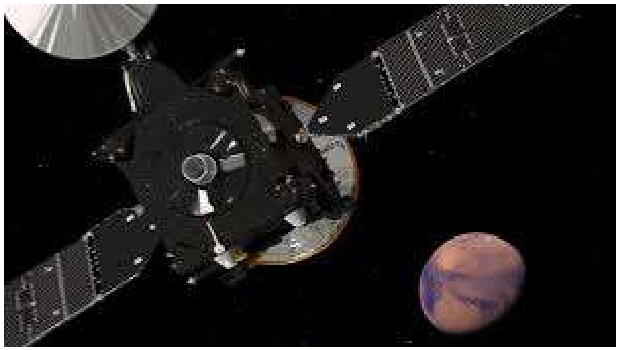
First Bounce (normalised to Last Gasp at m/z 43)
Ptolemy
COSAC
Last Gasp
250
200
150
100
50
0
20
25
30
35
40
45
50
55
60
65
70
75
80

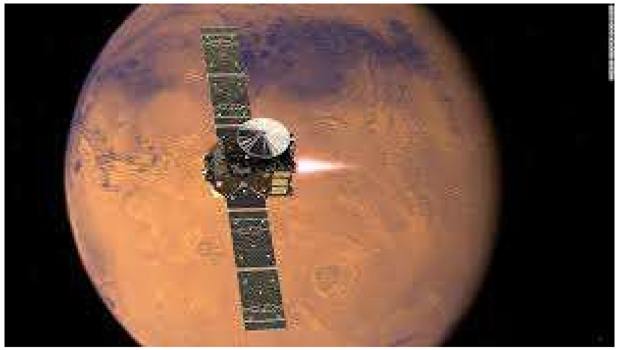


Stuck in a ditch: The evidence is unequivocal

Exomars

How long did it take to get there? 7 months



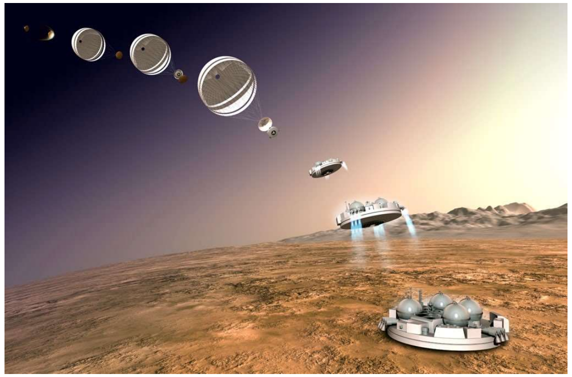


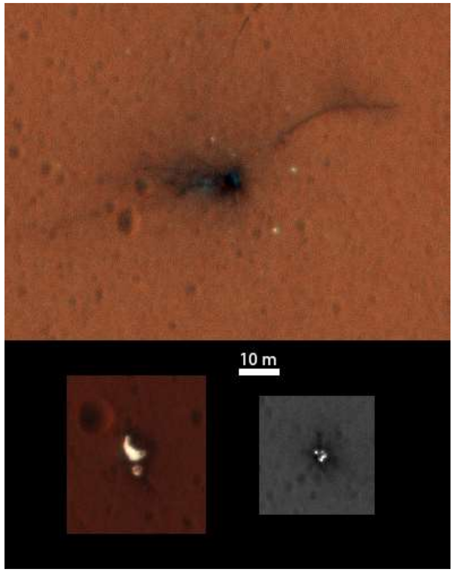
What did it do when it arrived?

Shiraparelli separated from TGO

It floated to Mars

It was meant to land





But crashed!

The home analytical scientist and implications for the future

- Earlier disease diagnosis
- Better disease control and medicine compliance
  - Less interventions and doctor/hospital visits
  - Prediction and understanding of disease exacerbations
- Longer term disease understanding (after a medicine is on the market)
  - Future design of new medicines
- Demonstration of the long term effectiveness of a medicine
- Real world data
- Potential to save money and resources for the NHS and other health care providers around the world
  - effectiveness of a medicine demonstrated
  - pay on performance
- Data transferred to doctor/hospital/pharmaceutical companies
  - Remote intervention and advice

The big BUT……..

- **Big Data** evaluation and interpretation

- Misuse or misunderstanding of the data
  - may encourages episodic treatment
  - only taking medicine when the device says there is a problem
  - guaranteeing the data is simply presented, easily interpreted and correctly understood

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- Matt Bonam - AstraZeneca, UK
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University Hospitals of Leicester NHS Trust NHS

Advion

BS Analytik

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So finally……..

What are your thoughts on this vision of the future?

Confidentiality Notice