



# Electronic Tongues

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University of Warwick

# Acknowledgements

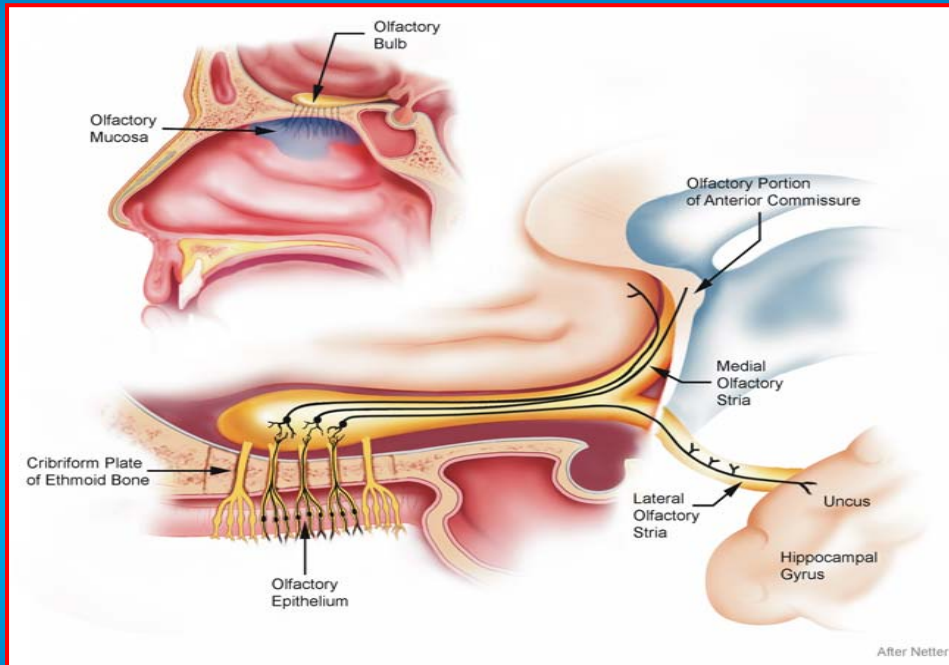


- Dr Marina Cole (e-tongue)
- Dr James Covington (e-nose & MSL)
- Research Students at Warwick
- Universities of PennState & Georgia Tech (USA)
- Royal Academy of Engineering - Global Award
- Royal Society and Wolfson Foundation

# Overview

- Research at Warwick on Biomimetic Devices
- Concept of artificial tongue
- 60 MHz dual delay-line miniature system
- Discrimination of basic human tastes
- Detection of bacterial loading in milk
- 433 MHz based microsystem with filter
- Artificial nose & tongue system

# Biomimetic devices: Warwick Electronic Nose

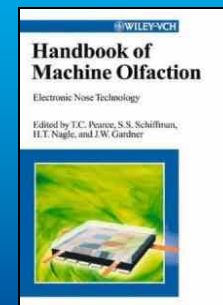
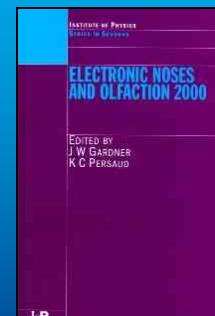
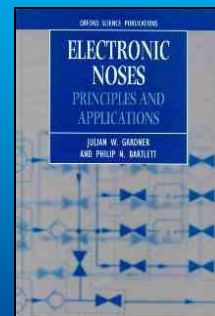
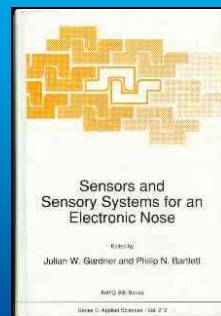
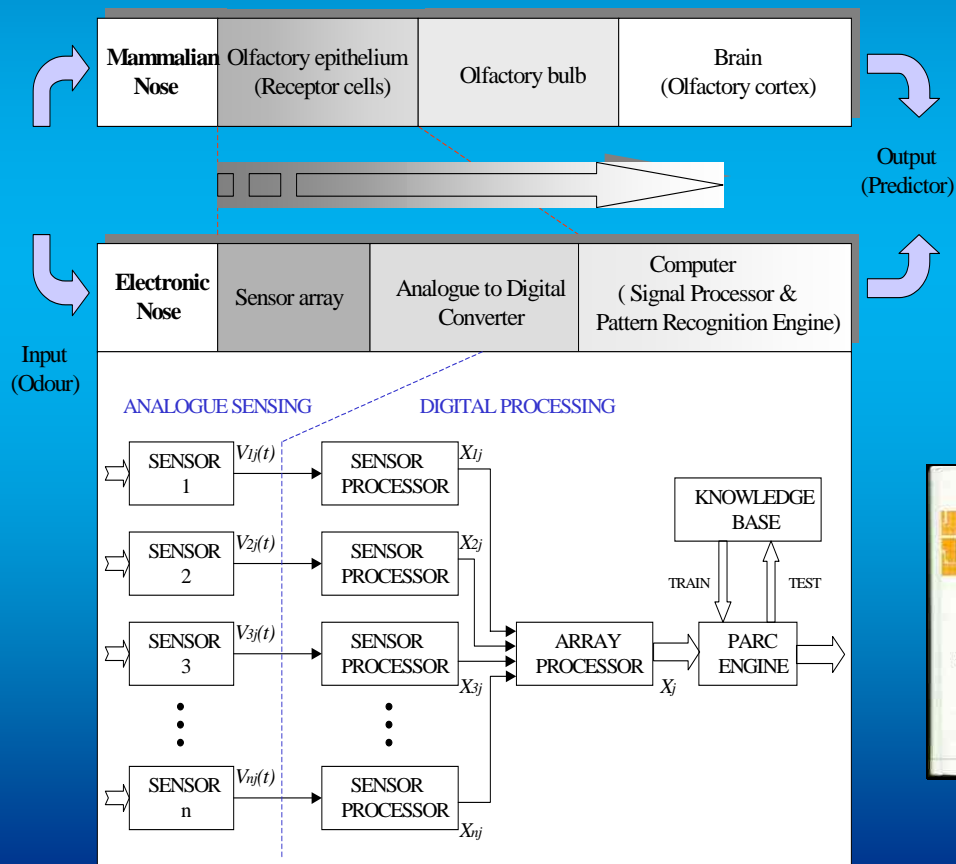


- 1-100 million olfactory receptor cells
- 300 genes that encode olfactory binding proteins
- 1,000s glomeruli nodes
- Mitral/tufted cells
- 1-2% genome coding!

- Device to mimic human olfactory system
- E-nose concept 1980s
- First companies created in 1990s
- Emerging market valued in 2003 at €10-20 M
- **Potential market €1.2B**

# Commercial E-nose Instruments from Warwick University

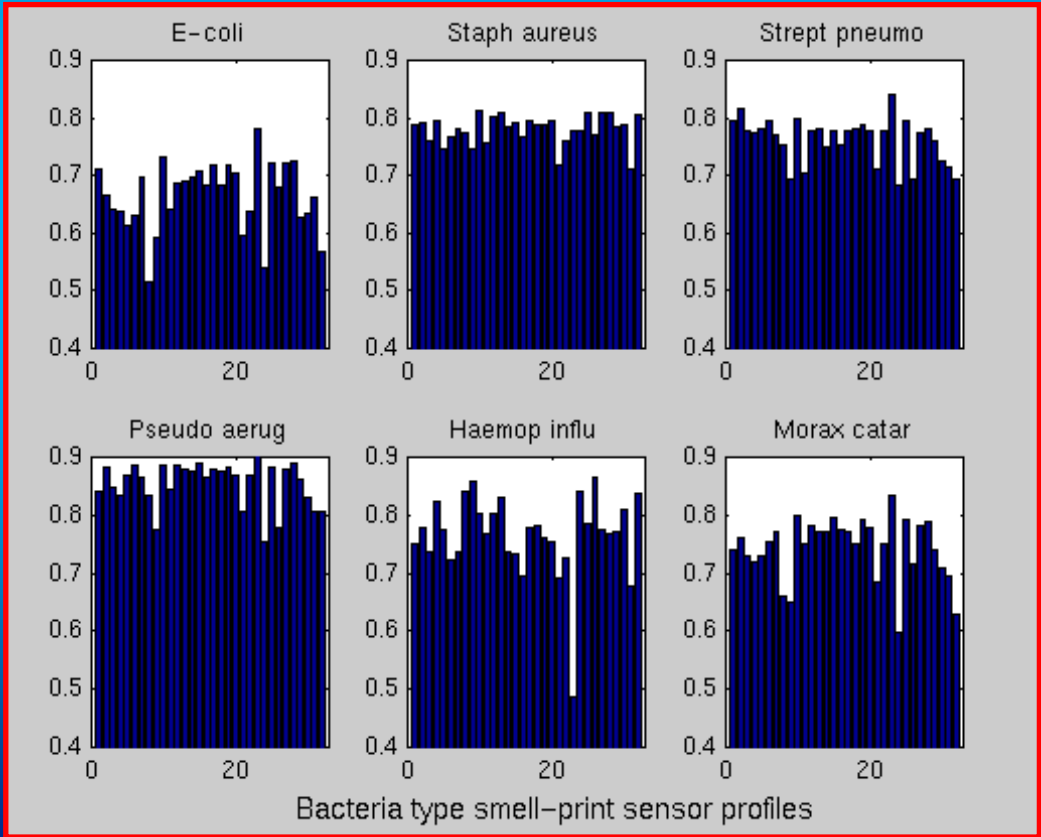
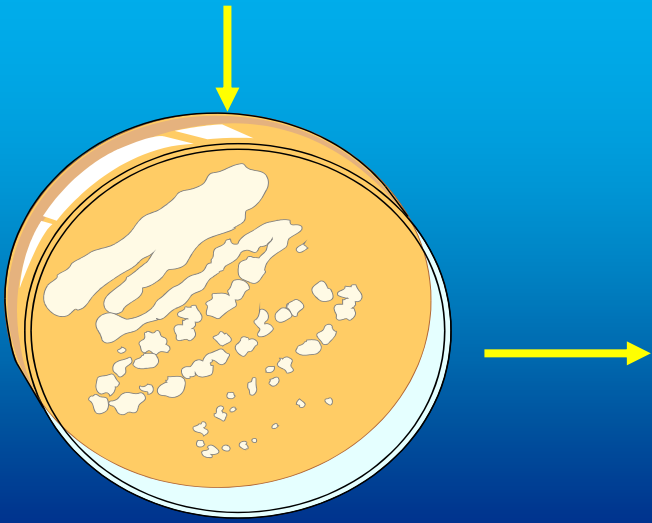
## Sensor-based e-nose





# Screening for pathogens

Medical diagnosis of ENT infections



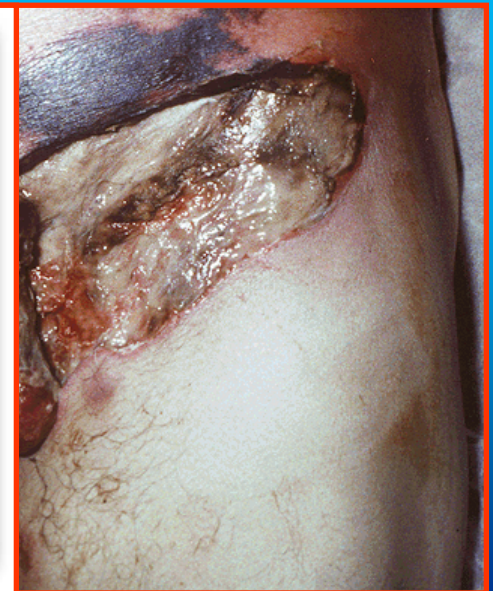
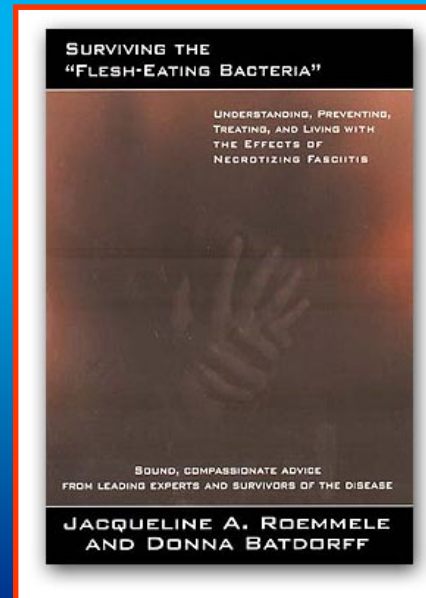




# Bacterial Population Genetics



*Streptococcus pyogenes*

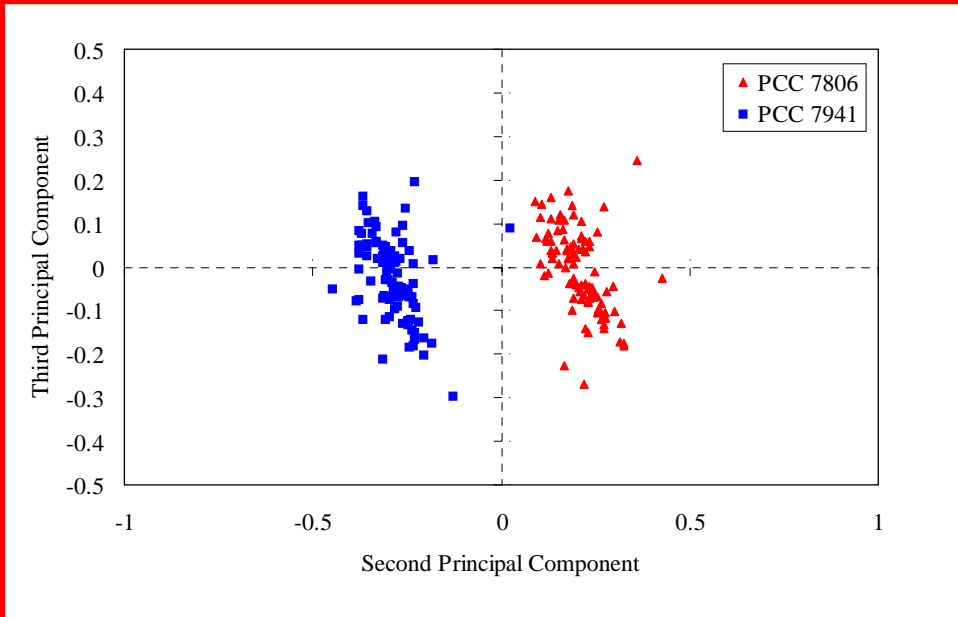




# Screening for strain

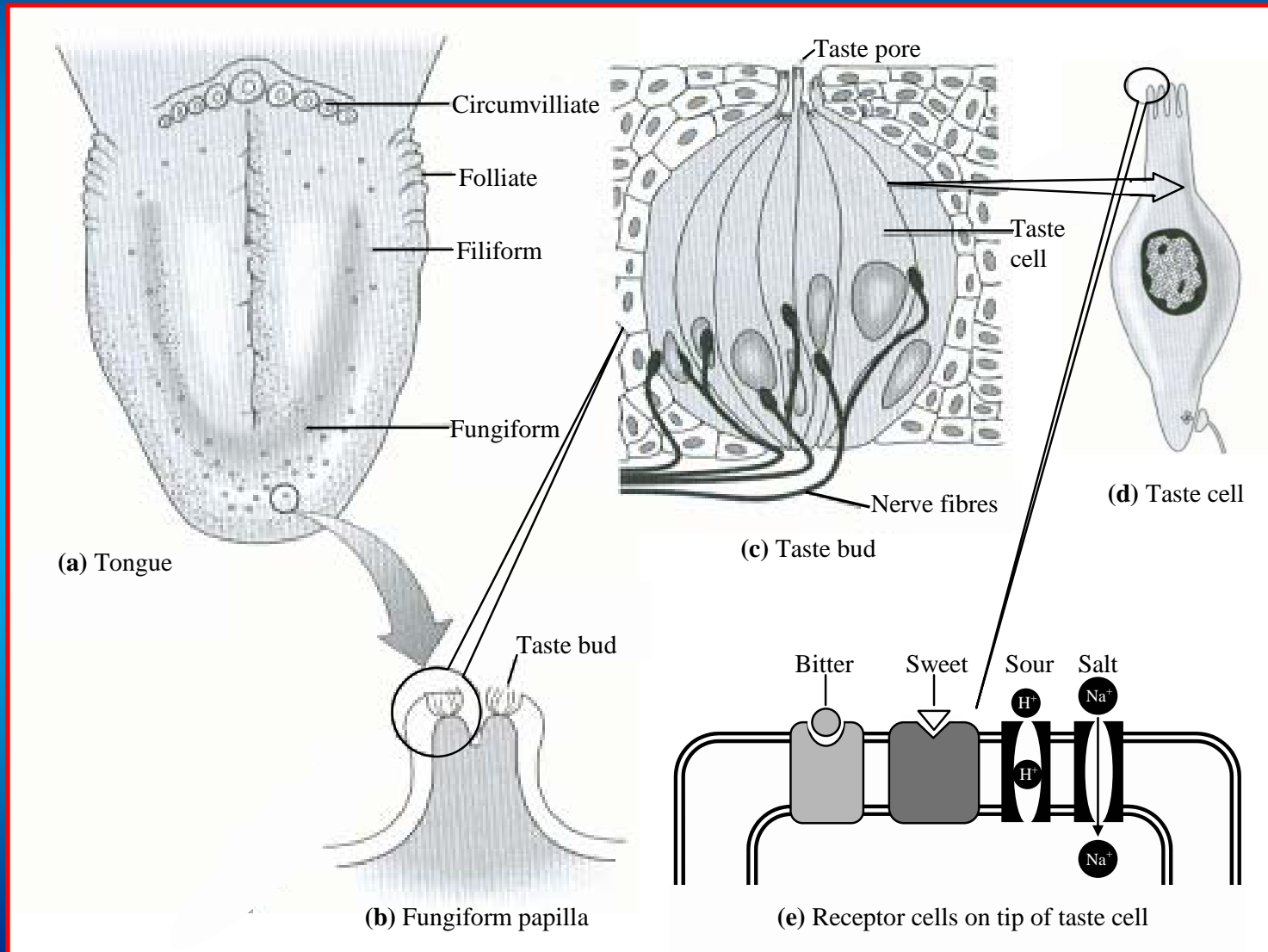
Environmental biohazards

Toxic strain of *Microcystis aeruginosa*





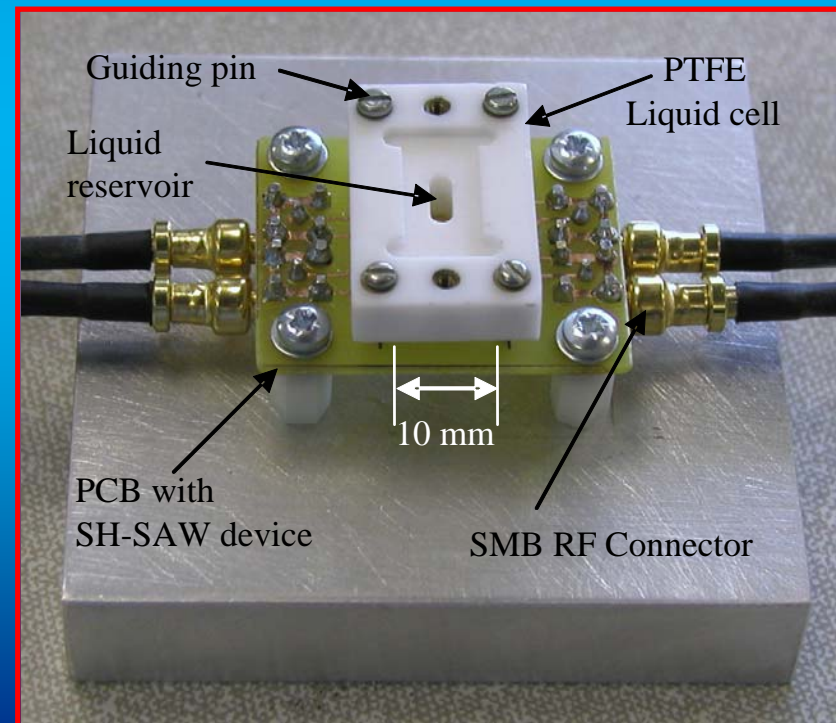
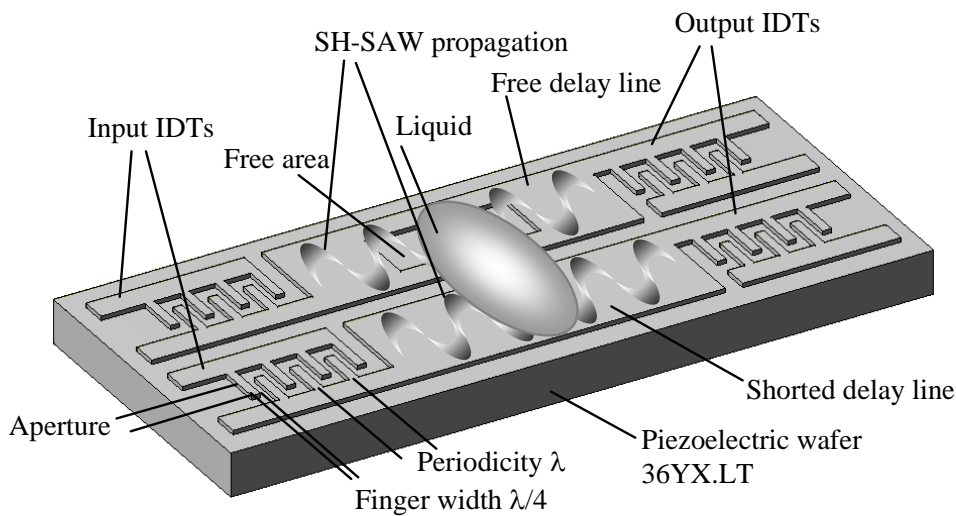
# Gustation





# Warwick Electronic Tongue

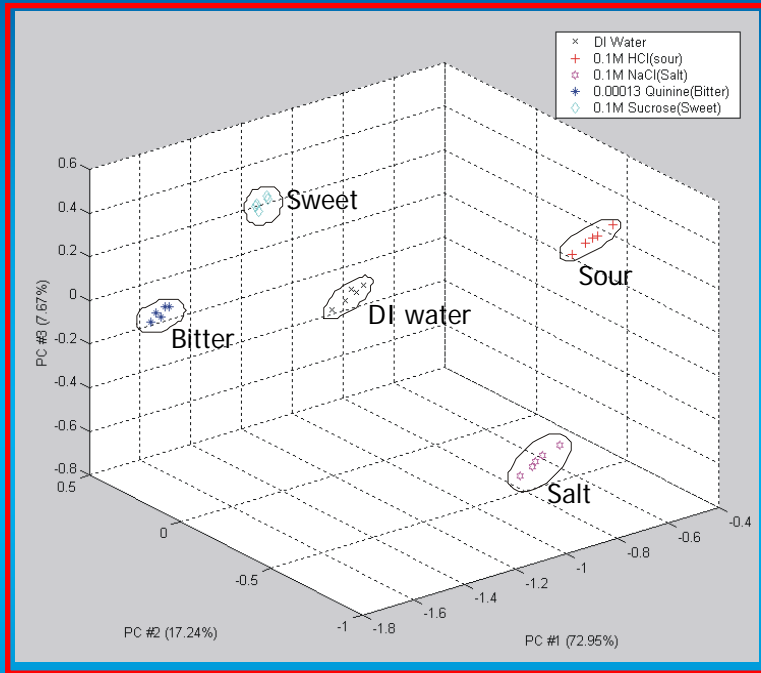
- Mimic human sense of gustation
- Concept in late 1990s
- Warwick SAW based design – 60 MHz



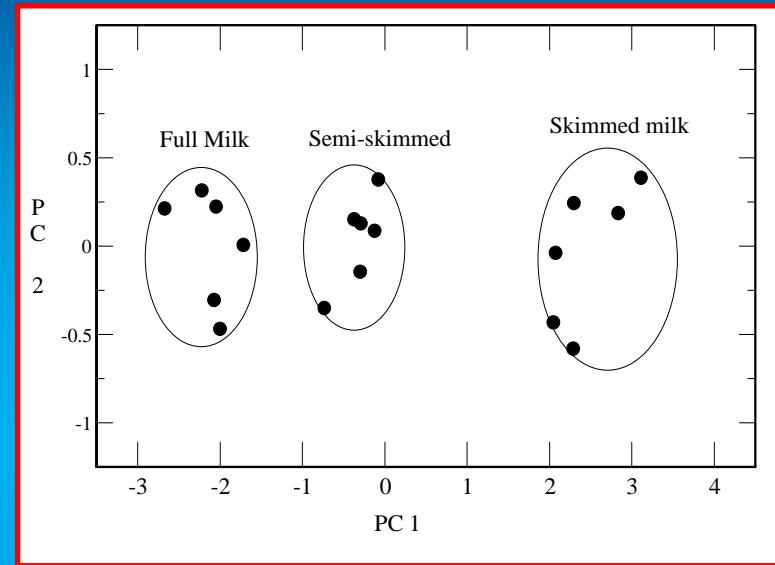
- No companies yet

# Smart Tongue Applications

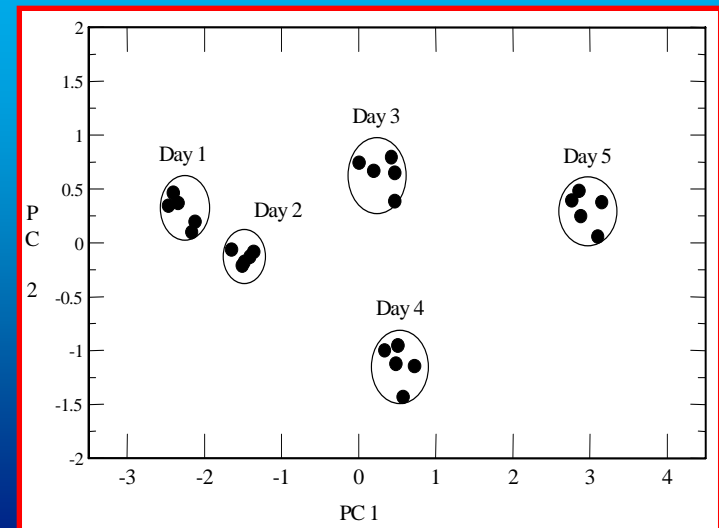
## Taste discrimination



## Fat content in Milk

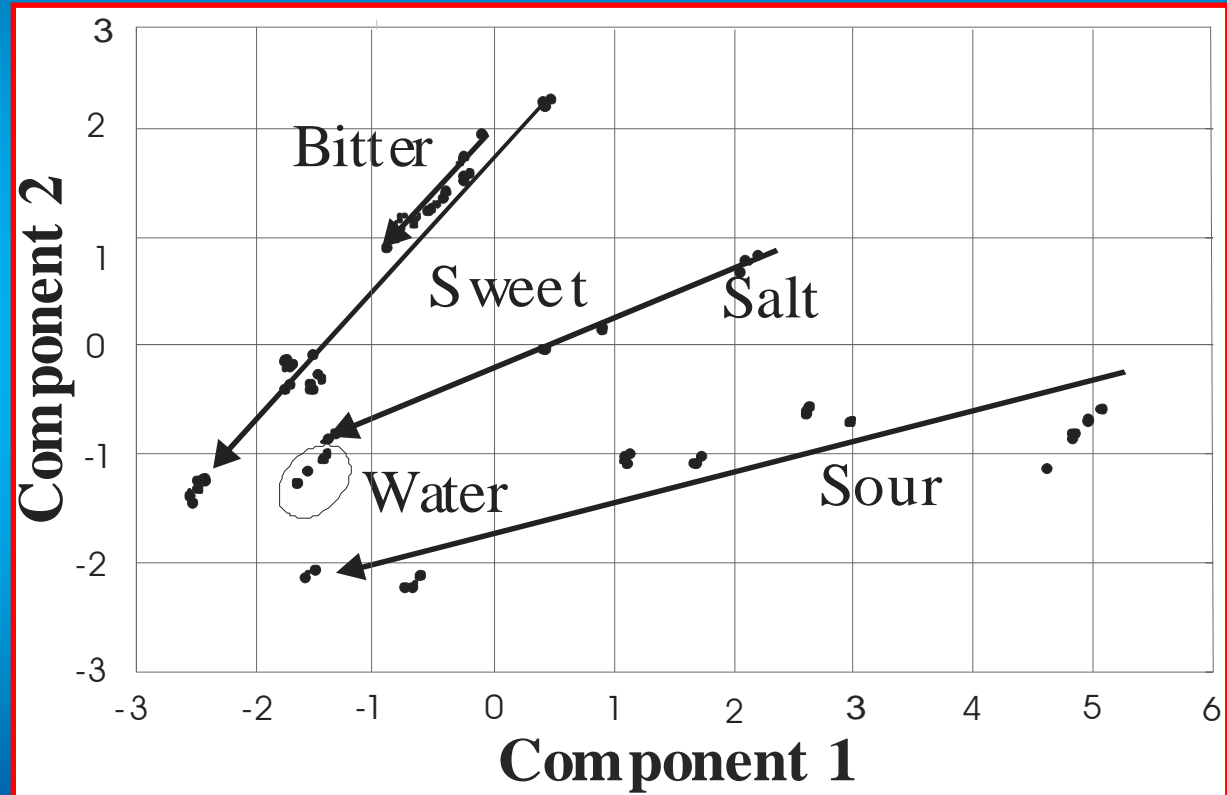


Milk freshness/  
bacterial load



# Dilution Tests

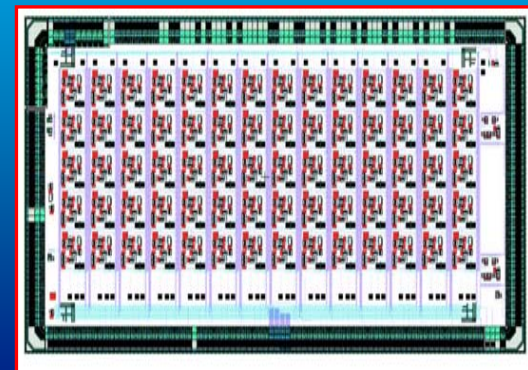
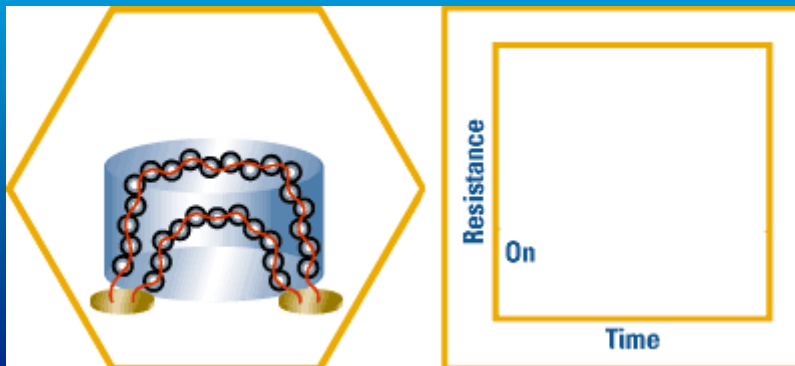
- Experiments performed with the original solutions diluted in steps by a factor of  $2^n$
- Volume of DI water was increased by  $2^n$  and added to fixed volume of solution
- As the concentration of the solutions decreased the results tended towards that of the DI water
- Typical limit of detection of 0.1% or 1 part in  $10^3$



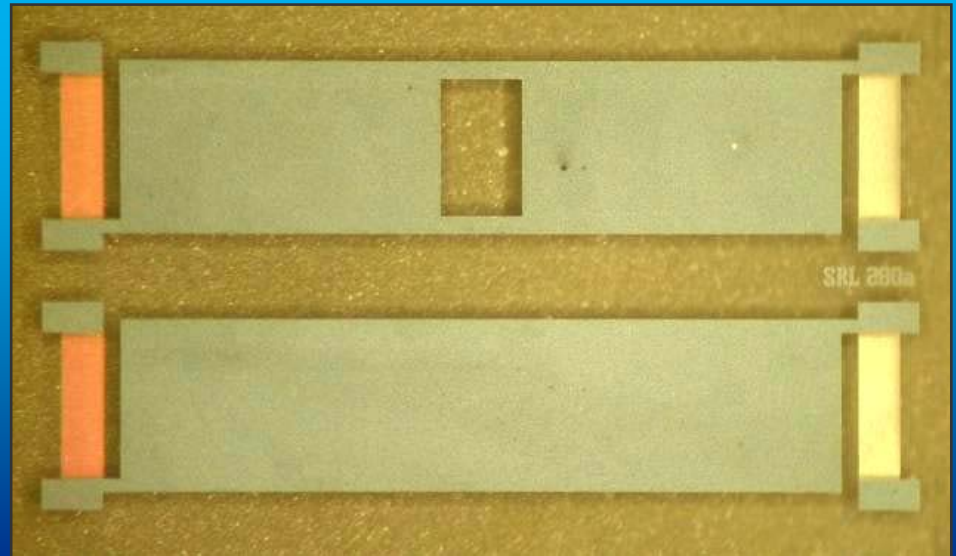
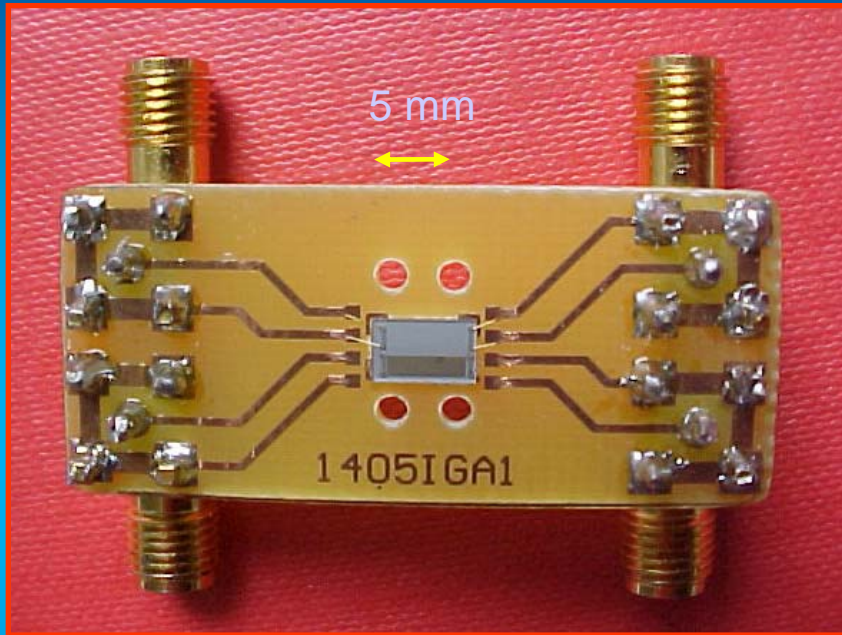


# Drivers for 3-D Microsystems

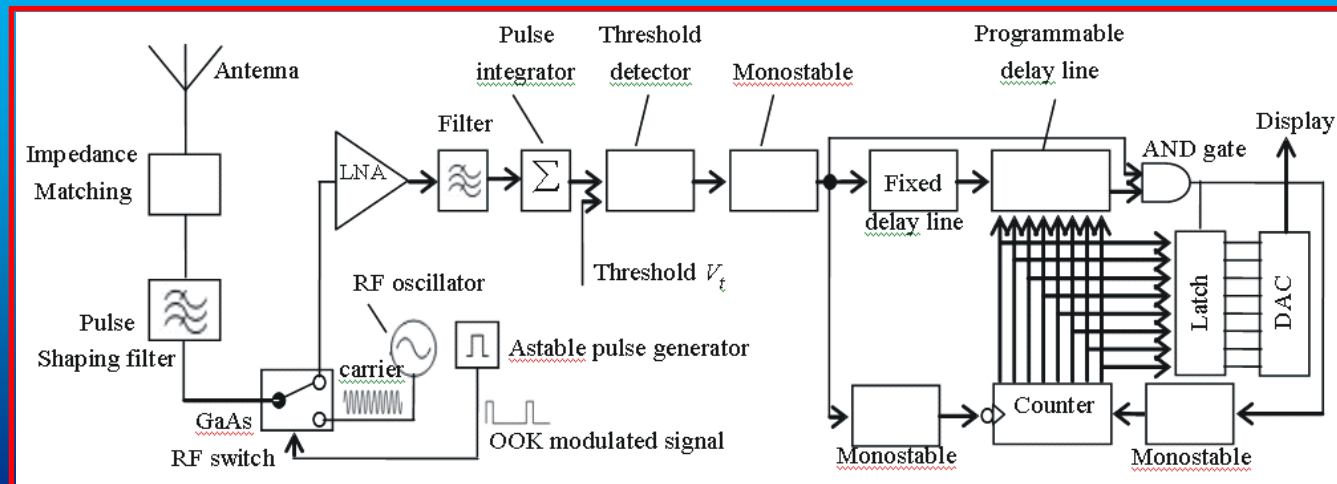
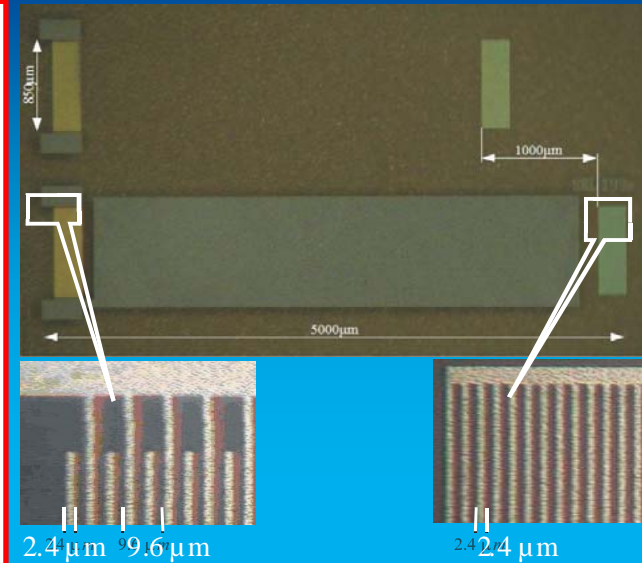
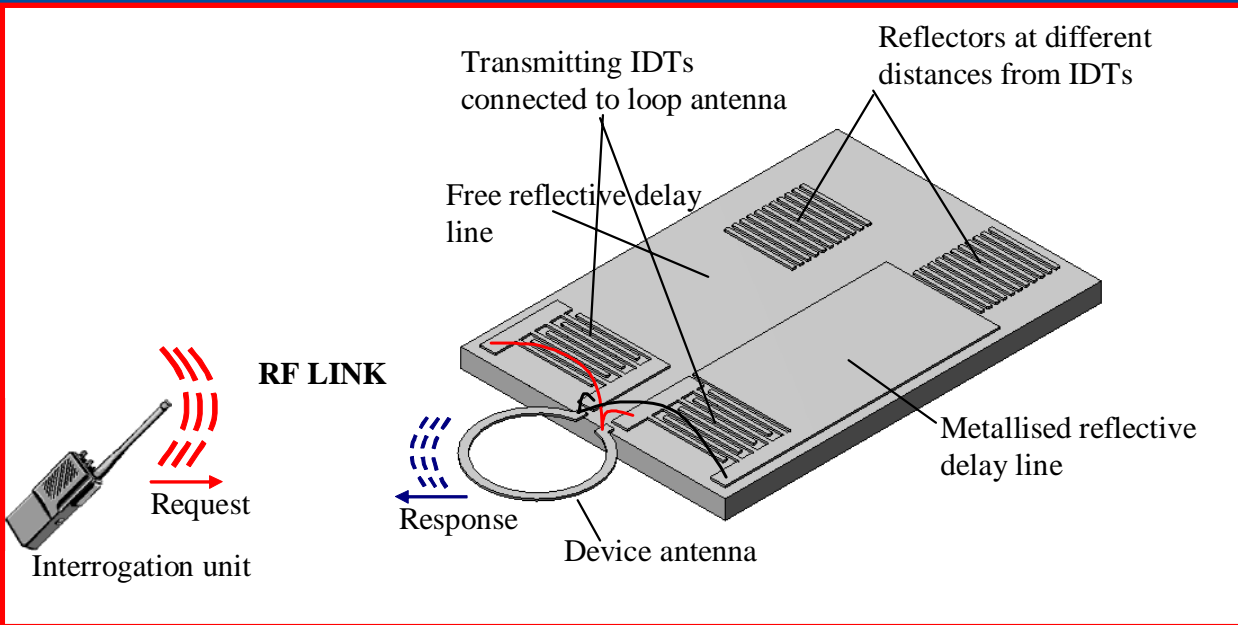
- Need to miniaturise e-noses and e-tongues
- Need to reduce cost and power consumption
- Need to penetrate mass market
- CMOS sensor array chips developed but need for integrated 3-D microfluidic packages



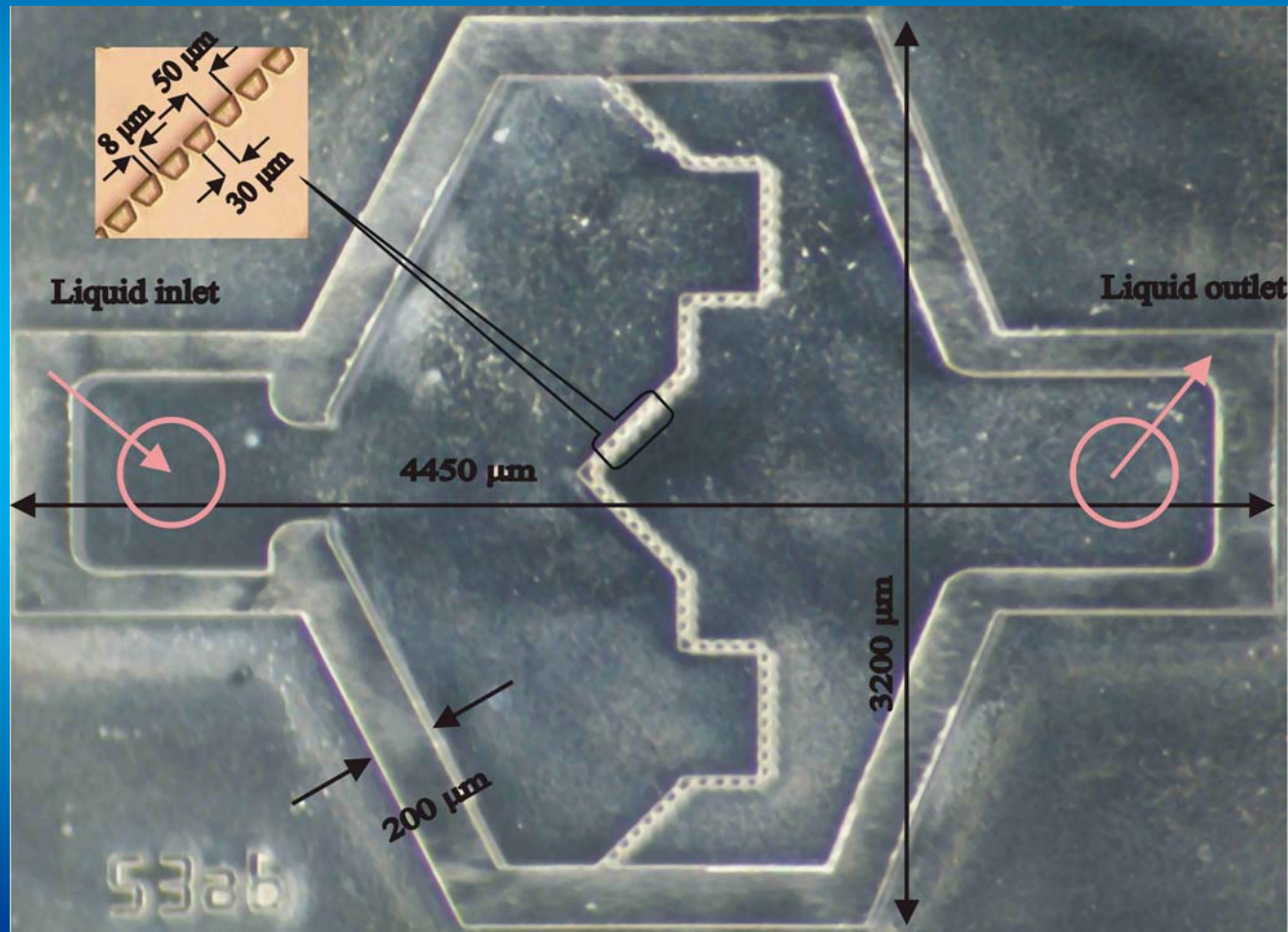
# Design of 433 MHz Electronic Tongue



# Wireless MEMS Tongue System



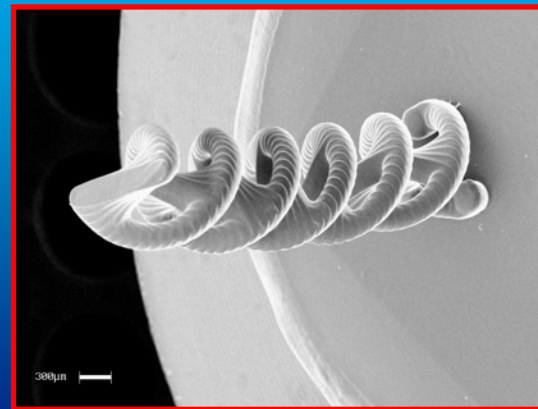
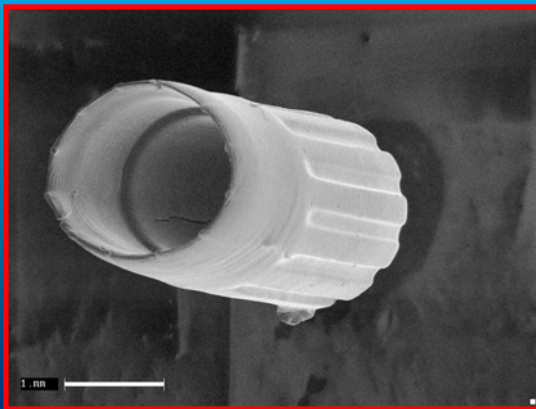
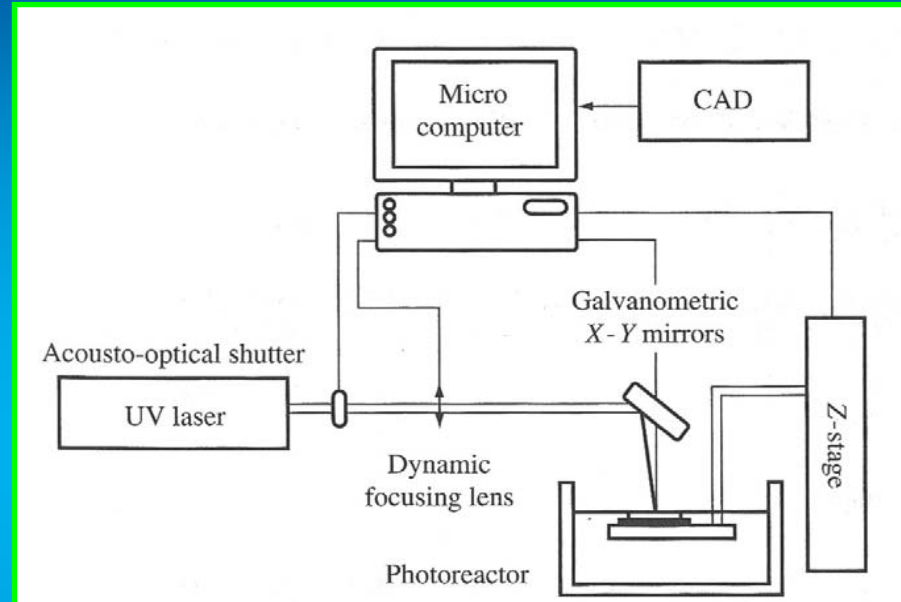
# Design of Micro-concentrator for Bacterial Screening





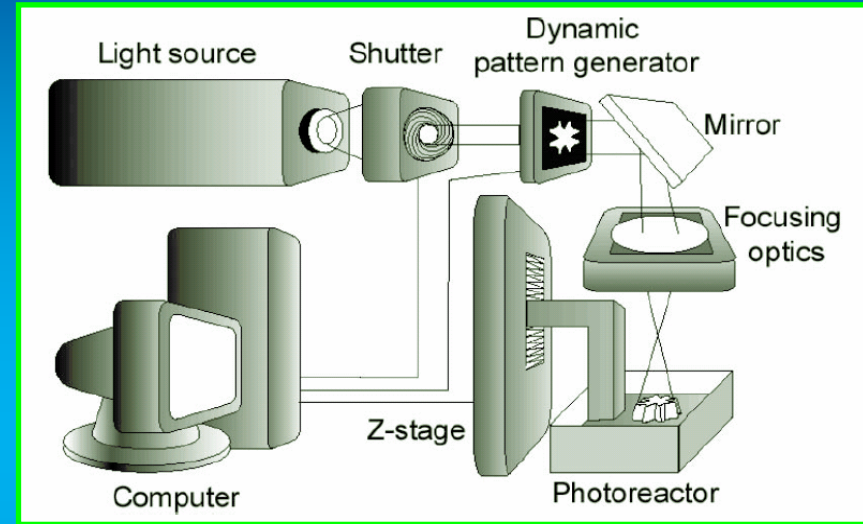
# Making 3-D Microfluidic Packages

- Direct writing of 3D structures in resins
- Developed in 1993
- Pioneered in US and Japan
- Capability from 50 microns to 50 nm



# Warwick 3-D Microsculpting Lab for Biomimetic Devices

- SRIF2 Funding from HEFCE £200k
- Royal Society Wolfson Foundation Award £200k
- Installed 2 EnvisionTec units of 25 micron resolution
- Electroplater for 3-D micro-antenna
- Custom submicron unit from PSU

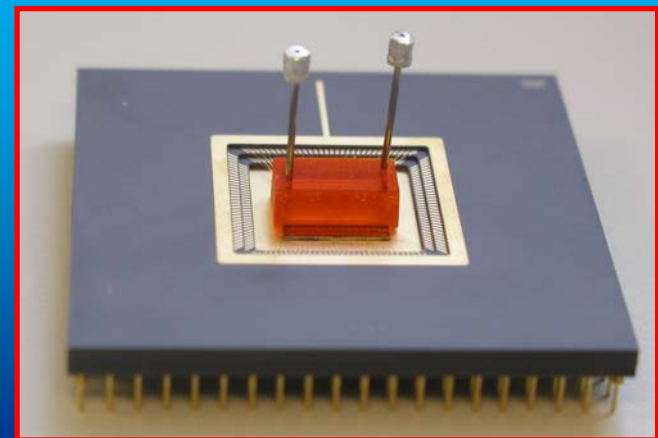
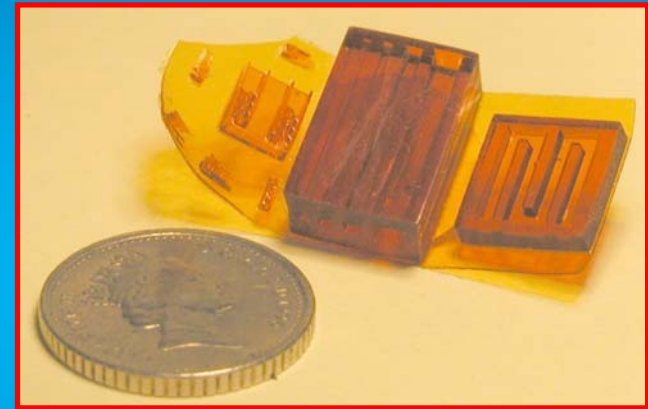


# 3-D Fluidic Micro-packages

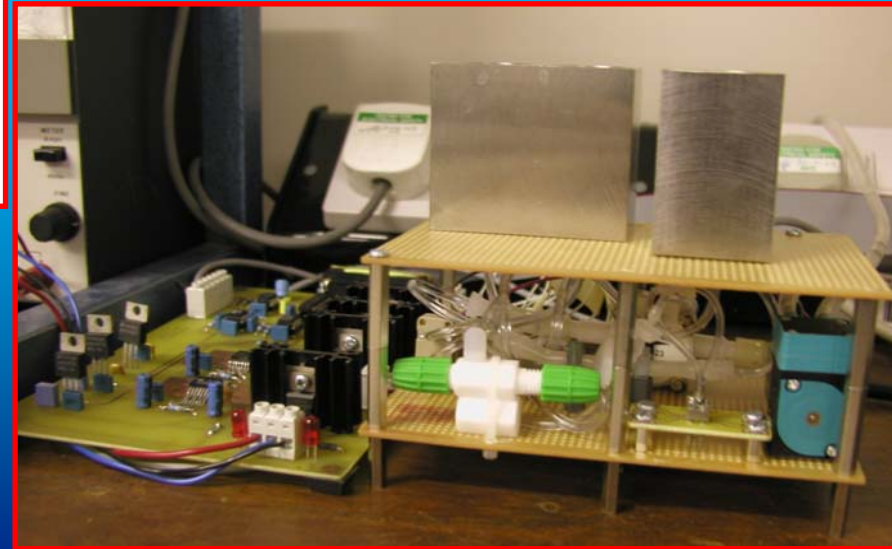
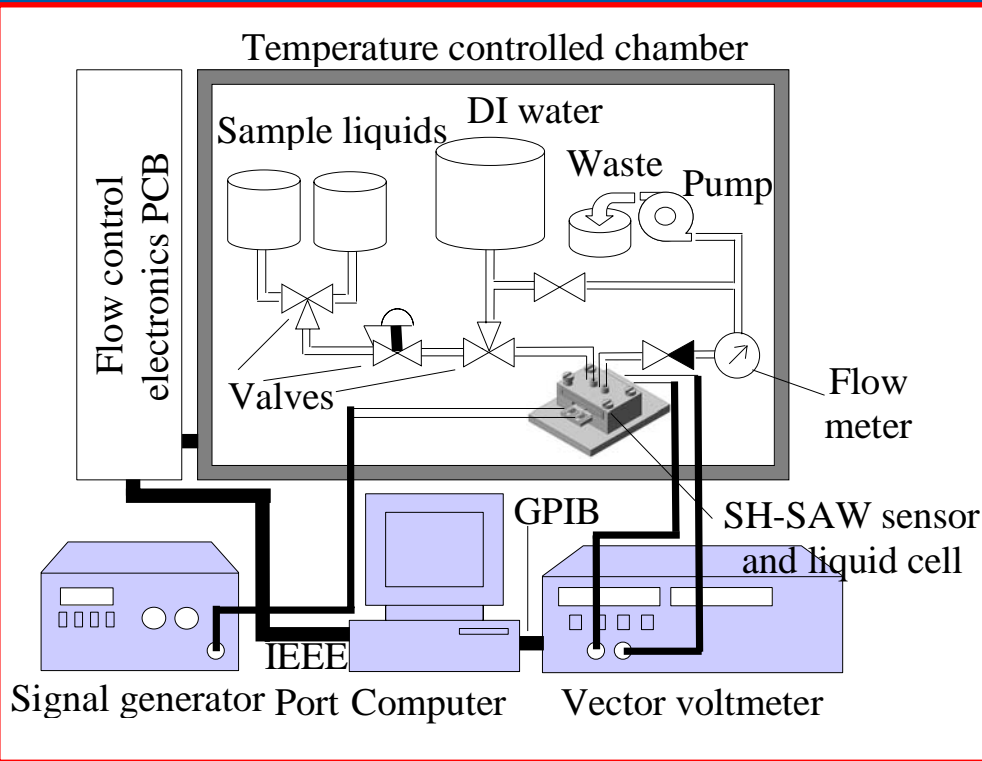
- Disposable microfluidic packages for e-tongue



Designed by Warwick made at GIT, USA

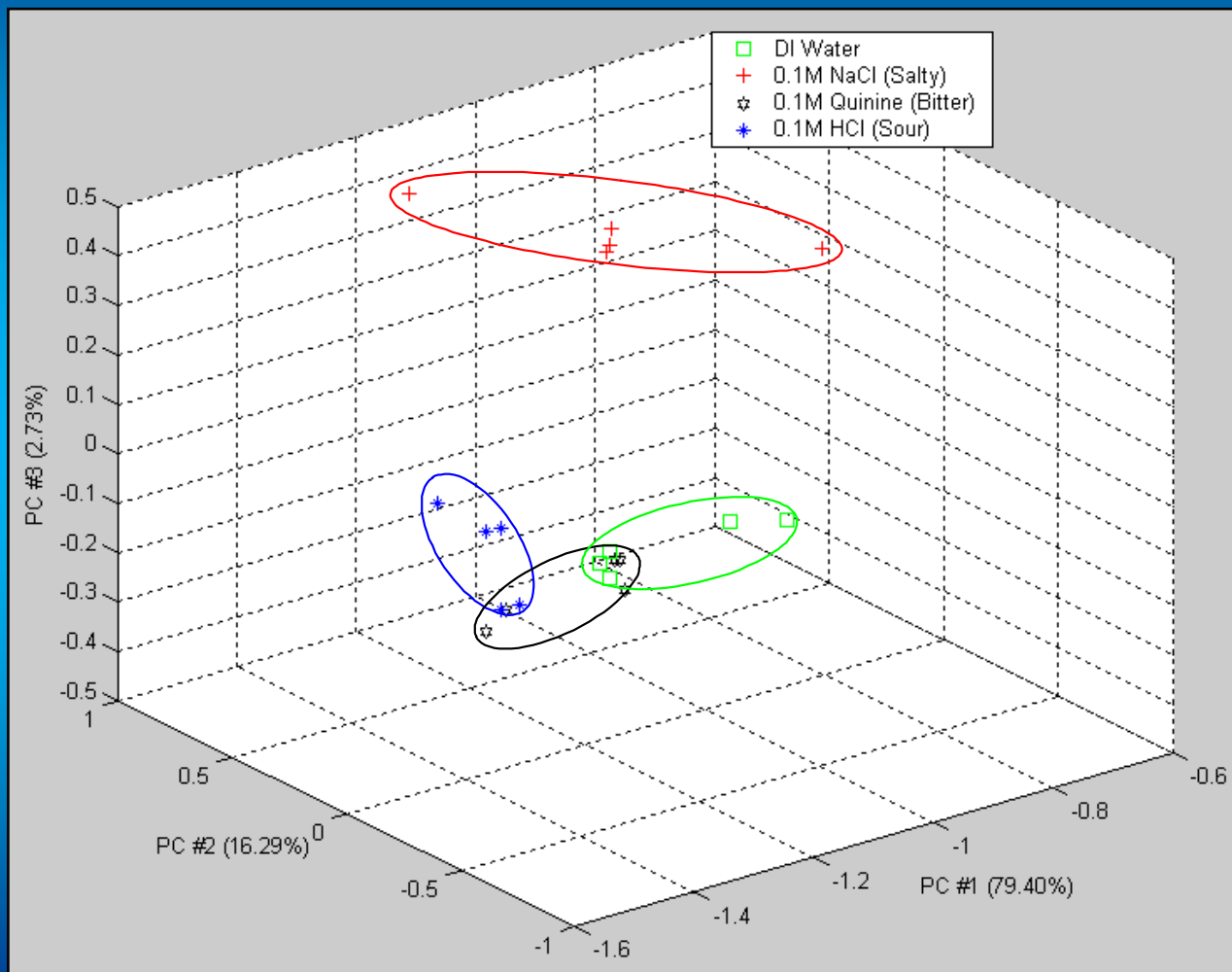


# Total Tongue System



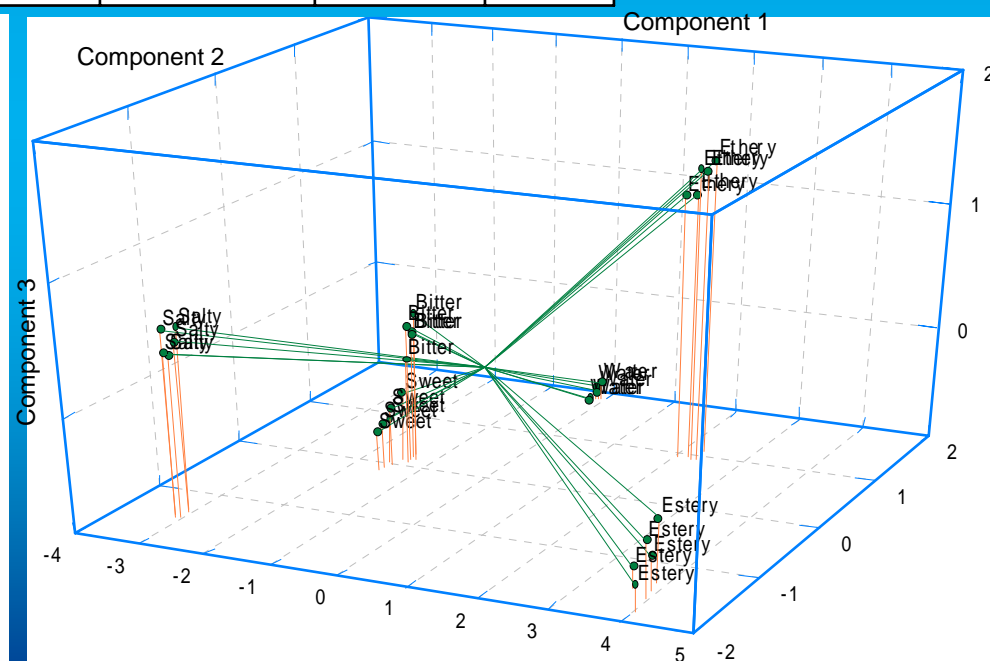
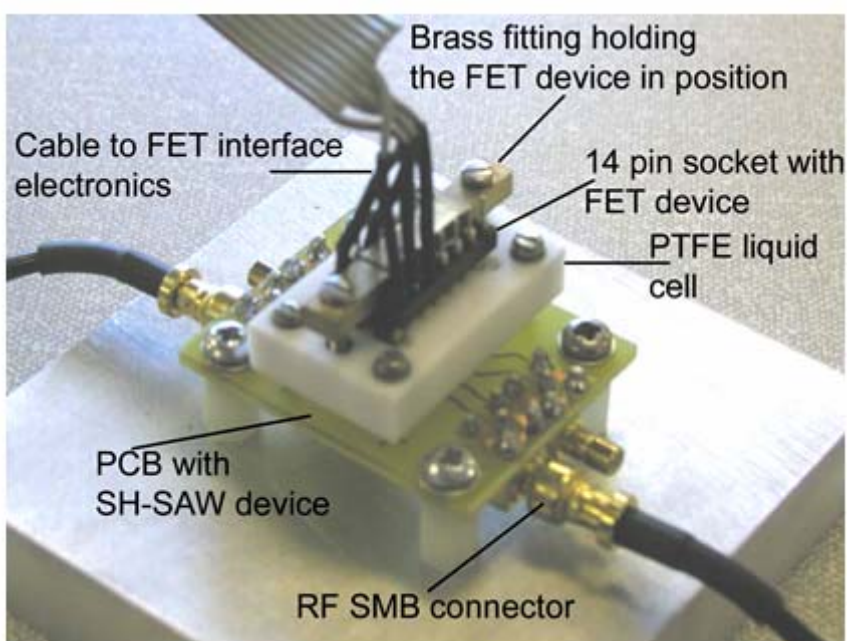


# Taste Discrimination at 433 MHz



# Combined Nose-Tongue System

Solution	Concentration	Vapour pressure	E-Tongue	E-Nose
NaCl (0.1M)	0.1 M	Very low	✓	✗
Sucrose (0.1M)	0.1 M	Very low	✓	✗
Quinine	1 mg/mL	Very low	✓	✗
Ethanol (ethereal)	1000 ppm	High	✗	✓
Ethyl acetate (estery)	1000 ppm	High	✗	✓



Ref: G. Sehra, PhD thesis, Warwick University, 2004

# Conclusions

- Dual delay based electronic tongues show promise in some screening applications
- High frequency, low cost MEMS devices feasible
- Combined e-nose/e-tongue can add discriminating power
- Biological coatings may be added for even greater specificity/sensitivity

# Recent Publications

## Journal Papers

- Cole M, Sehra G, Gardner JW and Varadan VK, *Development of smart tongue devices for measurement of liquid properties*, IEEE Sensors Journal, Vol. 4, No. 5, (2004), pp. 543-550.
- Sehra G, Cole M, and Gardner JW, *Miniature tasting system based on dual SH-SAW sensor device: an electronic tongue*, Sensors and Actuators B, 103, (2004), pp. 233-239.

## Conference Papers

- M. Cole, G. Sehra, J.W. Gardner and V.K. Varadan, *Fabrication and Testing of a Smart Tongue Device for Liquid sensing*, Proc. of IEEE Sensors 2002 Conference, June 12-14, 2002, Orlando, Florida, USA, pp. 237-241.
- Sehra G S, Covington JA, Cole MV, and Gardner JW *Combined electronic nose/tongue for liquid analysis*, Proc. of 9th International Symposium on Olfaction and Electronic Nose, eds A d'Amico and C di Natale, 29 September –2 October 2002, Rome, Italy, pp. 58-63.
- Sehra G, Cole M and Gardner JW, *Miniature taste sensing system based on dual SAW sensor device*, Proc. of 17th European Conference on Solid State Transducers Eurosensors XVII, 21-24 September 2003. Guimaraes, Portugal.
- I.I. Leonte, M.S. Hunt, G. Sehra, M. Cole, J.W. Gardner, M. Noh and P.J. Hesketh, *A wireless microsystem for liquid analysis*, Proc. of IEEE Sensors 2004 Conference, October 24-27, 2004, Vienna, Austria.
- I. Leonte, M. Hunt, G. Sehra, M. Cole and J. W. Gardner, *SAW bio-liquid sensors with RF interrogation*, Proc. Of IEEE High Frequency Postgraduate Students Colloquium, IEEE catalog no. 04TH8740, 6th and 7th September, 2004 UMIST Manchester, UK, pp. 47-52.