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The Unattended Water Sensor: Using microfluidics to build a fieldable system

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National Nuclear Security Administration

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Water Monitoring Challenges

We are fortunate to have cheap, plentiful water in this country

- **Standards for water quality**
  - **trace chemical contaminants**
  - **solids**
  - **microorganisms**

We generally expect this to continue so getting funding for developing analytical methods and technologies is a challenge

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Water Monitoring Systems

- Many sensing systems out there …most of which detect physicochemical properties…phosphate, turbidity, pH, total organic, conductivity

- Test strips are very cheap, but limited in the info you can get out…

- Options for biologicals are still relatively few

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Why Develop Fieldable Detection Platforms?

…when there are established laboratory approaches and still significant technical hurdles to overcome?

- Automated operation
- Rugged performance
- Translating assays to a fieldable format

Enabling Sampling and Analysis to be in the same place has many advantages…

- Reduces labor, logistics, overhead
- Enables dramatically faster response (from days to hours or minutes)

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Microfluidics can be used to develop analysis platforms

μChemLab

- Integrated liquid and detection modules
- Modular design for versatility
- Fieldable

Microfluidics allows:

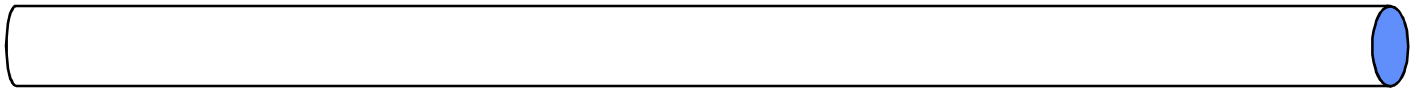
- Fast analyses
  - Time required for a separation is dramatically reduced
- Minimal reagent and sample volumes
- Multiple independent/orthogonal separations are facilitated
  - Provide differential selectivity
  - Improve detection reliability

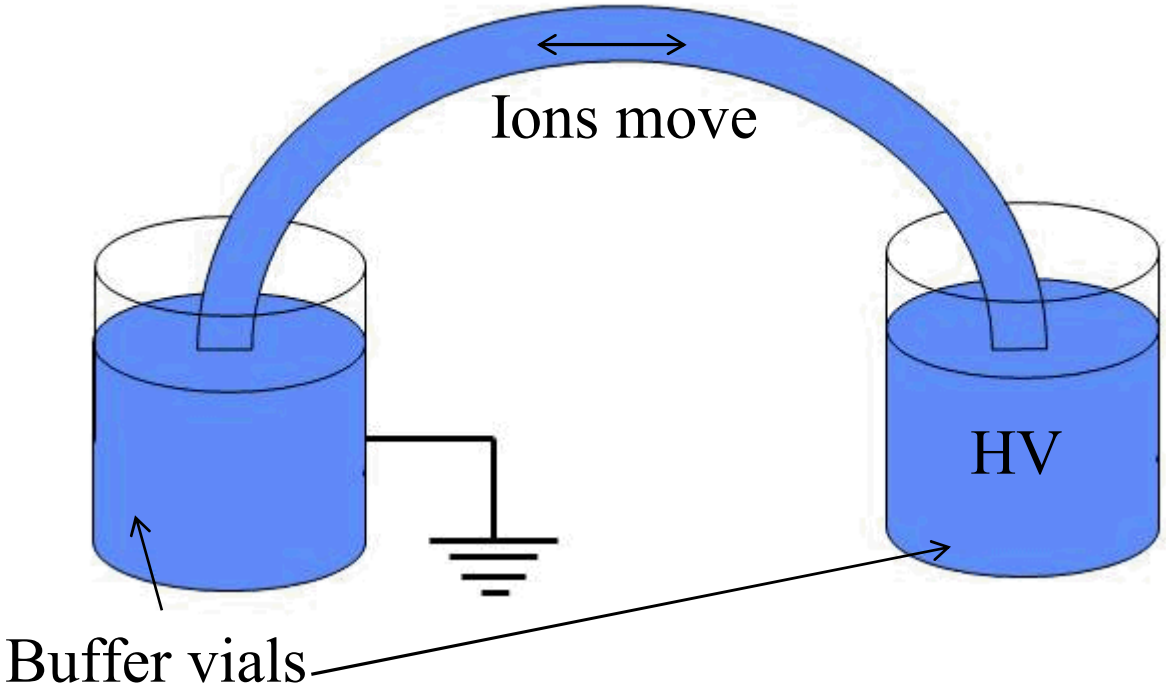
1) Julia A. Fruetel, *et. al.,* Microchip Separations of Protein Biotoxins Using an Integrated Hand-held Device, (2005) Electrophoresis, 26, 1144 – 1154.
2) Ronald F. Renzi, *et. al.,* , Hand-Held Microanalytical Instrument for Chip-Based Electrophoretic Separations of Proteins, (2004) Analytical Chemistry, 77, 435-441.

A Brief Introduction to Microfluidics and Electrophoresis

Dramatically different behaviors are seen at different size scales.

Imagine a glass drinking straw…





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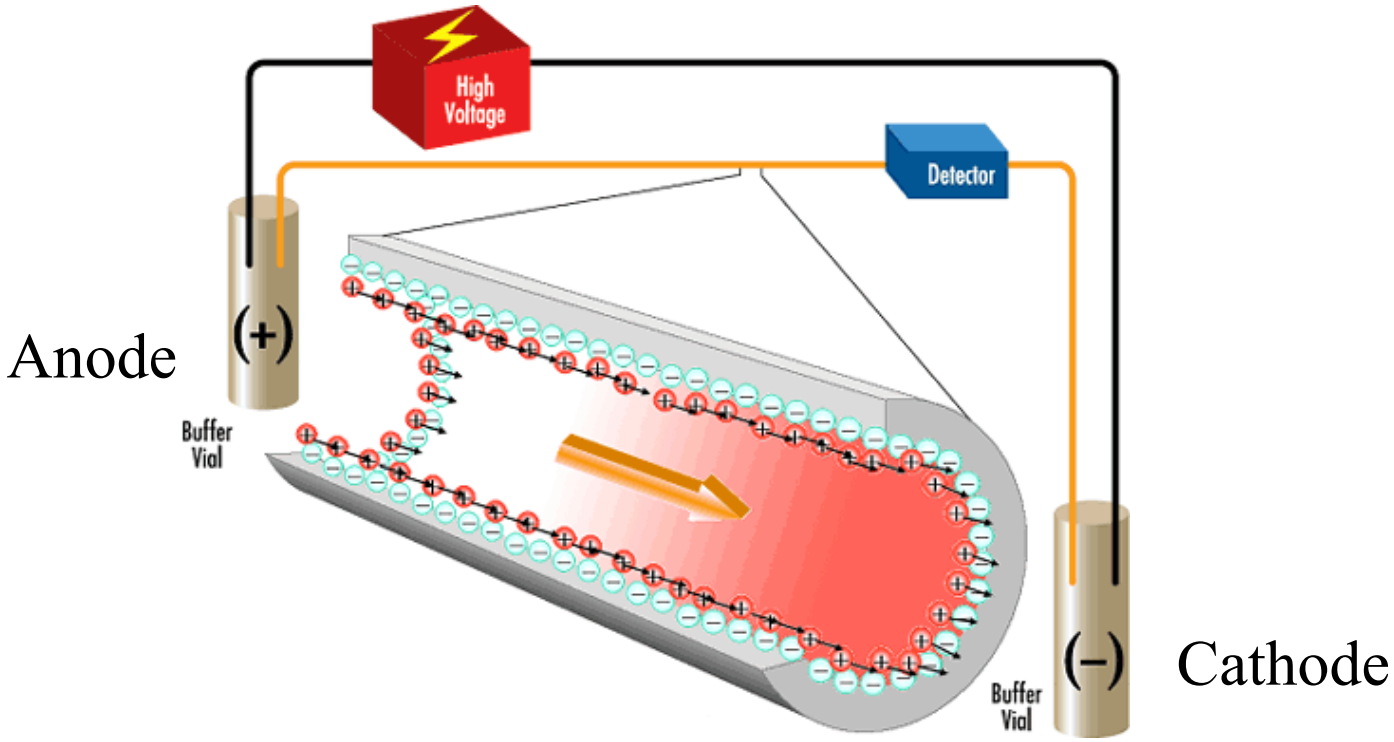
A Brief Introduction to Microfluidics and Electrophoresis

Now imagine your straw is the dimension of a human hair…



http://www.beckmancoulter.co.jp/images/product/product01/capzone_05.gif

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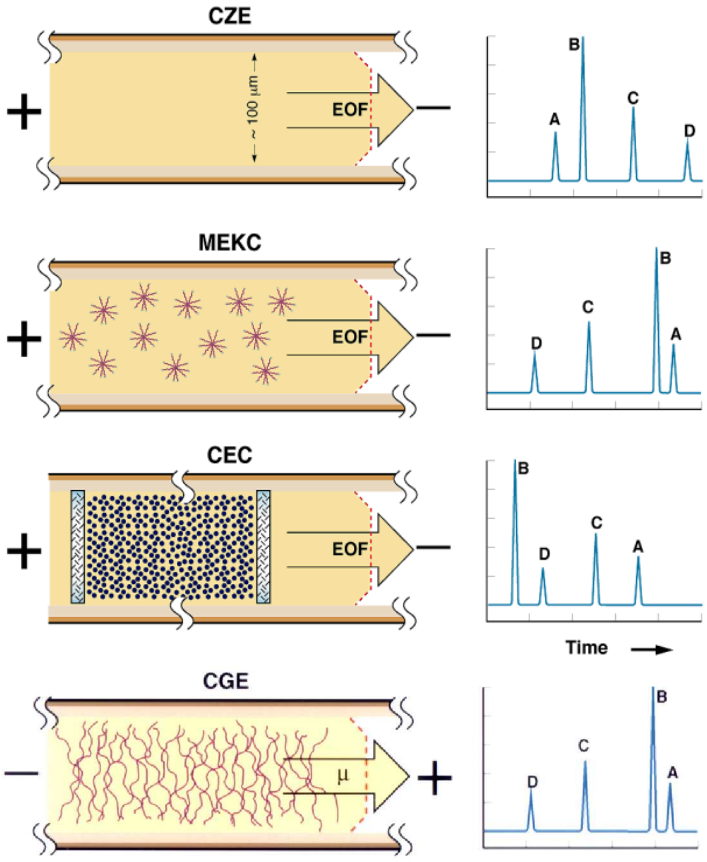
Electrophoresis is the basis for a wide variety of analytical techniques



Electrophoresis can be used to separate a wide range of molecules:

Proteins, Nucleic acids, Reporters, Chemicals and drugs

Used in the UWS

- Method suppresses EOF

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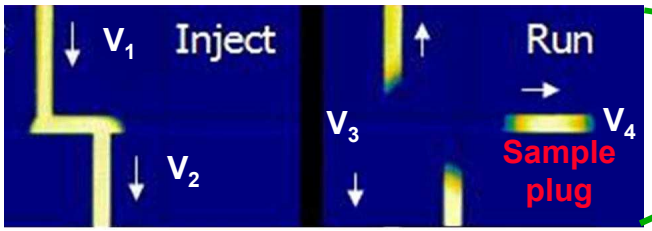
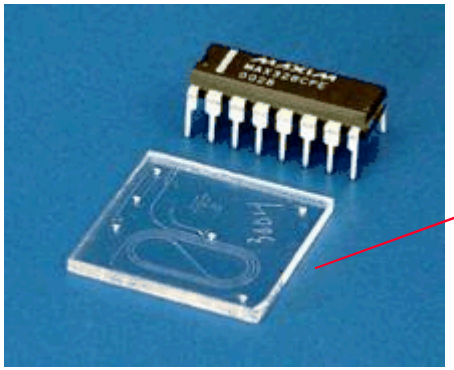
Rapid Analysis Carried out in Microfluidic Chip

Electrokinetic injection

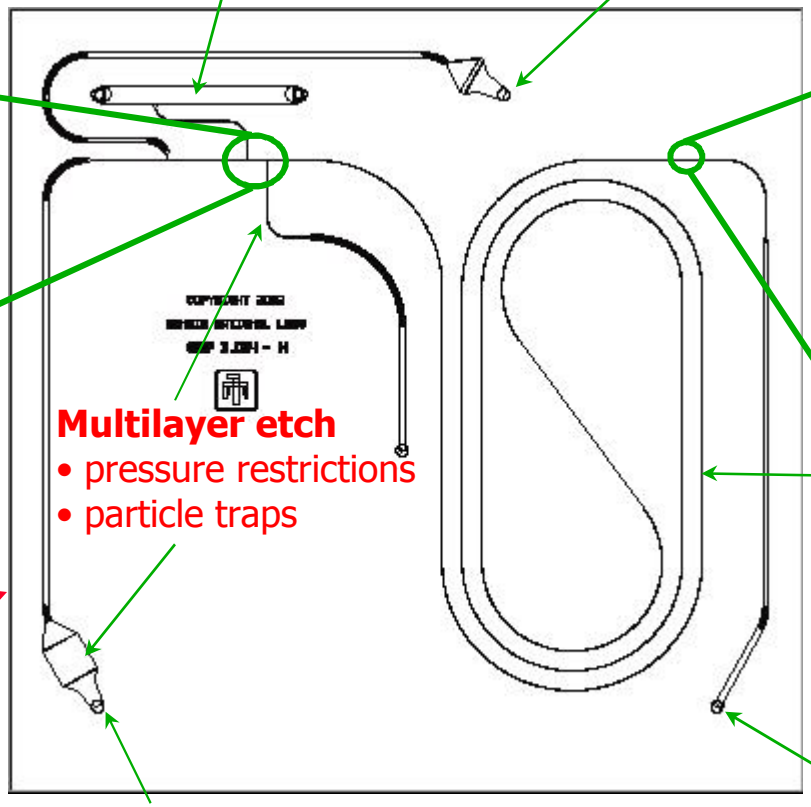




Overall 20 x 20 mm

Injection Loop

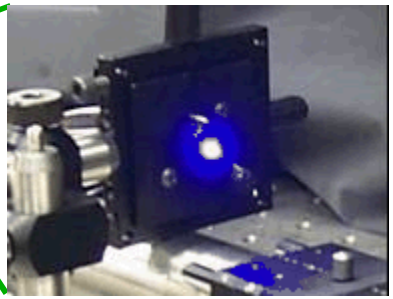
Flush port



Multilayer etch
- pressure restrictions
- particle traps

Channel Head

UV-LIF Detection



Separation column
- low dispersion turns for high resolution

Channel Waste

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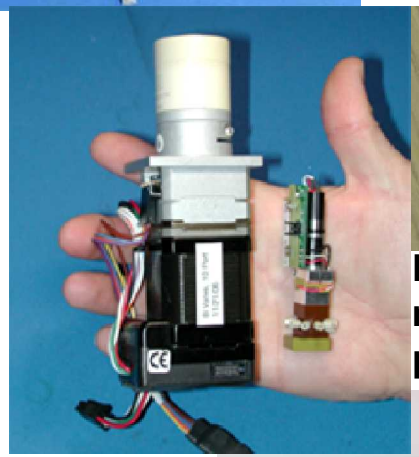
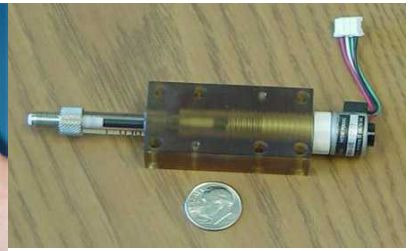
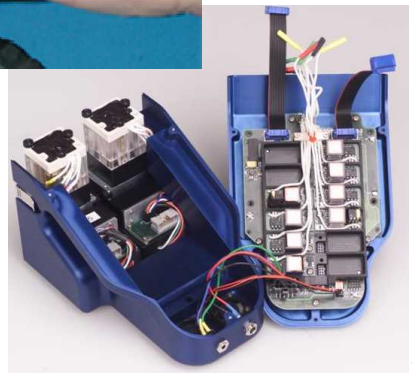
Enabling Technologies to list only a few…

Low-volume make and break fluid fittings and unions

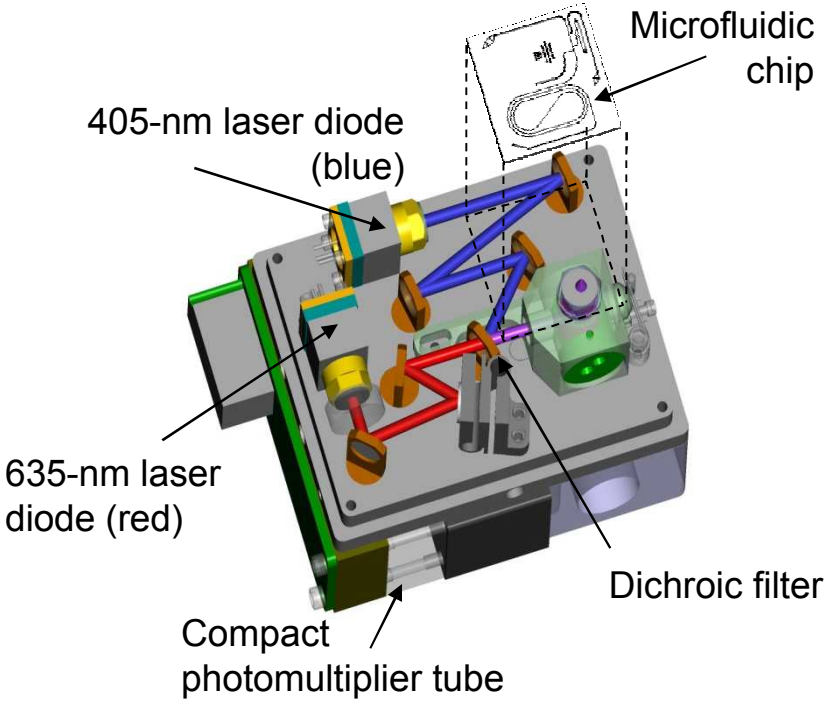




Electrically actuated microfluidic valves and pumps



Compact HV power supplies



Integrated compact two-color laser induced fluorescence detector

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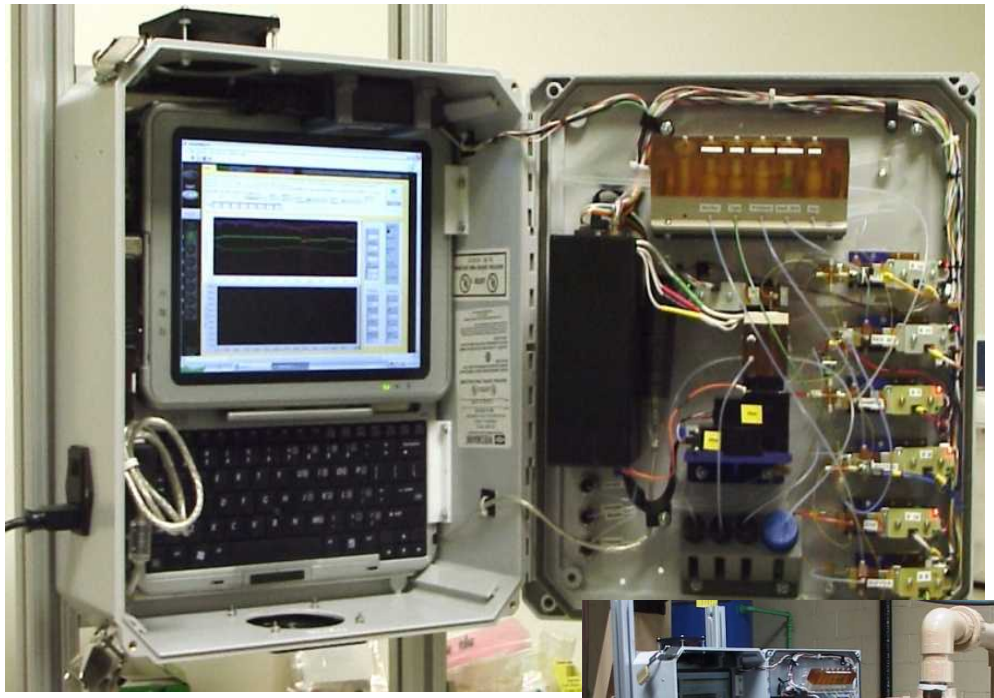
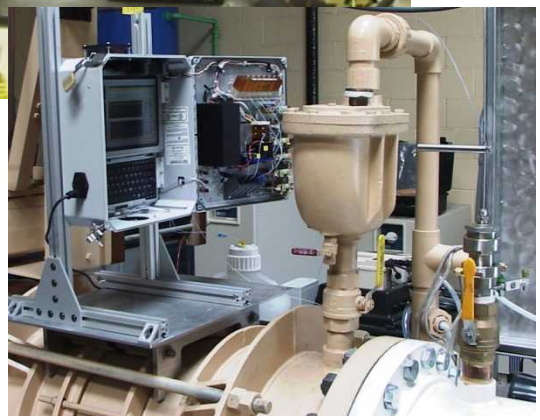
UWS Prototype System





Field Testing at Local Water Districts in Northern California and Arizona

- Fully automated and integrated sample preparation
  - 15 minute cycle time
  - Automated two color detection and analysis of protein toxins
- Modular design for fluids and components to ease system replenishment
  - Enough fluids/reagents onboard for 30 days
- Incorporation of system diagnostics
  - Pressure transducers
  - Positive controls
  - Data transmission and alarm capabilities

3) Victoria A. VanderNoot, Ronald F. Renzi, Bruce P. Mosier, James L. Van de Vreugde, Isaac Shokair, and Brent L. Haroldsen, Development of an Integrated Microfluidic Instrument for Unattended Water Monitoring Applications, *Electrophoresis,* (2010), **31**, 2632-2640.

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Expansion of the Analyte Types of UWS

Expanding the capability to detect other agents relevant to water monitoring

Detection of Bacteria (*E. coli*, nitrifying bacteria)

- Detection based on protein signature
- Use the existing hardware but requires incorporating sample preparation components to sort and lyse organisms and solubilize proteins

Detection of Protozoa (Cryptosporidia, Giardia)

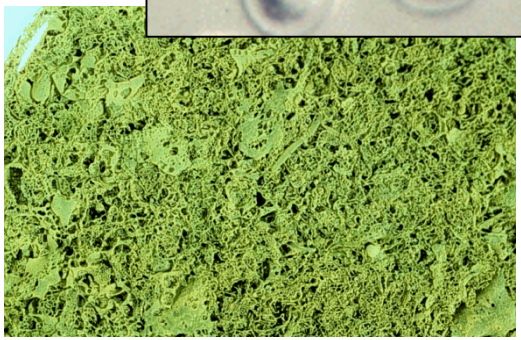
- Use the existing hardware
- Requires methods optimization

Detection of Algal Toxins (e.g. microcystins, marine toxins)

- Use the existing hardware
- Requires different labeling and extraction strategy

Giardia

Cryptosporidia



Microcystin producing blue green algae

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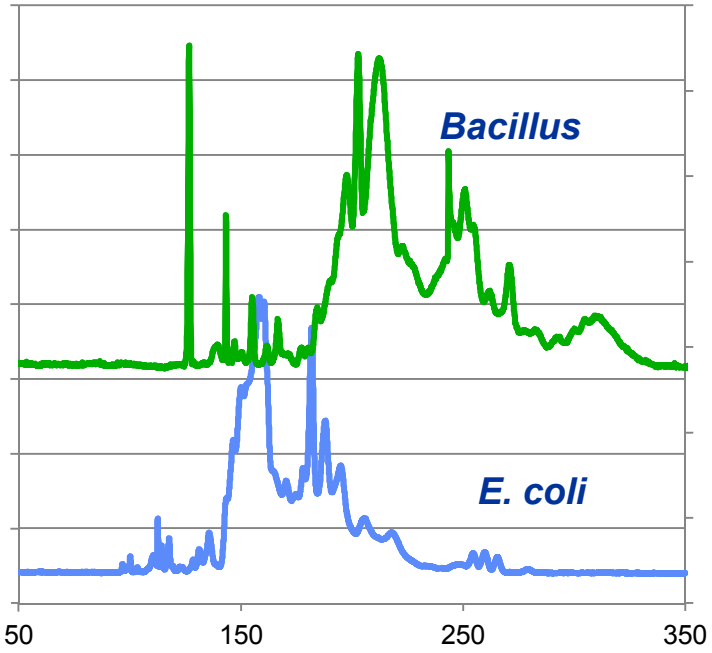
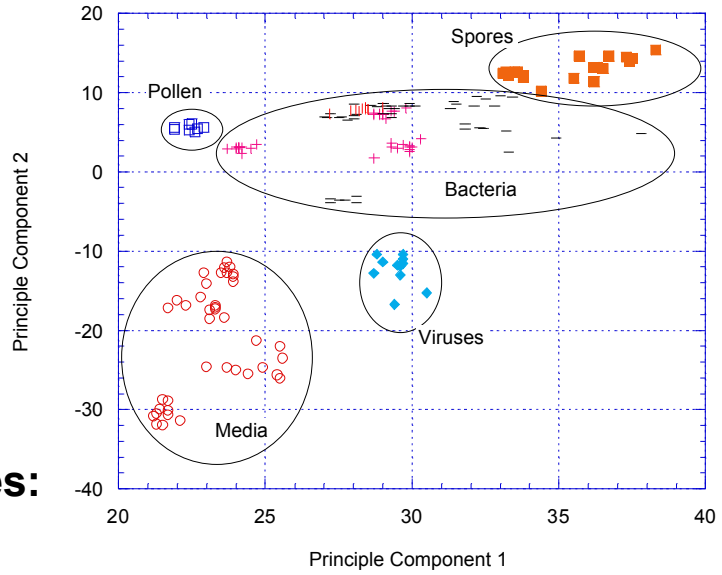
Microbial Signatures Analysis with µChemLab™



Database generation of microbial signatures:

- Signature recognition algorithms
- Principal Component Analysis

Principal Component Analysis



4) Shelly A. Pizarro, Pamela Lane, Todd W. Lane, Evelyn Cruz, Brent Haroldsen and Victoria A. VanderNoot Bacterial Characterization Using Protein Profiling in an Integrated Microchip Separations Platform, (2007) *Electrophoresis,* **28**, 4697–4704.

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Questions?

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