Using Lasers to Detect and Identify Bacteria: An Interdisciplinary Physics Project

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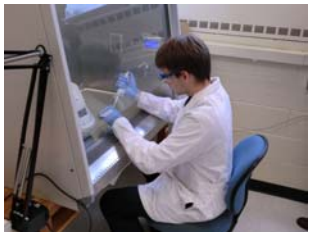
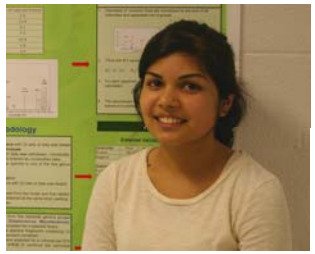
Using Lasers to Detect and Identify Bacteria: An Interdisciplinary Physics Project

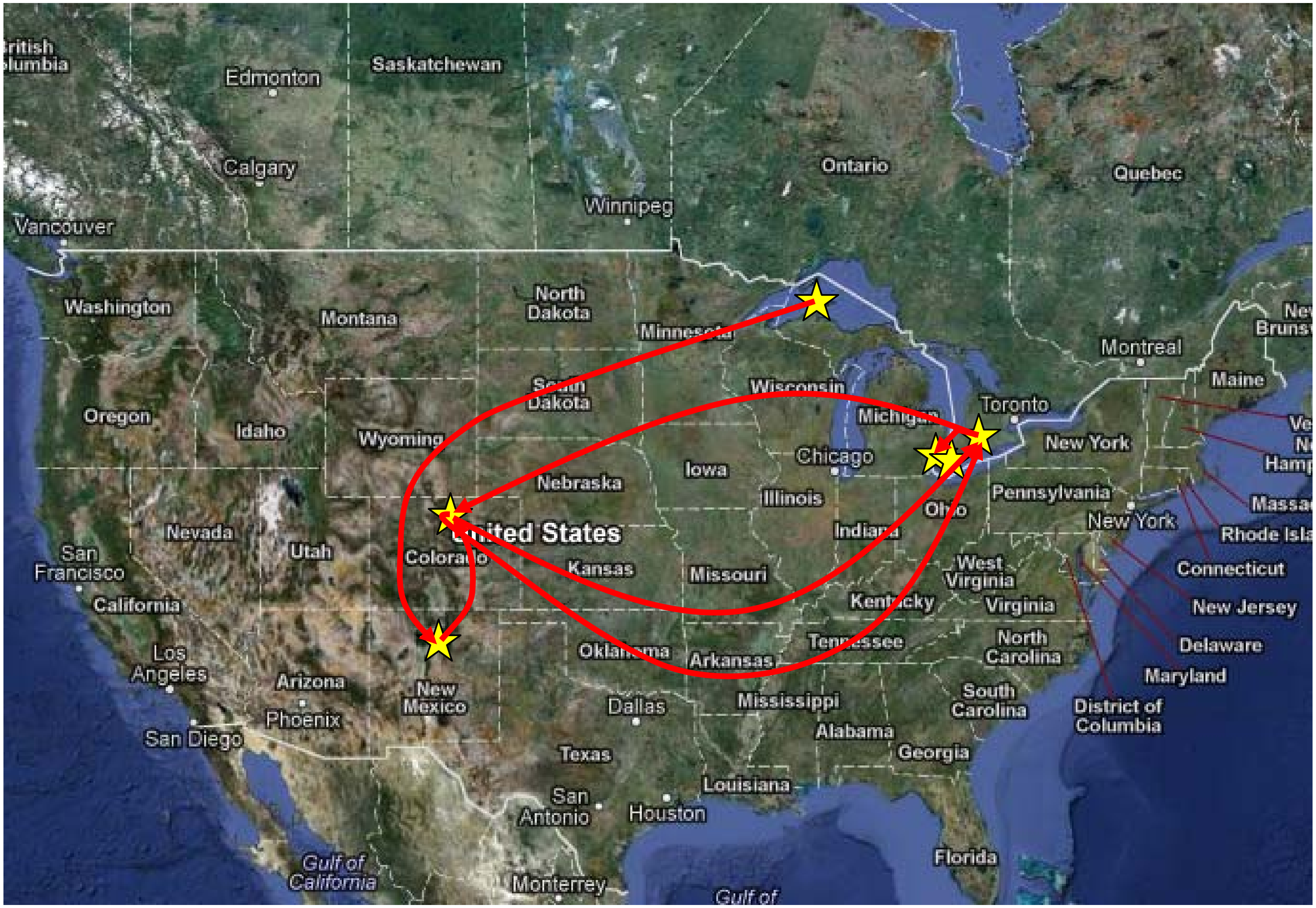

Khadijia Sheikh, Russell Putnam, Andrew Daabous, Ryan Woodman, Daniel Trojiand, Eric Lessard, Derek Gillies

University of Windsor, Department of Physics



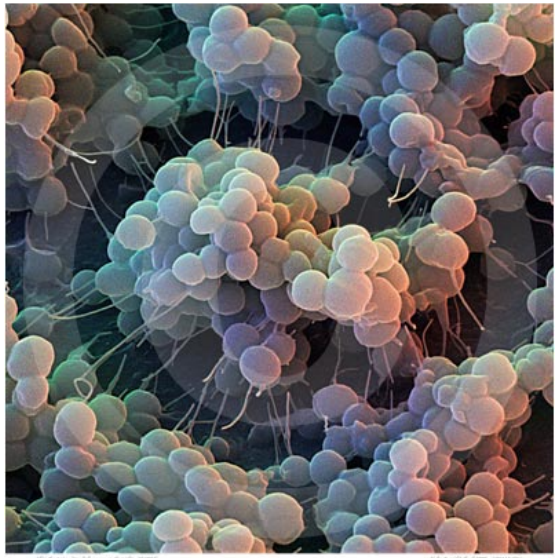



Free Physicist Career Advice #1



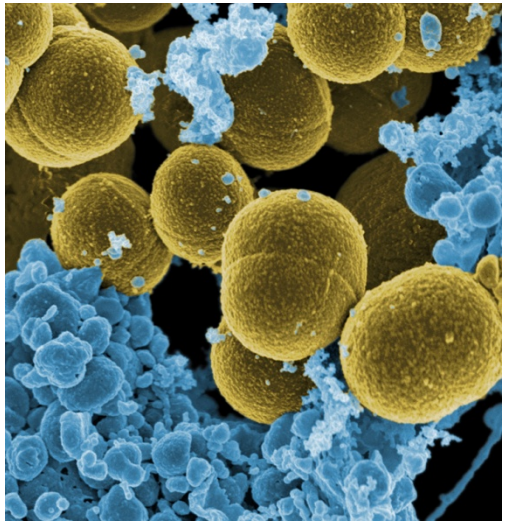
DO: feel free to go to where the skiing is excellent

DO: go to where the weather suits you



Staph. epidermidis

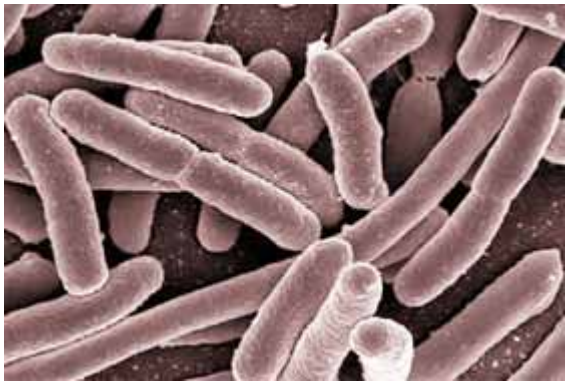
Staph. aureus



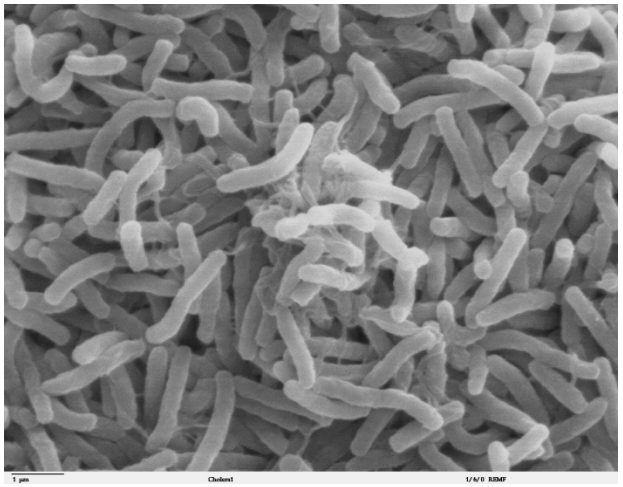
bacteria are ubiquitous

10x more prokaryotic cells in your body than eukaryotic cells

E. coli



V. cholerae



CNNhealth.com

updated 12:52 p.m. EDT, Sun August 24, 2008

Canada links Toronto plant to deadly listeriosis outbreak

updated 9:31 a.m. EST, Mon March 2, 2009

Antibiotic-resistant infections among children on the rise

The New York Times

Peanut Product Recall Grows in Salmonella

By GARDINER HARRIS
Published: January 28, 2009

December 8, 2003

Staph Infection Kills Football Player

By Norm Jones, Newswatch 16, Scranton, PA

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CDC: 756 ill from salmonella-tainted tomatoes

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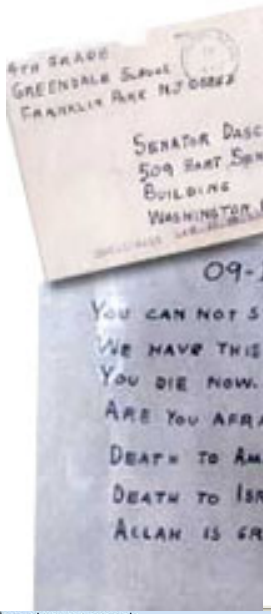
New superbugs emerge in U.K., Asia

Canadian cases reported in Vancouver, Alberta

Last Updated: Sunday, August 15, 2010 | 10:18 PM ET Comments 447



NEWS / Police And Fire

Suspicious powder at National Bank not dangerous, police say

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MYSTERIOUS POWDER INVESTIGATED

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'Suspicious Powder' Scare Empties Building In Downtown Windsor

April 18, 2012. 8:03 am • Section: Downtown Windsor

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Firefighters and hazardous material specialists gather on Pitt Street West in response to a report of a suspicious white powder at the Canada Post building on Ouellette Avenue in Windsor, Ont. on April 18, 2012. (Nick Brancaccio / The Windsor Star)

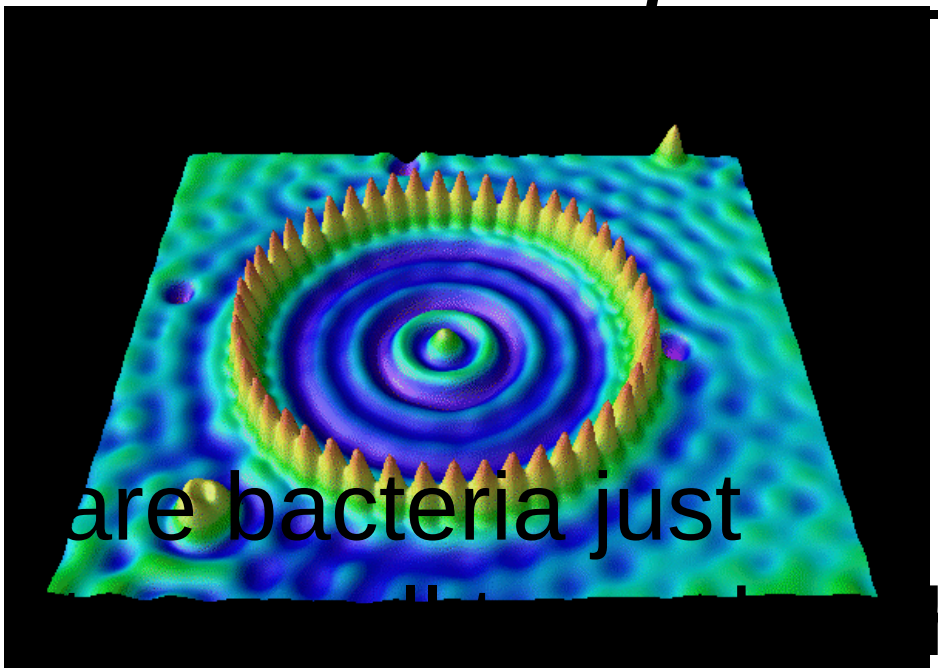
So why?

"It is well-accepted that the microbiological expertise and cost required to perform these identifications preclude their common use as a screening mechanism to prevent human infection."[1]

[1]Tarr, P.I. 1995. *Escherichia coli* O157:H7: clinical, diagnostic, and epidemiological aspects of human infection. Clin. Infect. Dis. 20, 1-8.

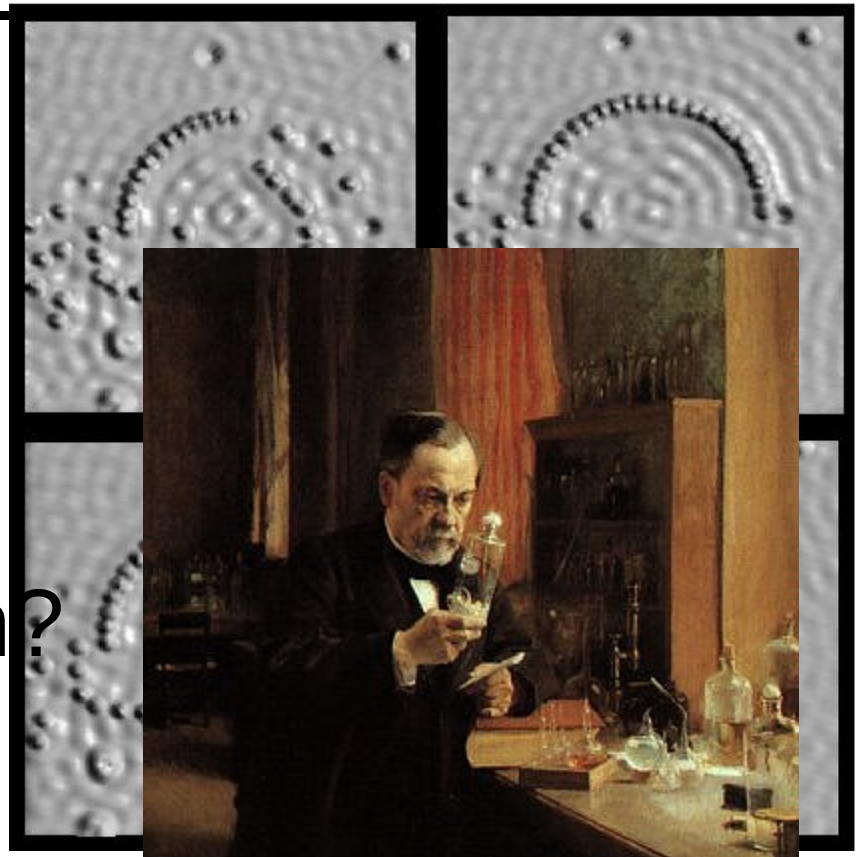
“Too small?”

What’s the problem?

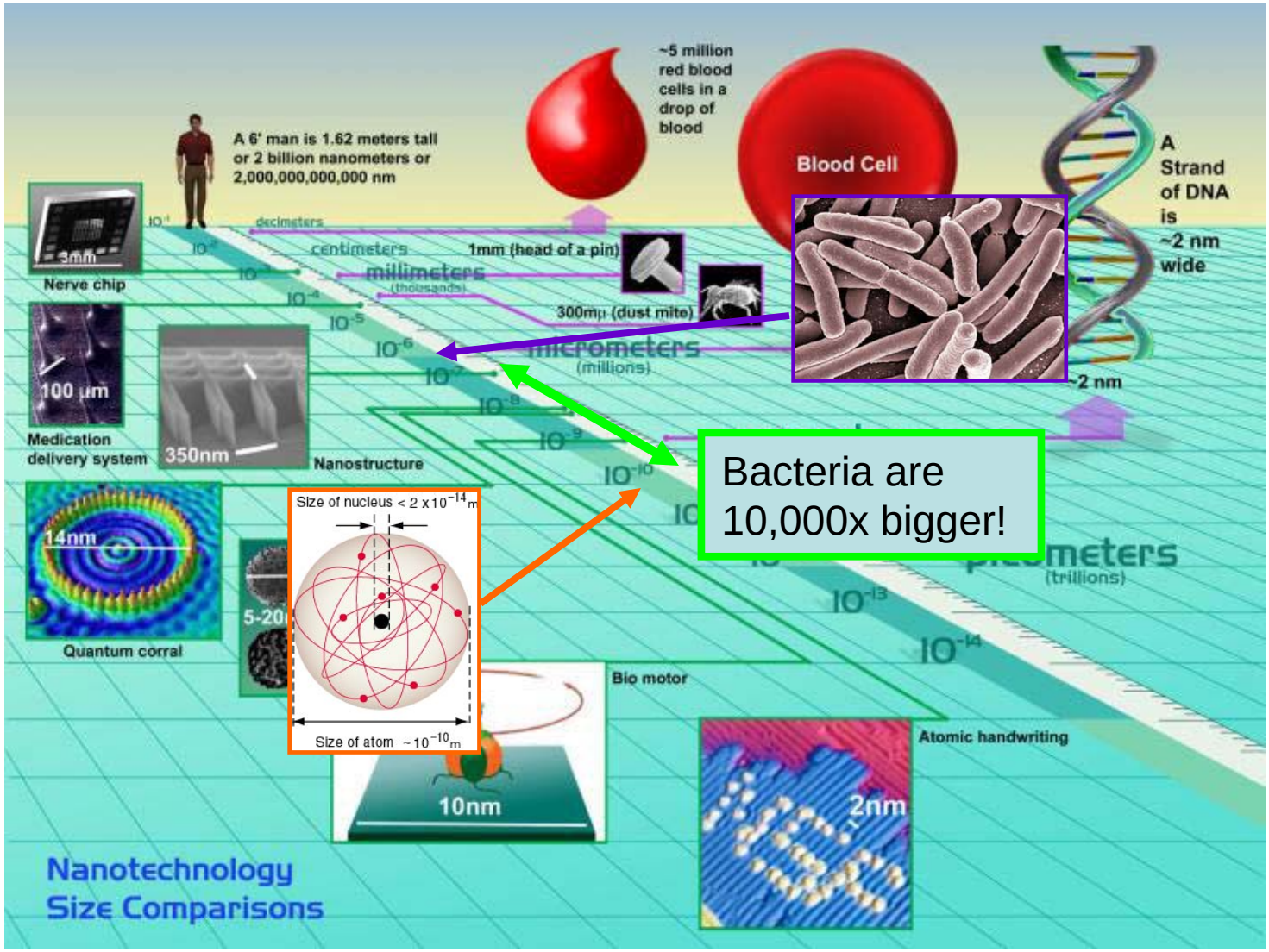


"Quantum Corral"

Scanning Tunneling Microscope image of **individual iron atoms** arranged intentionally on a copper surface in a circular ring, exposing quantum electron waves



AFM i eing

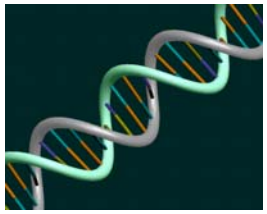


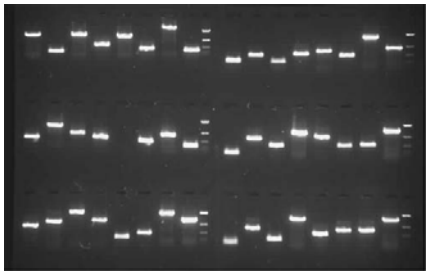
From “Nanopedia” at Case Western University

If it's not the size, it must be our methods

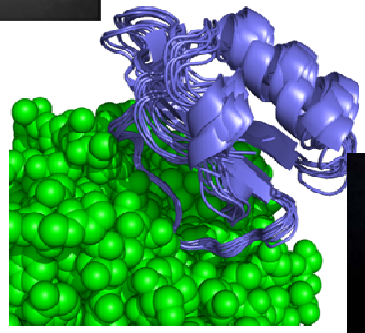
How do we identify bacteria?

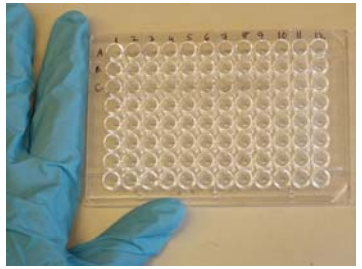
- ***genetic***

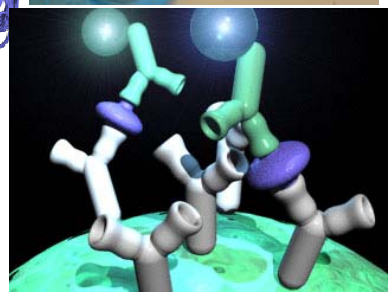




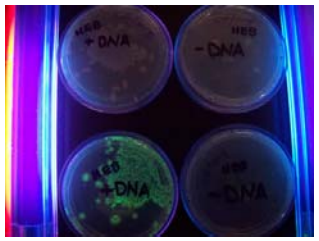
- ***serological (antigenic)***





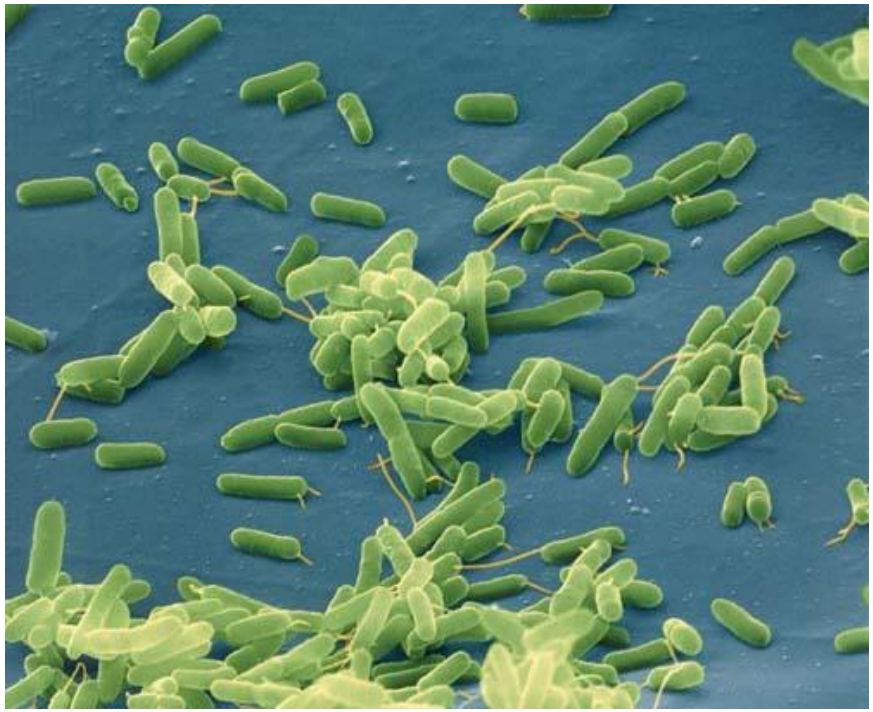


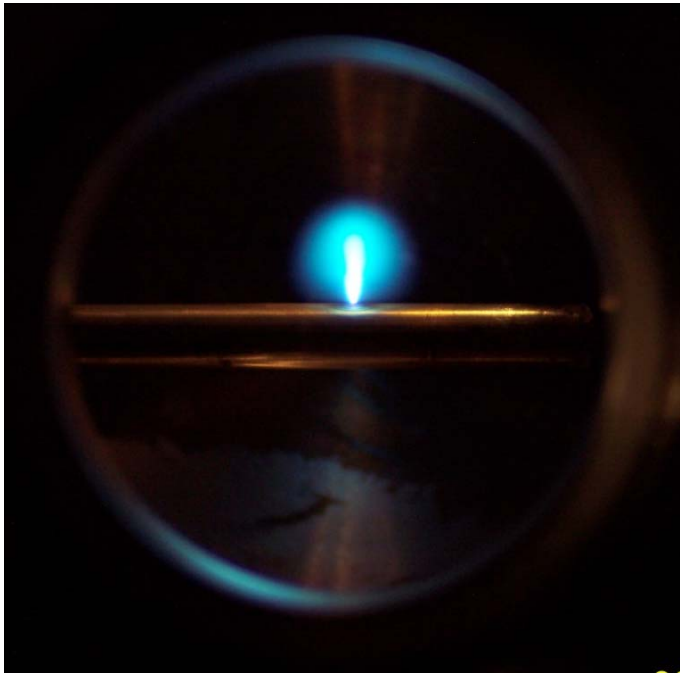
- ***microbiological (phenological)***



- ***compositional***
  - ***identifying bacteria by their unique combinations of atoms, molecules, or proteins***

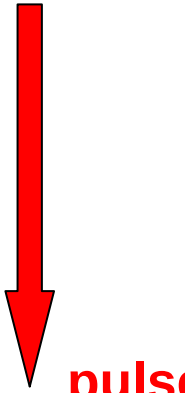
We Want to Use “Laser-Induced Breakdown Spectroscopy” (LIBS) to Identify Bacteria by Measuring all the Atoms in the Cell





Here’s How We Do It…

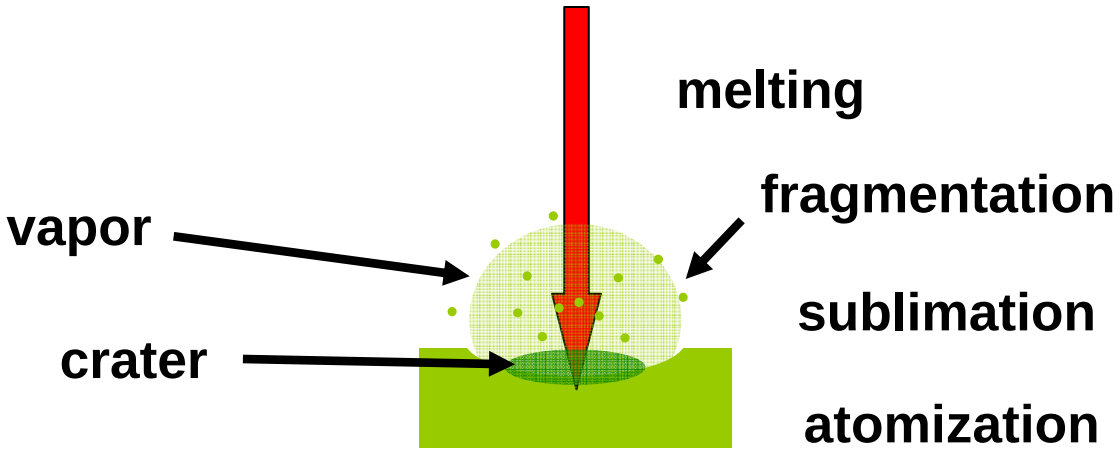
1) laser interaction with the target



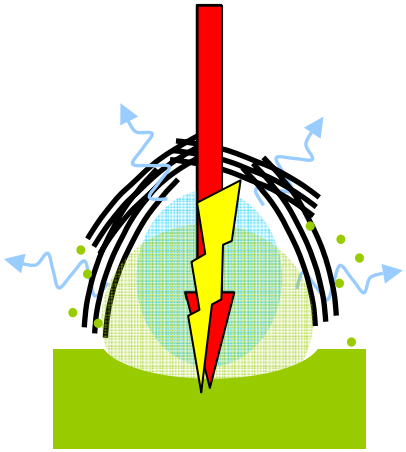
pulsed laser

absorption of laser energy

2) removal of samples mass (ablation)



3) plasma formation (breakdown)



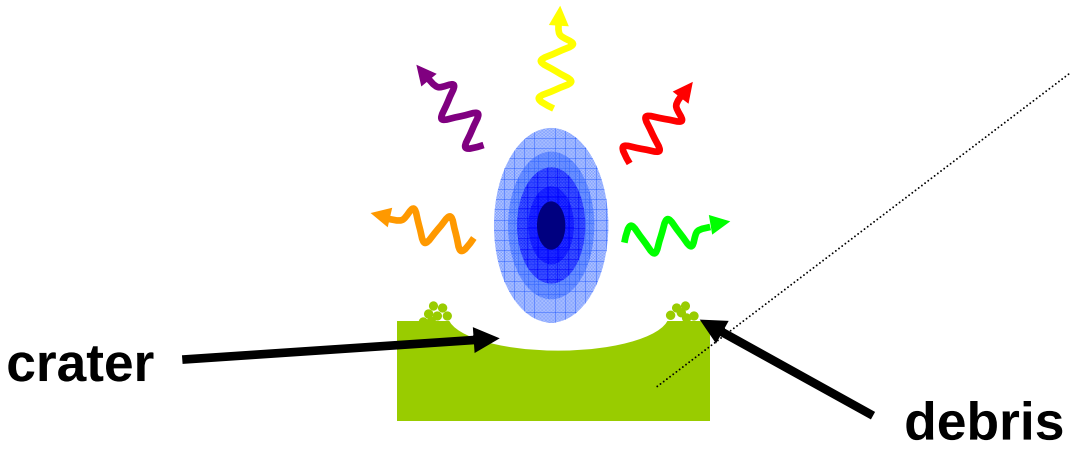
absorption of the laser radiation by the vapor

- continuum emission
- electrical breakdown and plasma formation
- shock wave
- bremsstrahlung

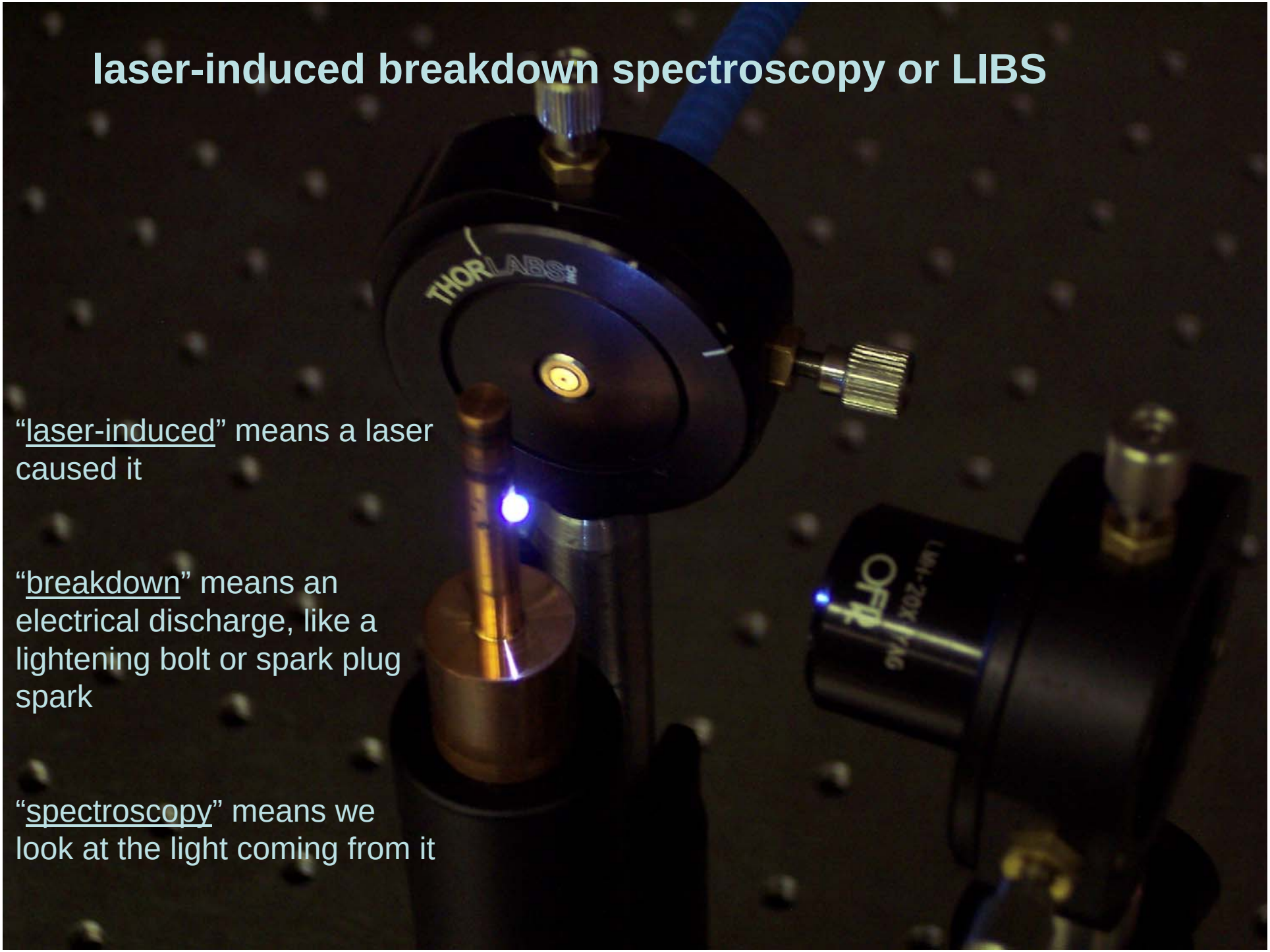
4) expansion and element specific emission (atomic or ionic)

we collect and analyze that light: it tells us what kind of atoms and how many!

spontaneous emission as atoms/ions decay to ground state



laser-induced breakdown spectroscopy or LIBS



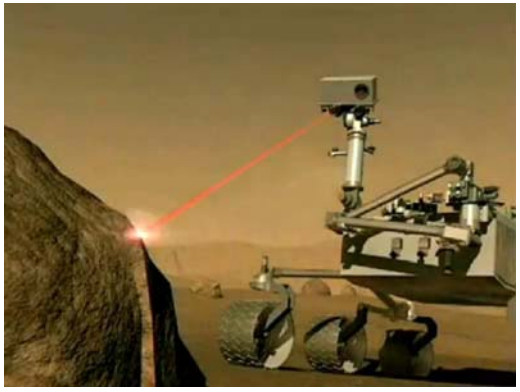
"laser-induced" means a laser caused it

"breakdown" means an electrical discharge, like a lightening bolt or spark plug spark

"spectroscopy" means we look at the light coming from it

The new “Mars Science Laboratory” (MSL), Mars Rover “Curiosity”, landed on Mars last August. Fired its LIBS laser for first time on Aug. 19 (see my webpage)

http://mars.jpl.nasa.gov/msl/



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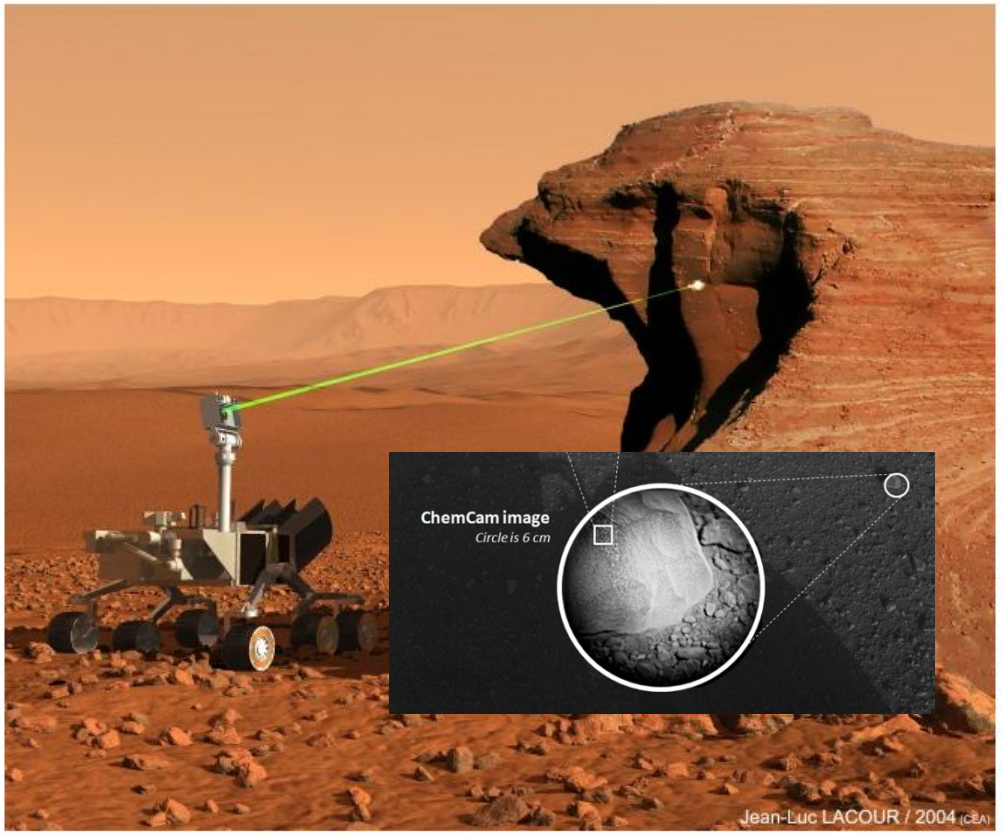
New Lasers Fight Crime, Martians

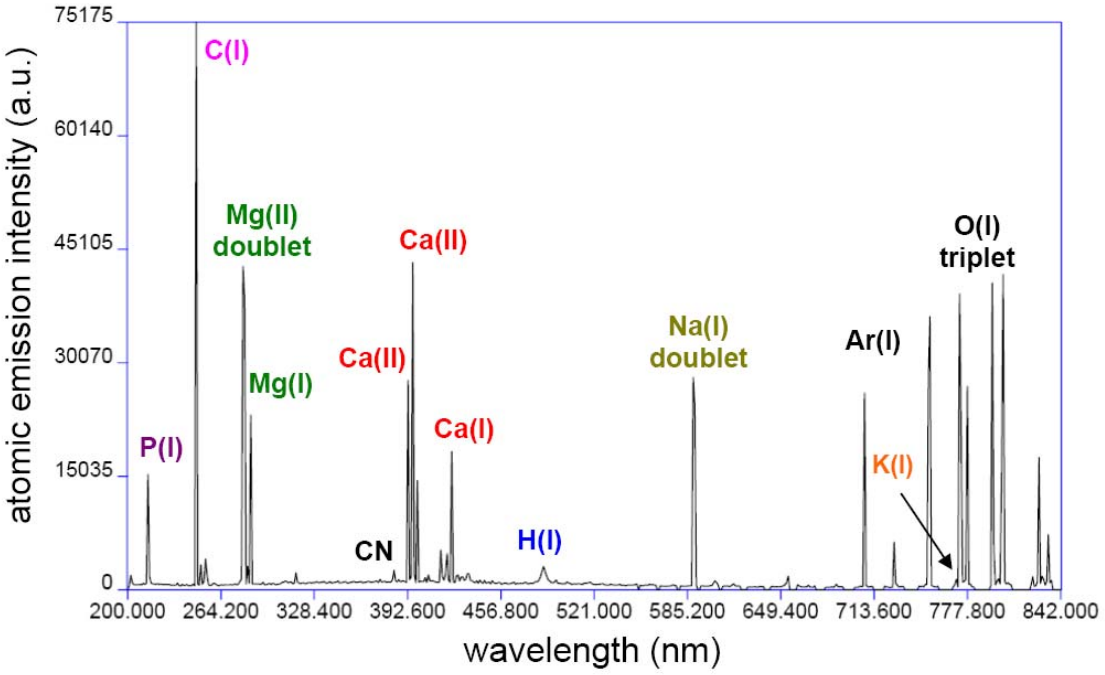
By Alexis Madrigal February 16, 2010 | 6:26 pm | Categories: Physics, Space



A new technique that uses a laser to vaporize materials like rocks and steel to analyze their chemical composition is finding new applications from Mars to forensics.

bacterial composition

Ratios of elements create a unique "spectral fingerprint" for each bacteria.



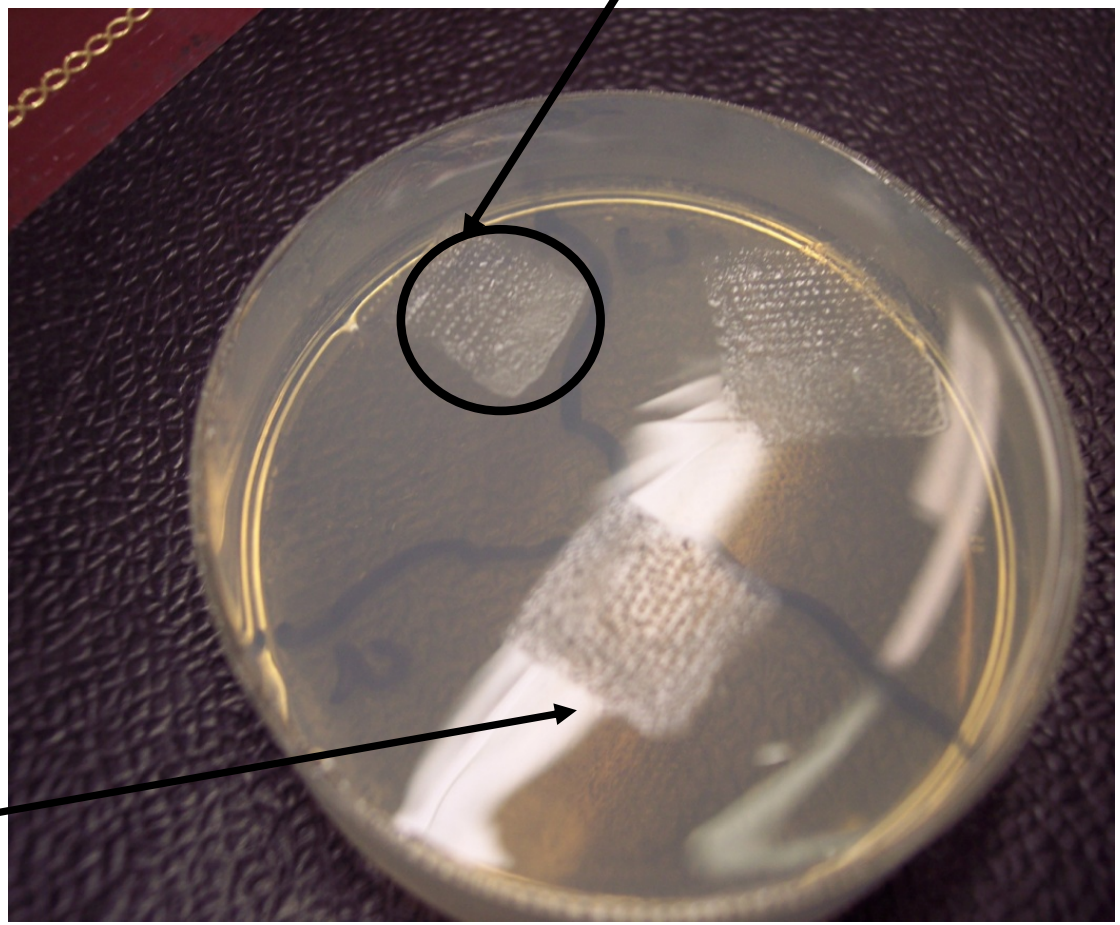
LIBS-based pathogen identification is inorganic element based (at this point)

from "*The Bacteria: A Treatise on Structure and Function*" I.C. Gunsalus and R.Y. Stanier, eds

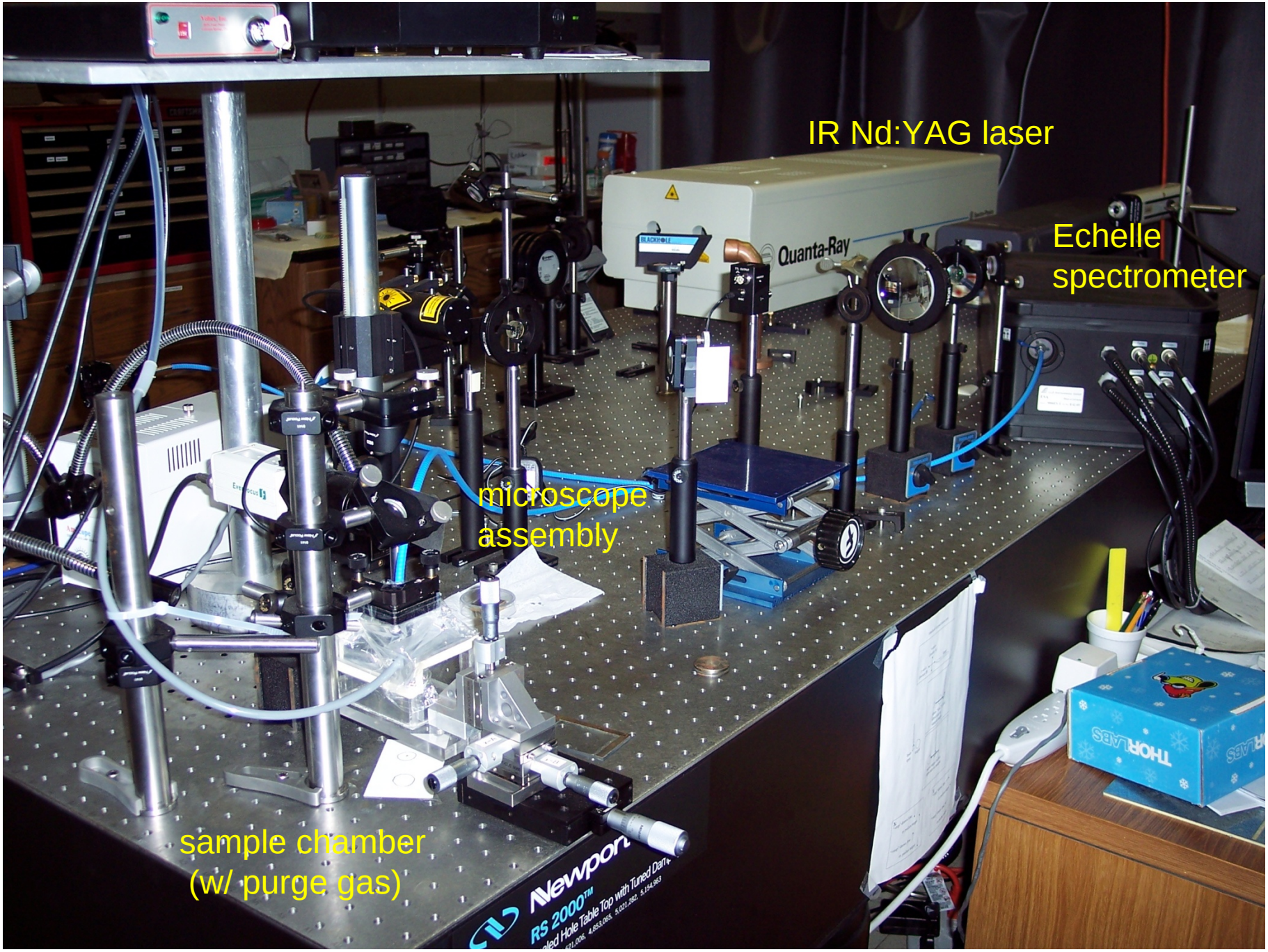
Element	% of fixed salt fraction
Sodium	2.6
Potassium	12.9
Calcium	9.1
Magnesium	5.9
Phosphorus	45.8
Sulfur	1.8
Iron	3.4

how we do it…

10 microliter



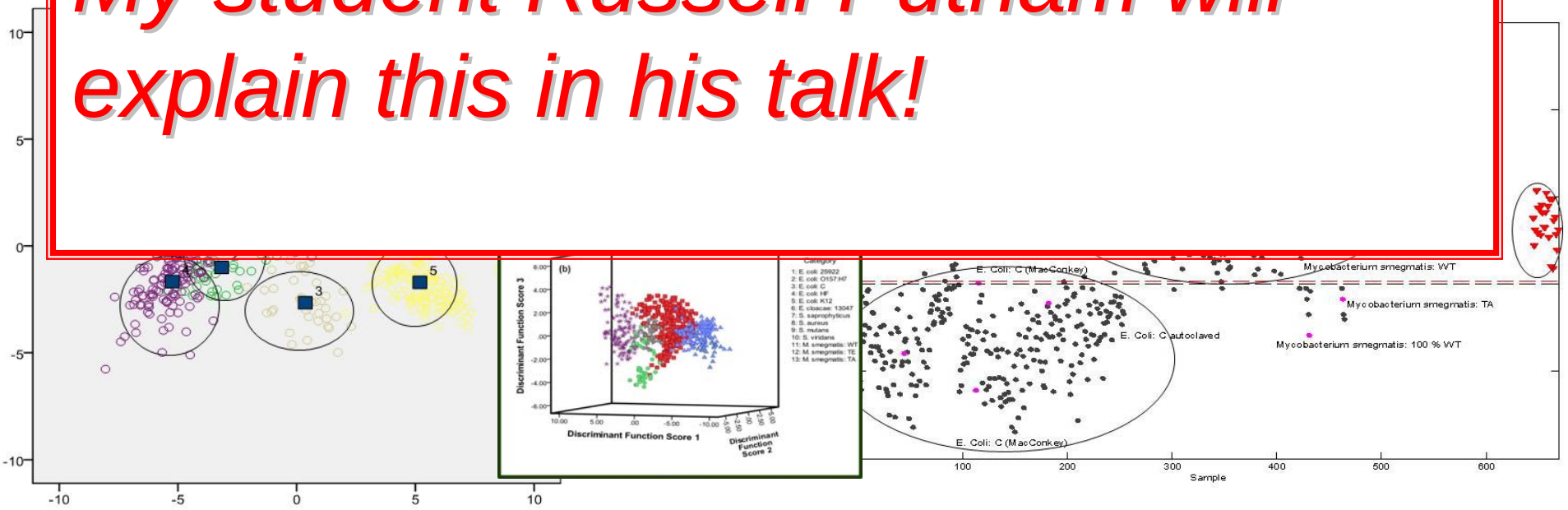
about 500-1500
bacteria per
sampling location


IR Nd:YAG laser
Quanta-Ray
Echelle
spectrometer
microscope
assembly
sample chamber
(w/ purge gas)
Newport
RS 2000™
THORLABS

To "discriminate" one bacterial spectrum from another, multivariate analysis "chemometrics" required

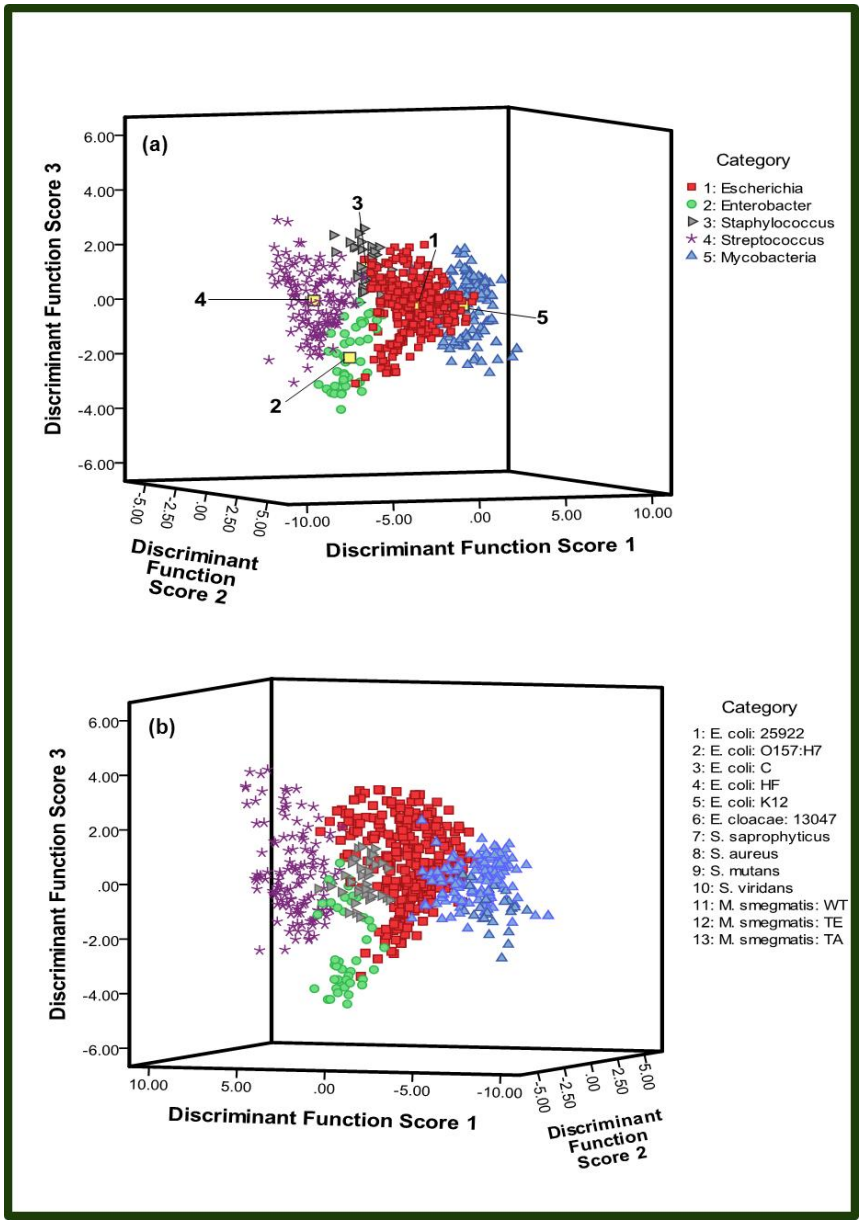
- Intensity of lines, ratios of intensities used as independent variables

My student Russell Putnam will explain this in his talk!



Using a LIBS spectrtal fingerprint, we have already demonstrated…

We can identify a bacterial species, certainly its genus, on the basis of its atomic composition with high sensitivity and low rates of false positives



Using LIBS, we have already demonstrated…

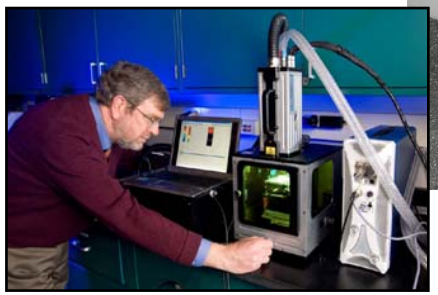
The LIBS spectral fingerprint is:

- growth-medium independent
- independent of state of growth (how “old” the bacteria are)
- independent of whether the bacteria are live or dead (or inactivated by UV light)
- obtainable even when other types of bacteria or contaminants are present (mixed samples)
- obtainable from urine specimens
- capable of strain discrimination
- obtainable from about 500 bacteria

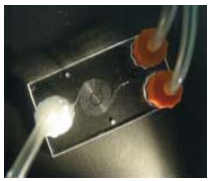
8 publications in Applied Physics Letters, Journal of Applied Physics, Applied Optics, Applied Spectroscopy, Spectrochimica Acta B, and others

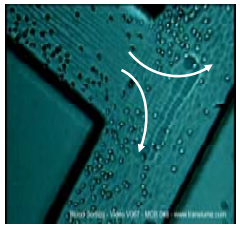
Much remains to be done…

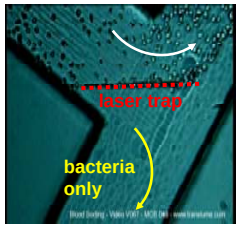
1. Making LIBS a realistic medical diagnostic (hardware/software)



2. Isolating bacteria from clinical specimens (blood? urine? CSF? saliva?) and concentrating them into the LIBS plasma







3. Benchmarking against gold-standards and other technologies on clinical isolates

We could use your help to do it!

Always looking for new graduate students!

Much remains to be done…

But all tests to date have proven the possibility of using LIBS for a rapid pathogen diagnostic, as well as numerous other biomedical applications.

University of Windsor
thinking forward

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Natural Sciences and Engineering Research Council of Canada
Conseil de recherches en sciences naturelles et en génie du Canada

Work continues, with generous help from the University of Windsor, a Discovery Grant from NSERC, and a CFI-LOF grant

Thank you for your attention!

http://www.uwindsor.ca/rehse/