Rapid Methods and Automation in Microbiology: 25 Years of Development and Predictions

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Kansas State University, Manhattan, Kansas

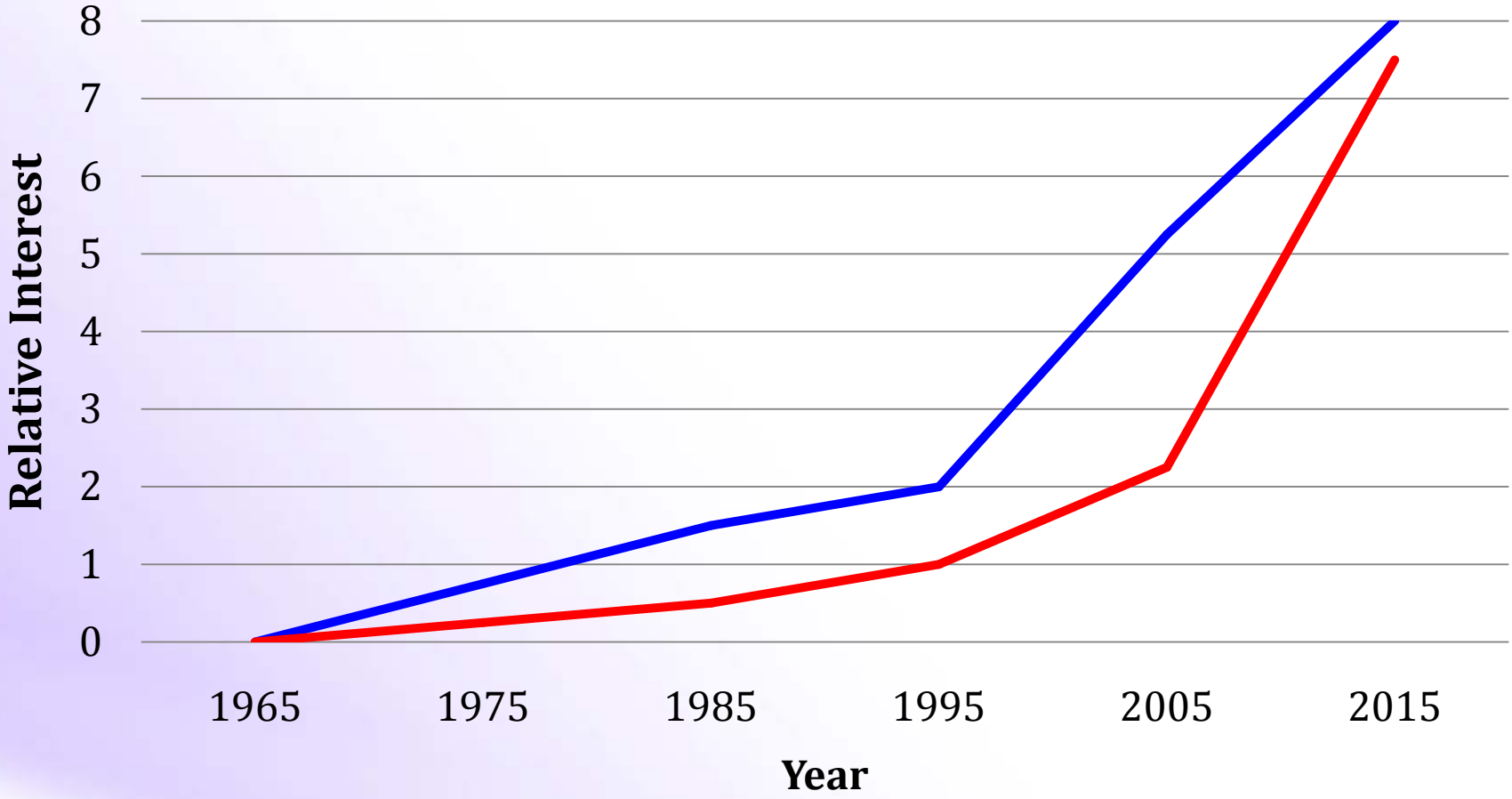
University Distinguished Professor

Universität Autónoma de Barcelona, Spain





Development of Interest in Rapid Methods



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Food Microbiology

- Sample preparation
- Total viable cell count
- Differential cell count
- Pathogenic organisms
- Enzymes and toxins
- Metabolites and biomass

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Foodborne pathogens recognized as predominant in the United States in the last 20 years

Campylobacter jejuni

Campylobacter fetis* ssp. *fetus

Cryptosporidium cayetanensis

***Escherichia coli* O157:H7 and related *E. coli* (e.g. O11:NM, O104:H21)**

Listeria monocytogenes

Norwalk viruses

***Nitzchia pungens* (cause of amnesic shellfish poisoning)**

Salmonella Entertidis

***Salmonella Typhimurium* DT 104**

***Vibrio cholerae* 01**

Vibrio vulnificus

Vibrio parahaemolyticus

Yersinia enerolitica

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Examples of pathogens associated with fruits and vegetables involved in outbreaks of foodborne disease

Agent	Implicated Food	Reference
B. cereus	Sprouts	Portnoy (1976)
Campylobacter	Cucumber	Kirk (1997)
C. jejuni	Lettuce	CDC (1998)
C. botulinum	Vegetable Salad	PHLS (1978)
Cyclospora	Raspberries	Herwaldt (1997)
E. coli O157:H7	Radish Sprouts	WHO (1996)
E. coli O157:H7	Apple Juice	CDC (1996)
E. coli O157:H7	Iceberg Lettuce	CDR (1997)
Fasciolia hepatica	Watercress	Hardman (1970)
Hepatitis A	Iceberg Lettuce	Rosenblum (1990)
Hepatitis A	Raspberries	Ramsay (1989)
Salmonella Agona	Coleslaw, Onion	Clark (1973)
S. Oranienburg	Watermelon	CDC (1979)
S. Poona	Cantaloupes	CDC (1991)
S. Stanley	Alfalfa Sprouts	Mahon (1997)
Shigella flexneri	Mixed Salad	Dunn (1995)
S. sonnei	Tossed Salad	Martin (1986)
Vibrio cholerae	Salad, Vegetables	Shuval (1989)

Methods for the Detection of *Escherichia coli* O157:H7 in Foods

1. Conventional methods – Time honored, "Gold Standard", up to5 days
2. ELISA-Enzyme Linked Immunoabsorbant Assay – Manual and automated
3. Dipsticks – Rapid detection after enrichment
4. DNA/RNA probes
5. PCR – Polymerase chain reaction and many modifications
6. Ribotyping – Pin-point source of contamination
7. Epifluorescence microscopy
8. Electrochemical reactions
9. Fiber-optic biosensor
10. Fluorescent bacteriophage
11. Light Addressable Potentiometric Sensor
12. Electrochemiluminescent Detection of Immunomagnetic captured antigens

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MANHATTAN

Table 4. Numbers of Total Plate Count, Coliform Count, and specific pathogen tests performed by respondents

Tests	# Doing the test				Average #			
	1981-7 (55)	1989 (31)	1990 (34)	1991 (41)	1981-7 (55)	1989 (31)	1990 (34)	1991 (41)
Total Plate counts	44	25	26	31	12,786 (250,000)*	16,378 (182,500)	25,509 (73,000)	12,585 (60,000)
Coliform counts	43	10	24	31	25,023 (840,000)	4,546 (10,000)	10,112 (73,000)	10,558 (50,000)
Salmonella	34	23	19	23	1,500 (15,000)	3,753 (18,000)	2,278 (10,000)	2,955 (36,000)
Listeria	12	9	12	17	520 (15,000)	2,900 (12,000)	1,740 (8,000)	750 (4,800)
Campylobacter	5	2	5	10	4 (100)	250 (400)	330 (1,500)	187 (500)
S. aureus	6	8	3	6	330 (6,000)	2,370 (7,200)	284 (500)	3,009 (6,000)
E. coli	6	7	2	3	2,000 (50,000)	2,543 (8,000)	5,250 (10,000)	2,100 (5,000)

Numbers in parenthesis indicate number of respondents

* Maximum number of tests done


NEW COLI

One-Shift Pathogen Tests – 6 to 8 hr.

Validated:

- **Neogen** *E. Coli* O157:H7 – 8 hr. test

Under development:

- **Umedic** *E. Coli* O157:H7 – 8 hr. test
- **Detex** *E. Coli* O157:H7 – 8 hr. test
- **MicroStar** *E. Coli* – 8 hr. test

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Real Time Results – Minutes

RBD2100: viable cell counts – 30 minutes

DEFT: viable cell counts – 60 minutes

Aflatoxin tests: 10 – 20 minutes

ATP tests: 10 – 20 minutes

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Advances in Total Viable Cell Count Methodologies

- Stomacher vs. Pulsifier
- Petrifilm, Redigel, Isogrid, and Spiral Plater data
- Fung's Double Tube for 6 hr. *Clostridium perfringens* enumeration

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Stomacher



Pulsifier



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Pulsifier vs. Stomacher

Total Viable Cultures from 96 food samples

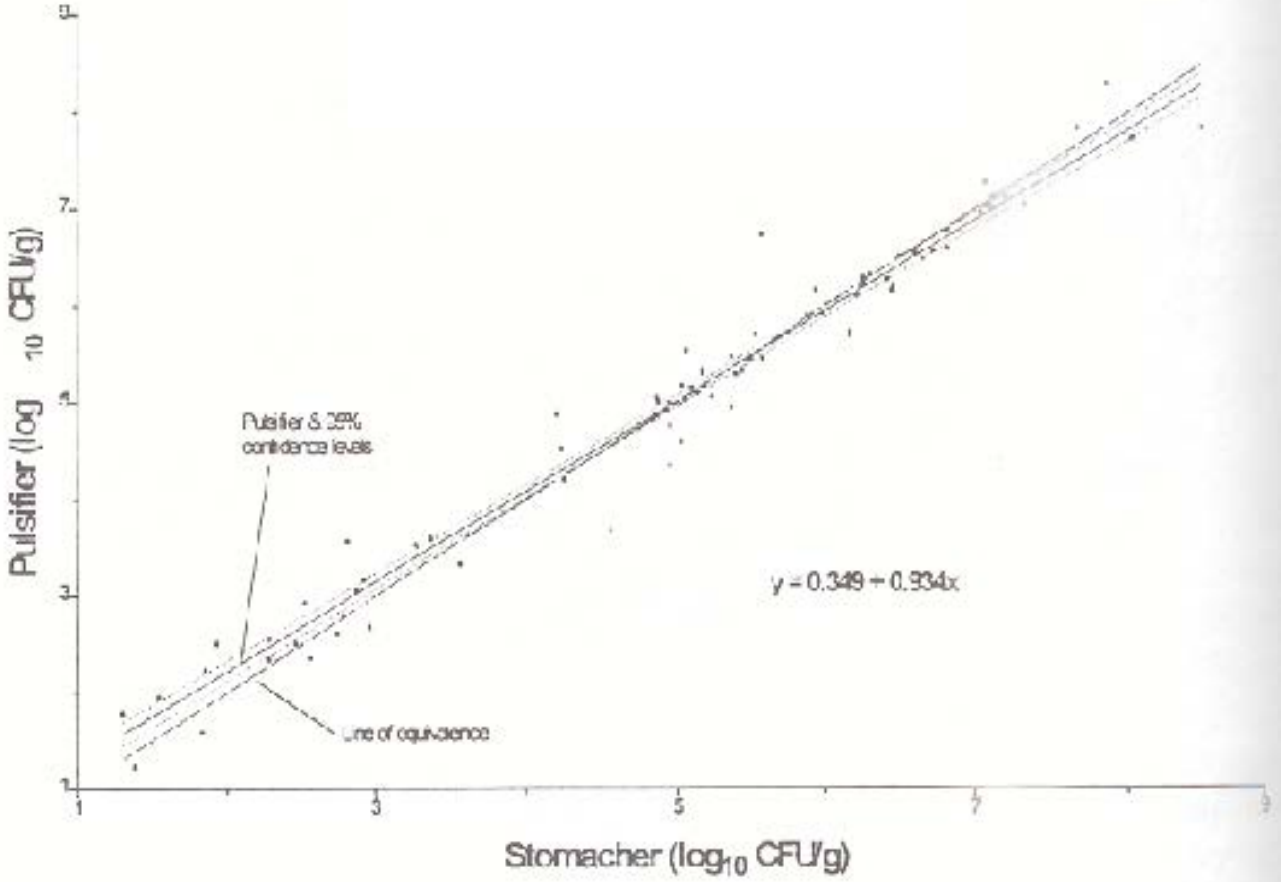


FIG. 2. REGRESSION LINE AND 95% CONFIDENCE LIMITS FOR TOTAL AEROBIC COUNTS BY PULSIFIER®, AND LINE OF EQUIVALENCE WITH A STOMACHER® 400

Smasher© by AES Chemunex



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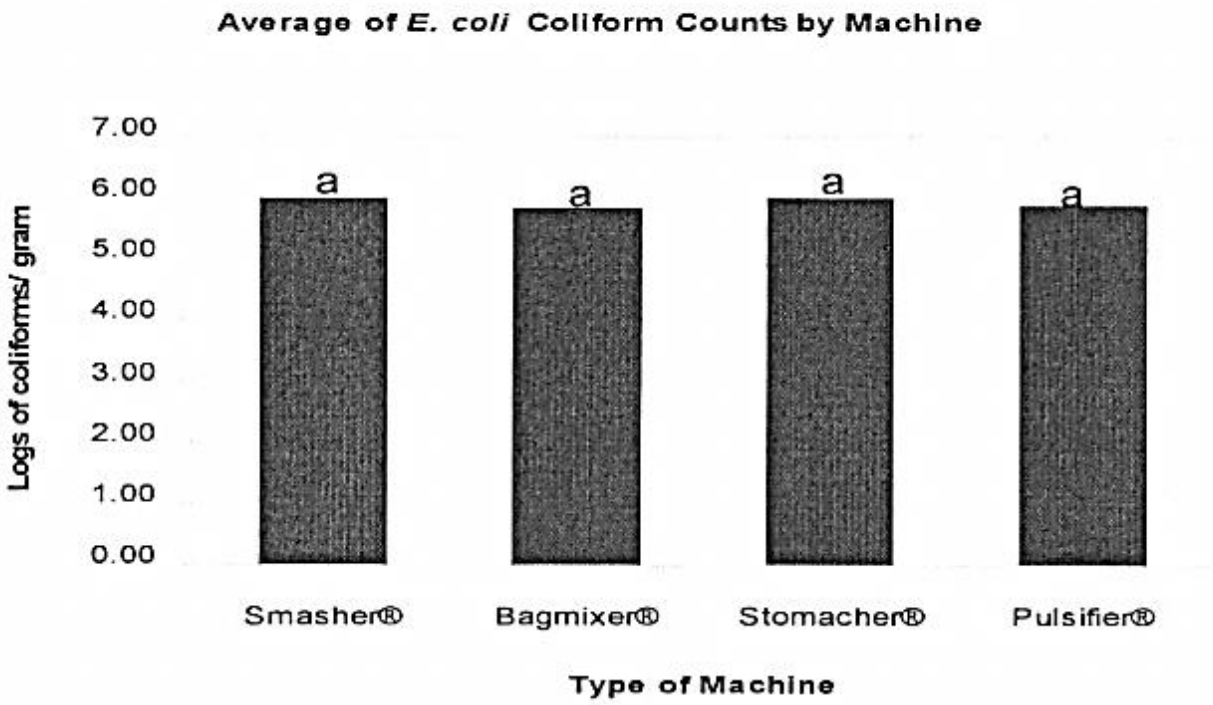
List of Abbreviations used:

Food	Abbreviation
Ground Beef	G. Beef
Hot Dogs	H. Dogs
Spinach Leaves	S. Leaves
Alfalfa Sprouts	A. Sprouts
Chicken Drum Sticks	C. Sticks
Chicken Wings	C. Wings
Fish Meat	F. Meat
Milk	Milk
Tofu	Tofu
Peanuts	Peanuts

All food samples were acquired at local grocery stores. The first experiment was the uninoculated control and had no inoculum added, afterwards Viable Cell Counts were evaluated with the help of an inoculum. The inoculum used was generic *E. coli* ATCC # 51813, incubated at 37°C for 24 hours in Tryptic Soy Broth (Becton, Dickinson, and Co., Sparks, MD).

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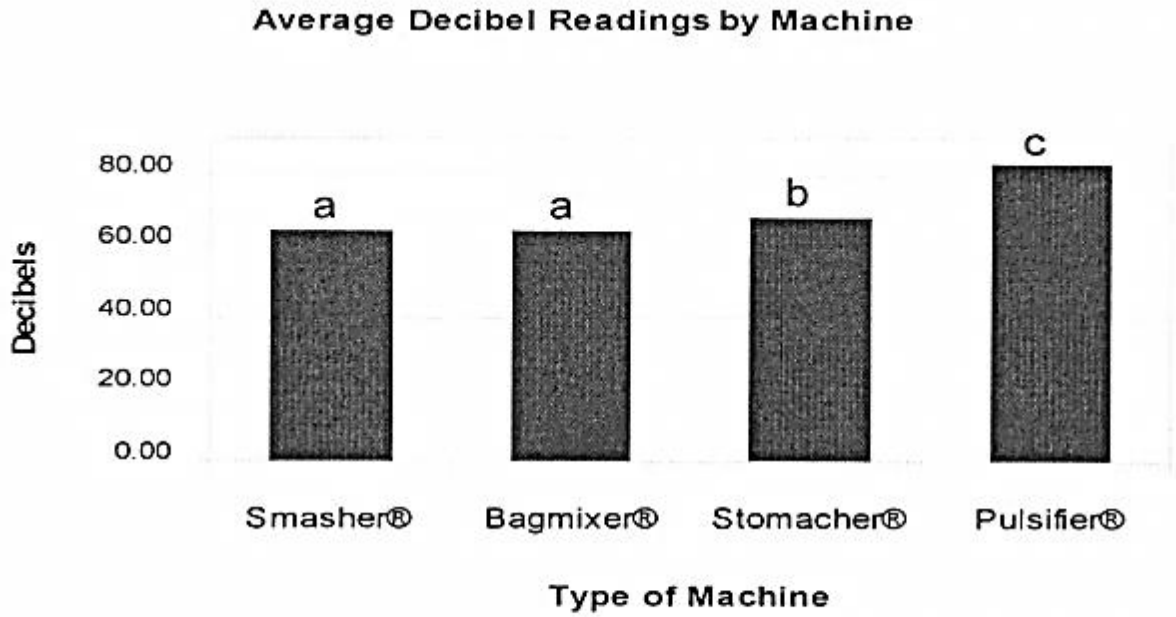
Average of 3 *E. coli* Coliform Counts datasets, measured as Logs of Coliform CFU/g of food sample of each instrument for: G. Beef, H. Dogs, S. Leaves, A. Sprouts, C. Sticks, C. Wings, F. Meat, Milk, Tofu, and Peanuts. N= 30 observations per machine



*Data series in bars with the same letter are not statistically different (P>0.05)

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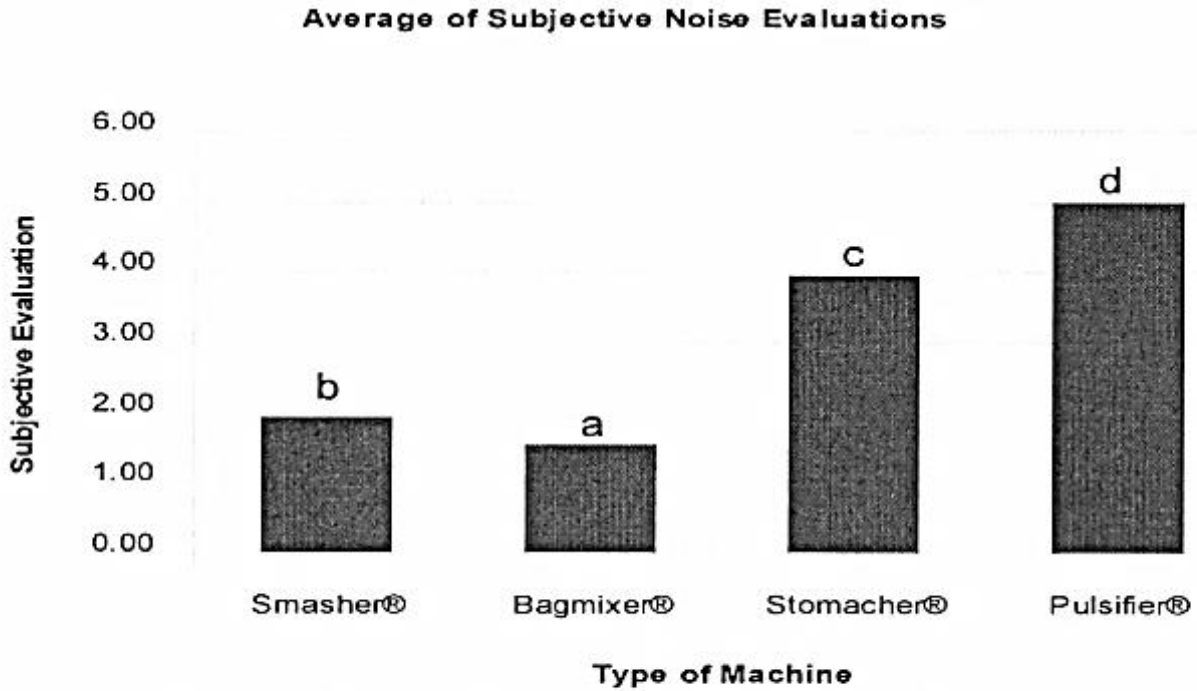
Average of 3 Decibel readings datasets measured by Decibel Meter (Music Flash Sound Level Meter M. 33-1028) located at five feet (1.52 meters) of each instrument. The data corresponds to the average Decibel readings of each instrument for the ten food samples: G. Beef, H. Dogs, S. Leaves, A. Sprouts, C. Sticks, C. Wings, F. Meat, Milk, Tofu, and Peanuts. N= 30 observations per machine



*Data series in the bars with same letters are not statistically different, while data series in bars with different letters are statistically different ($P<0.05$)

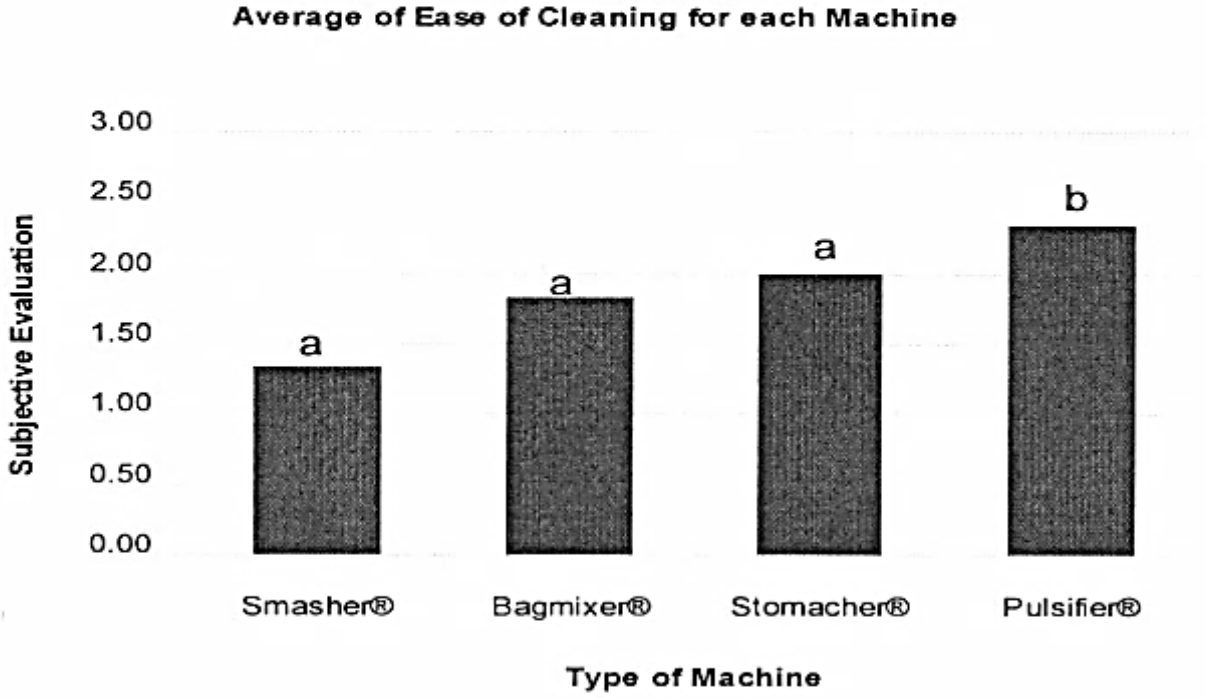
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Average of 3 Subjective Evaluations of Noise Levels datasets, measured by four laboratory personnel located at five feet (1.52 meters) of each instrument. The data corresponds to the average subjective evaluations of each instrument for the ten food samples: G. Beef, H. Dogs, S. Leaves, A. Sprouts, C. Sticks, C. Wings, F. Meat, Milk, Tofu, and Peanuts. N= 3 observations per machine.



*Data series in the bars with same letters are not statistically different, while data series in bars with different letters are statistically different ($P<0.05$)

Average of 3 Ease of Cleaning datasets, measured by four laboratory personnel of each instrument. The data corresponds to the average subjective evaluations of each instrument for the ten food samples: G. Beef, H. Dogs, S. Leaves, A. Sprouts, C. Sticks, C. Wings, F. Meat, Milk, Tofu, and Peanuts. N= 3 observations per machine.

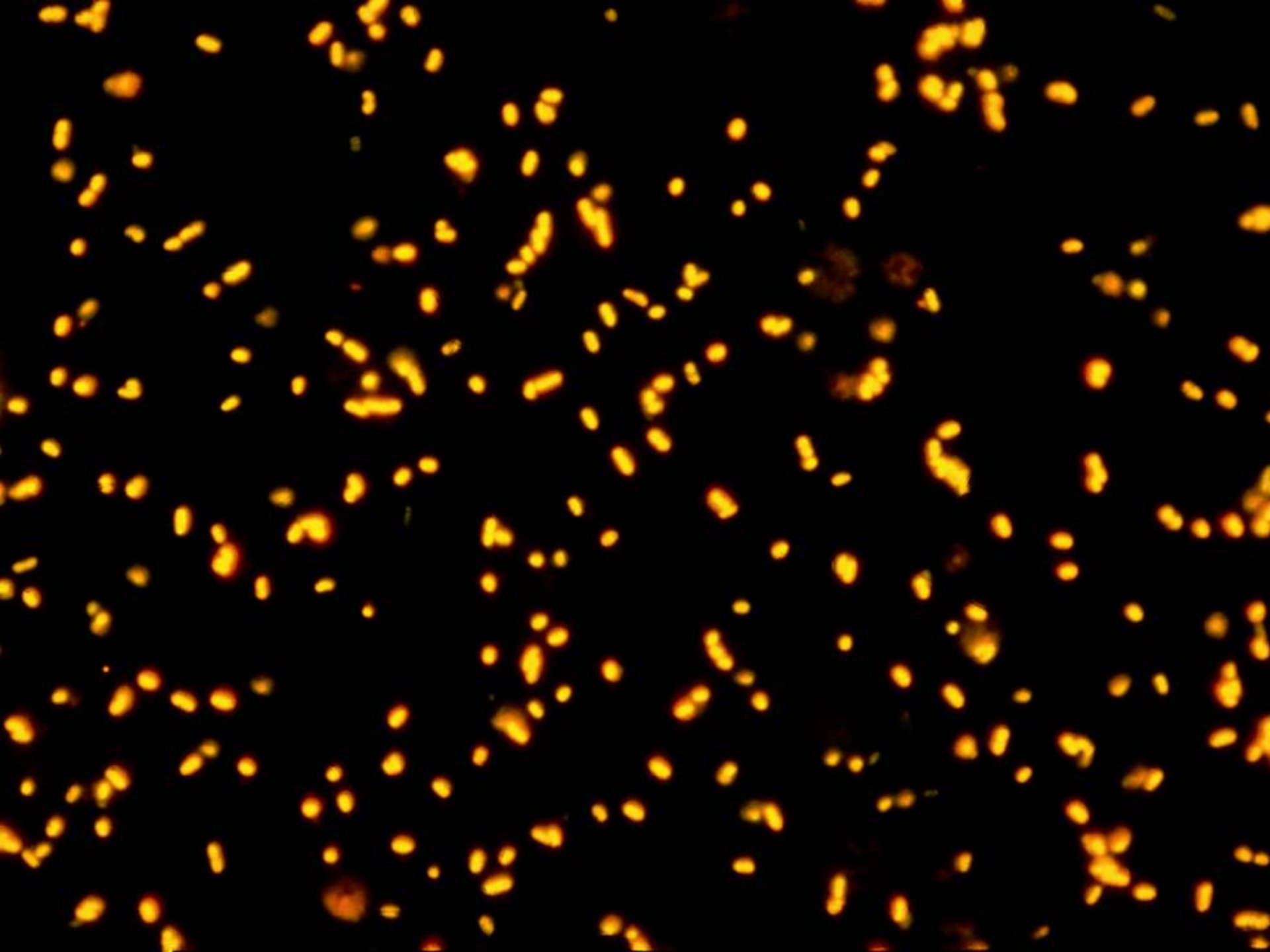


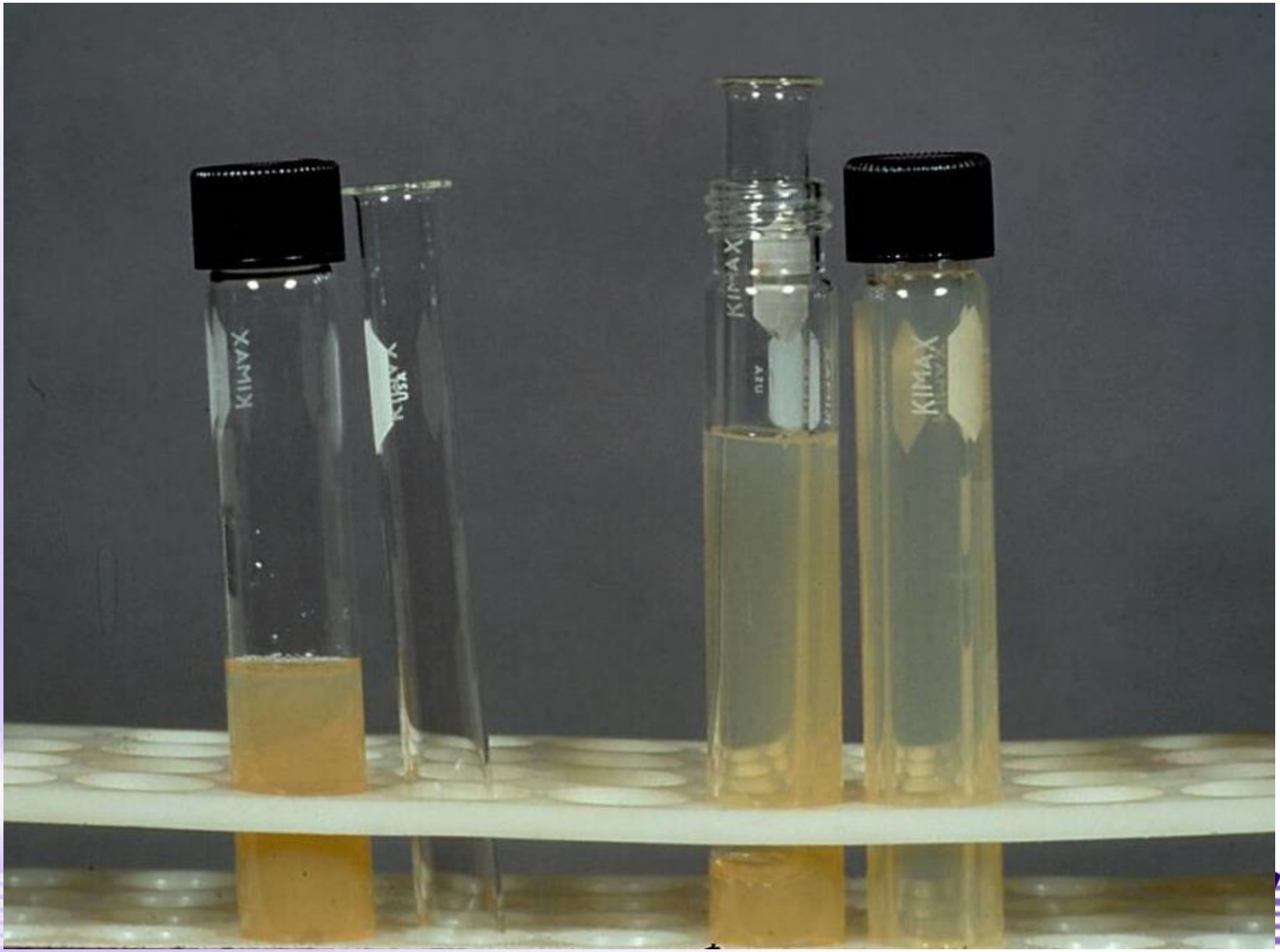
*Data series in the bars with same letters are not statistically different, while data series in bars with different letters are statistically different ($P<0.05$)

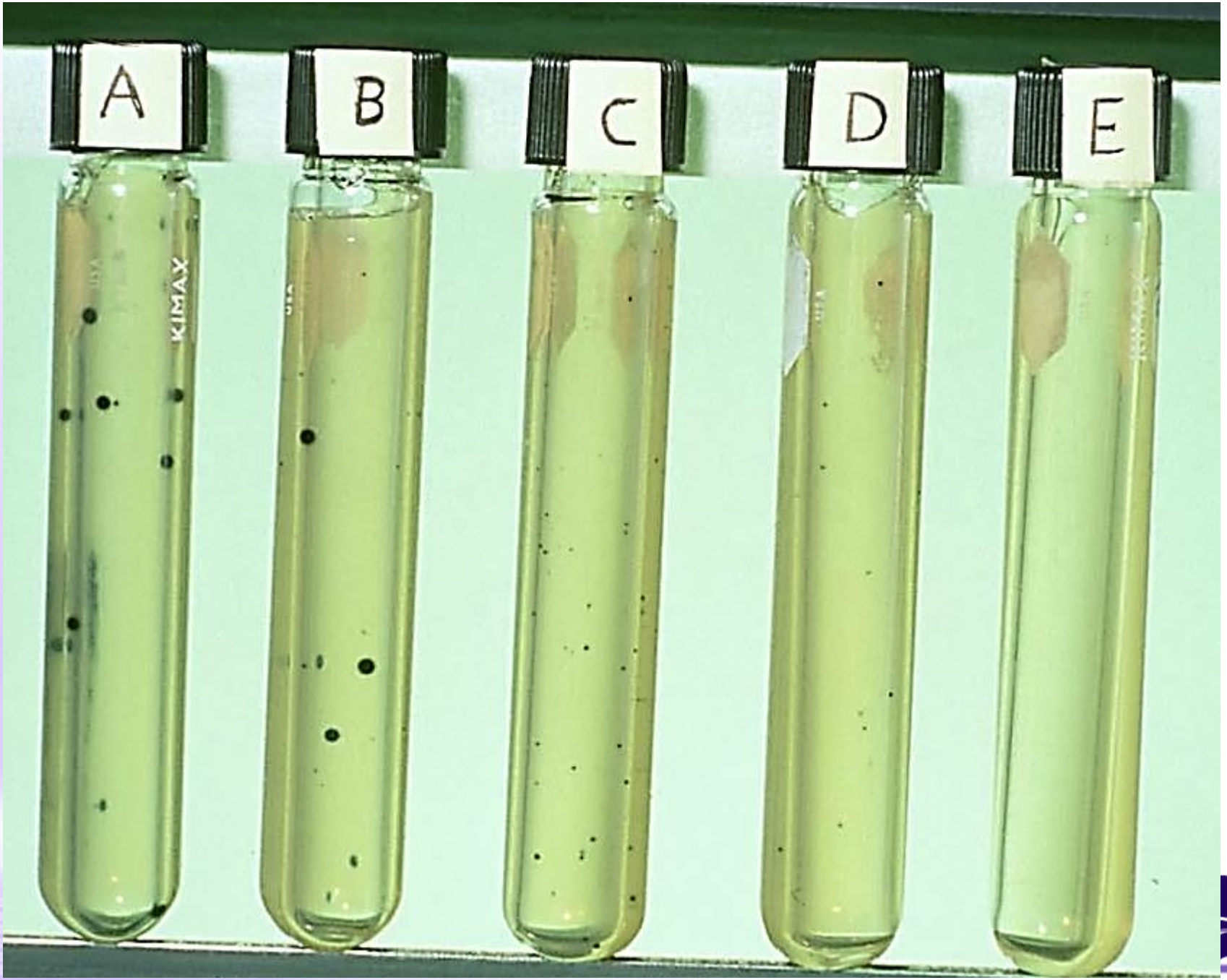
Comparative Analysis of Sampling Methods in Chicken Breast by Pearson Correlation Coefficient

	SPC	Redigel	Petrifilm	Spiral P.	Isogrid
SPC	1.00000	0.99855	0.99963	0.97017	0.96992
Redigel	0.99855	1.00000	0.99916	0.96917	0.96875
Petrifilm	0.99963	0.99916	1.00000	0.97089	0.97056
Spiral P.	0.97017	0.96917	0.97089	1.00000	0.99988
Isogrid	0.96992	0.96875	0.97056	0.99988	1.00000

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A
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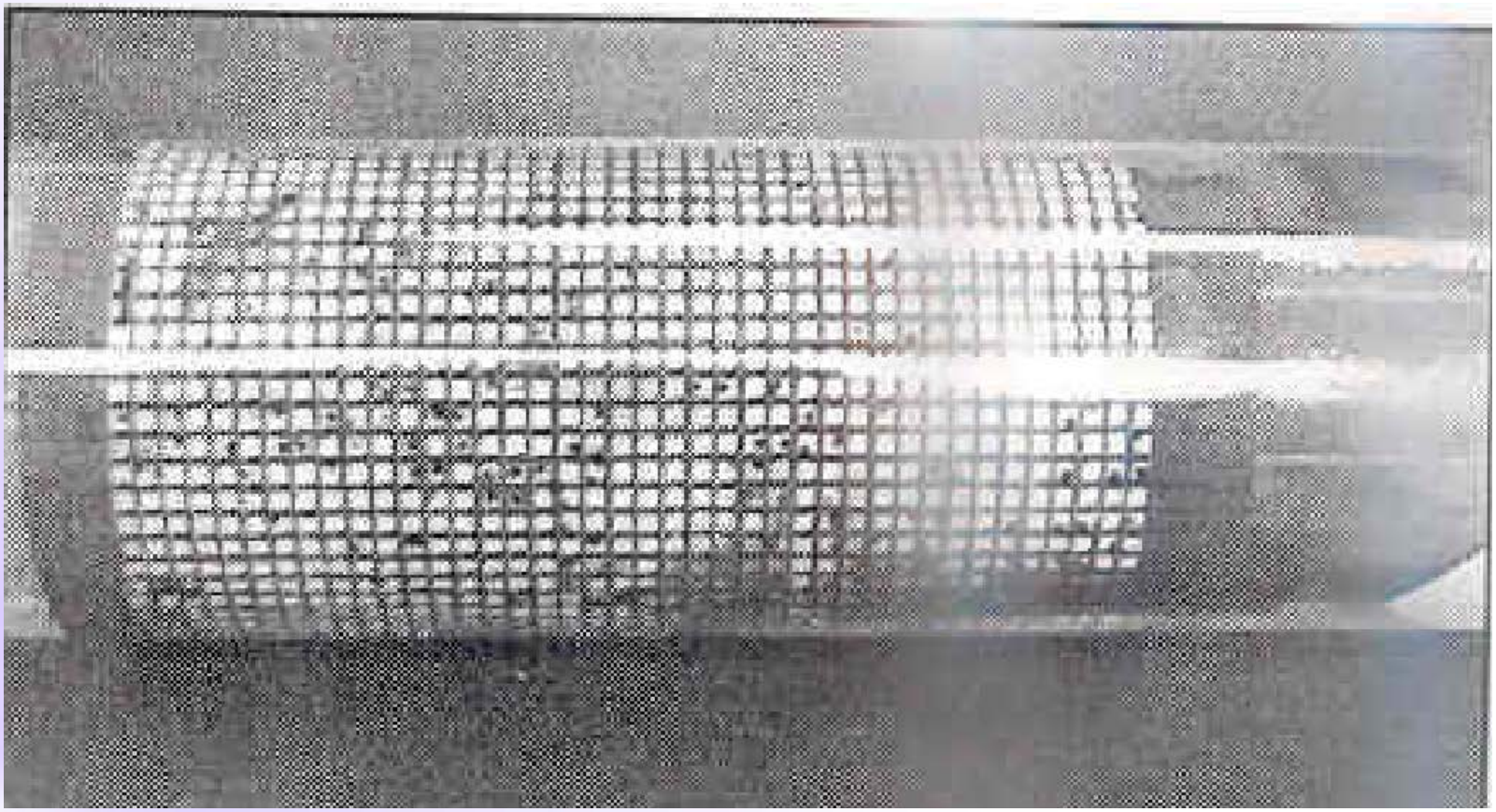
Fung/Fujioka Scale for Beach Water Pollution Based on Single Sample Concentrations (cfu/100 mL) of *Clostridium perfringens* Using the Fung Double Tube (FDT) Method

Pollution category	FDT (cfu/10 mL)*	Extrapolated FDT (cfu/100 mL)	Scale of beach pollution
I	0	<10 cfu	Uncontaminated
II	1-10 cfu	10-100 cfu	Nonpoint contamination
III	11-50 cfu	110-500 cfu	Sewage contamination
IV	>50 cfu	>500 cfu	Elevated sewage contamination

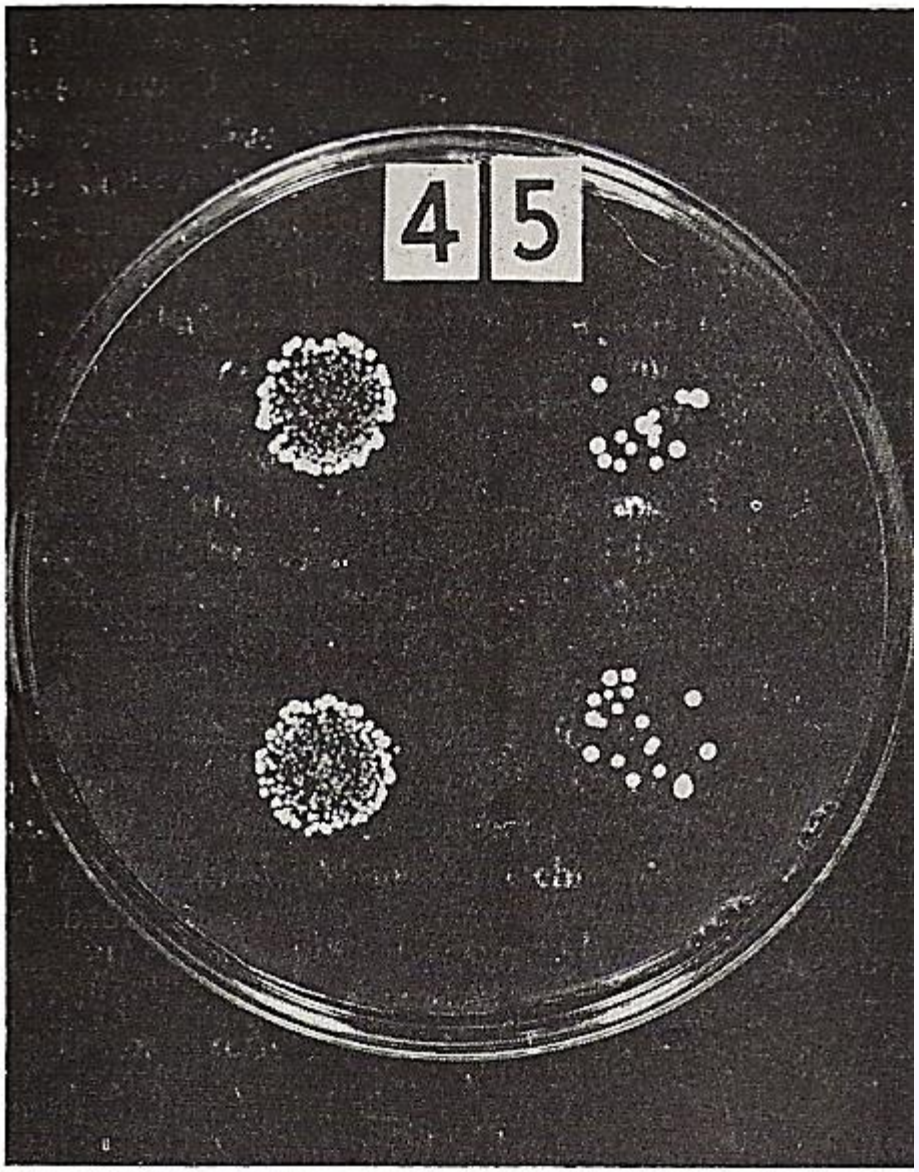
* After confirmation with conventional method.
cfu, colony forming units in Shahidi Ferguson Perfringens agar medium at 42C in 6 h.

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Isogrid

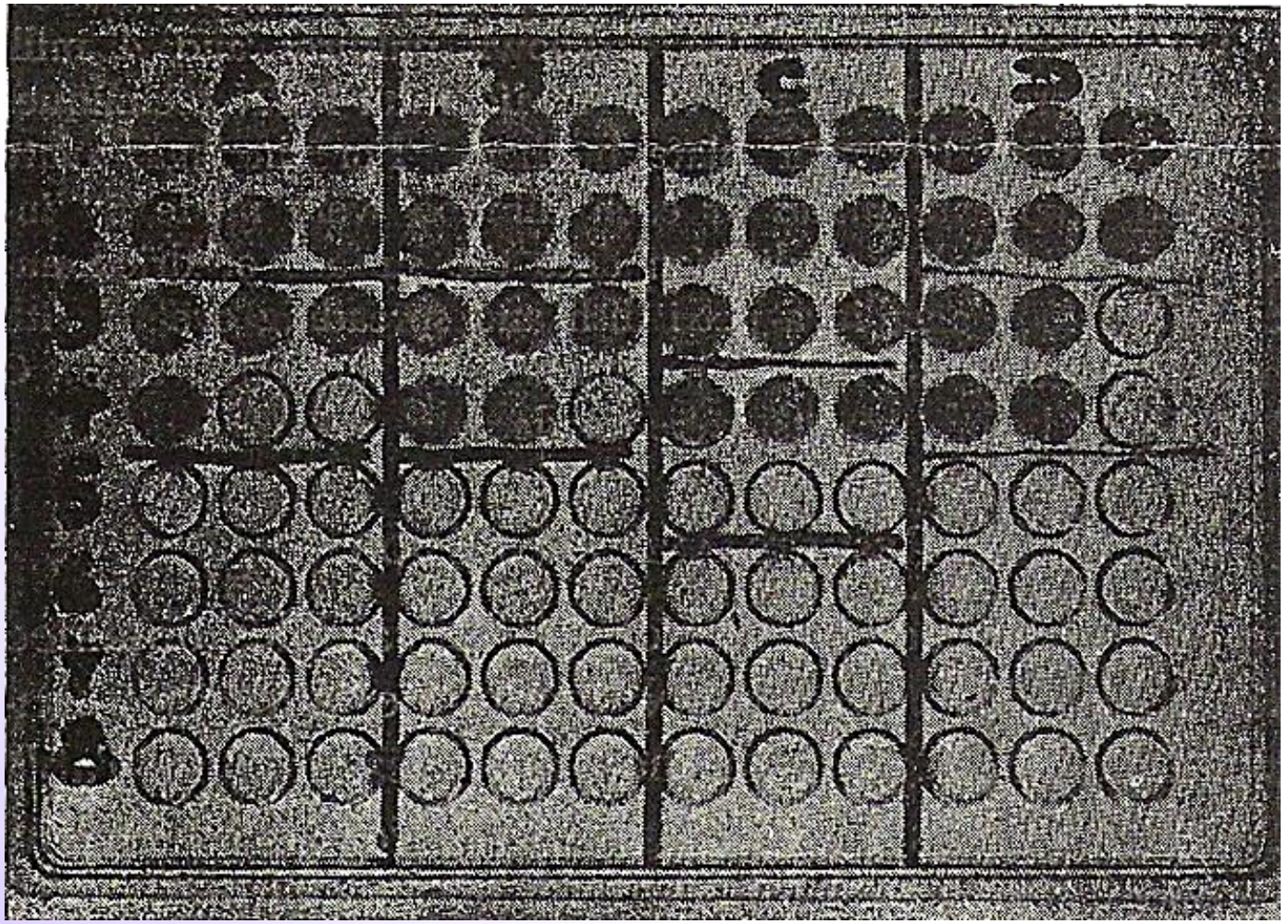


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Duplicate spots of different dilutions from a milk sample. The numbers 4 and 5 represent 10^{-4} and 10^{-5} dilutions, respectively. Data obtained from the 10^{-4} dilution were used to calculate cell density.

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Microtiter plate – MPN evaluation. Turbidity of the wells indicates growth. MPN of sample A is obtained by multiplying 45 (from table 1; 3+/3, 1+/3) x 4 x 10^{4-2} or 1.8x10^{4} organisms/mL.

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TEMPO® EC
LOT 0810110
2008-10-11
2004081011100000091780
2°C
25°C
bioMérieux® SA
1258714

tempo™

The TEMPO® solution

Two ergonomic work stations:

A preparation station which comprises:

- computer with a waterproof mini-keyboard, barcode scanner and a WIFI card
- intuitive preparation software
- 144 tests capacity media stand
- 4 dispensers for media rehydratation
- TEMPO® Filler instrument for inoculating and sealing the cards
- 4 filling trays
- 12 incubation/reading trays



Relayed through a wireless WIFI connection, the two stations communicate in real time, although they are not in the same room.

A reading station which comprises:

- computer with a barcode scanner and a mouse
- intuitive software for reading and managing results
- administration software for managing the configuration
- TEMPO® Reader instrument for reading the cards
- wireless WIFI transmission router printer
- bidirectional connection with the lab computer (optional)



BIOMÉRIEUX INDUSTRY

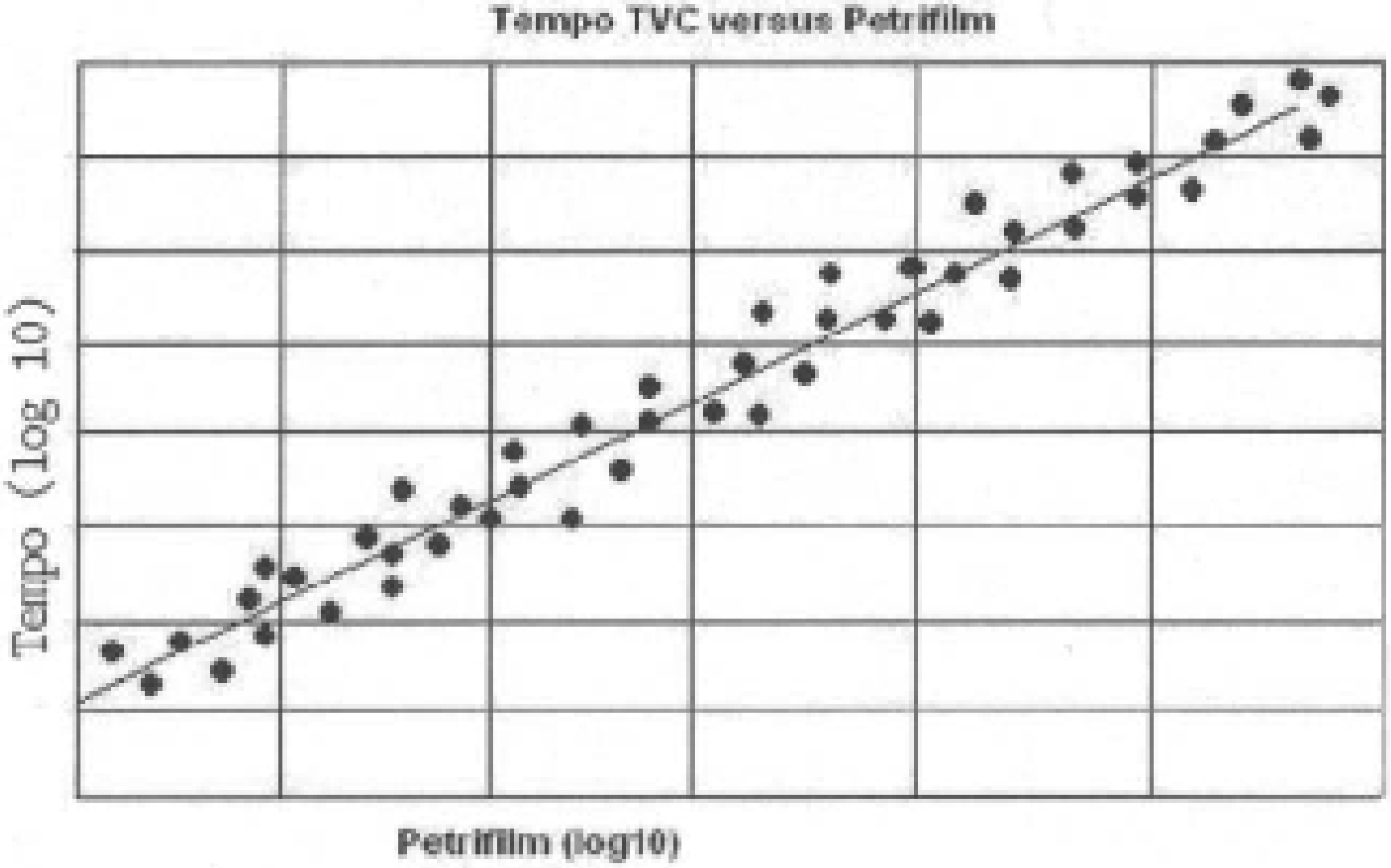
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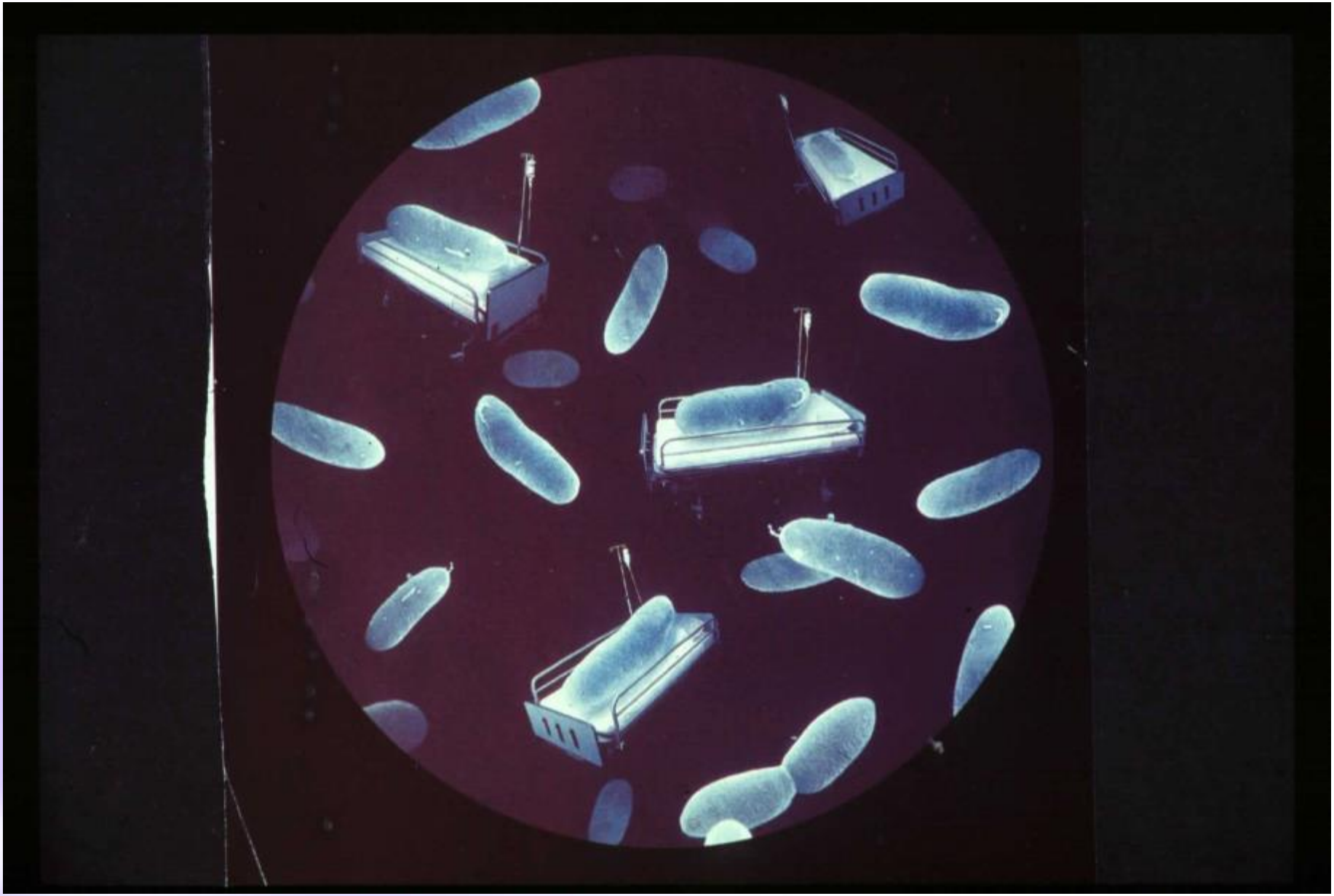
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Tempo TVC versus Petrifilm
Tempo (log 10)
Petrifilm (log10)

Kang and Fung

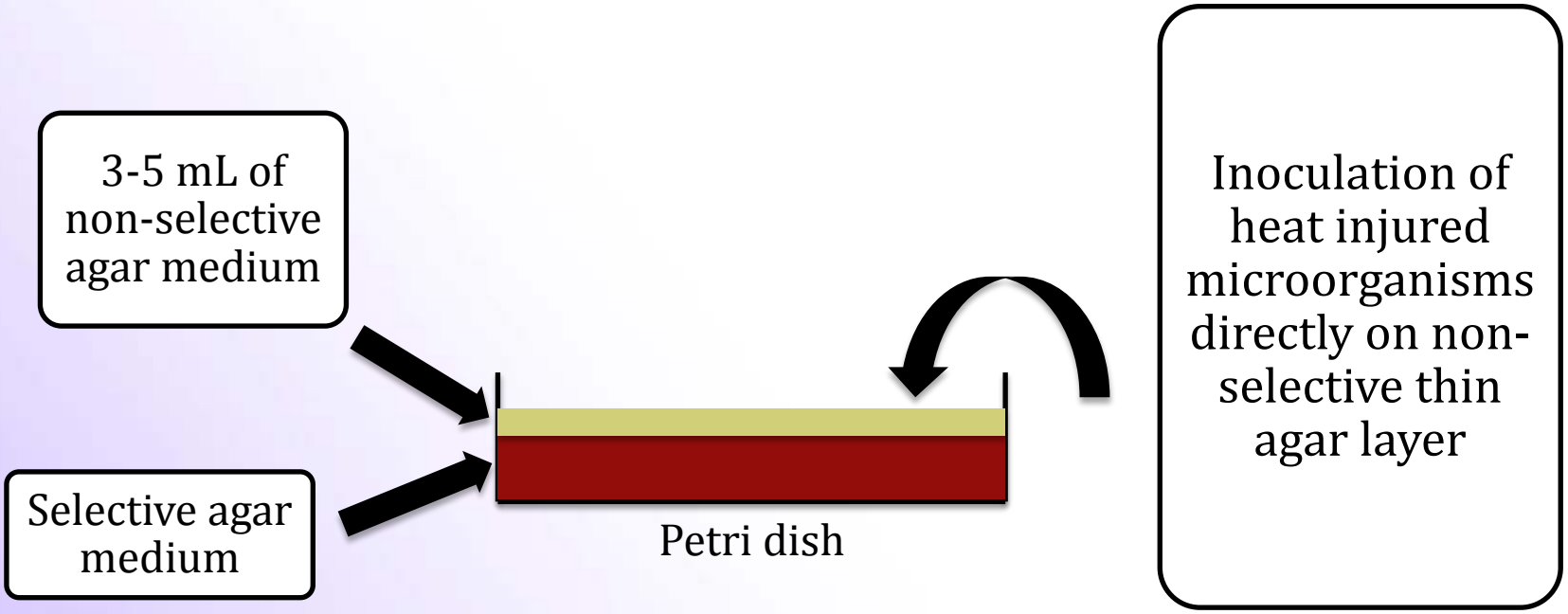
- Thin agar layer method for the recovery of injured cells in foods and environments

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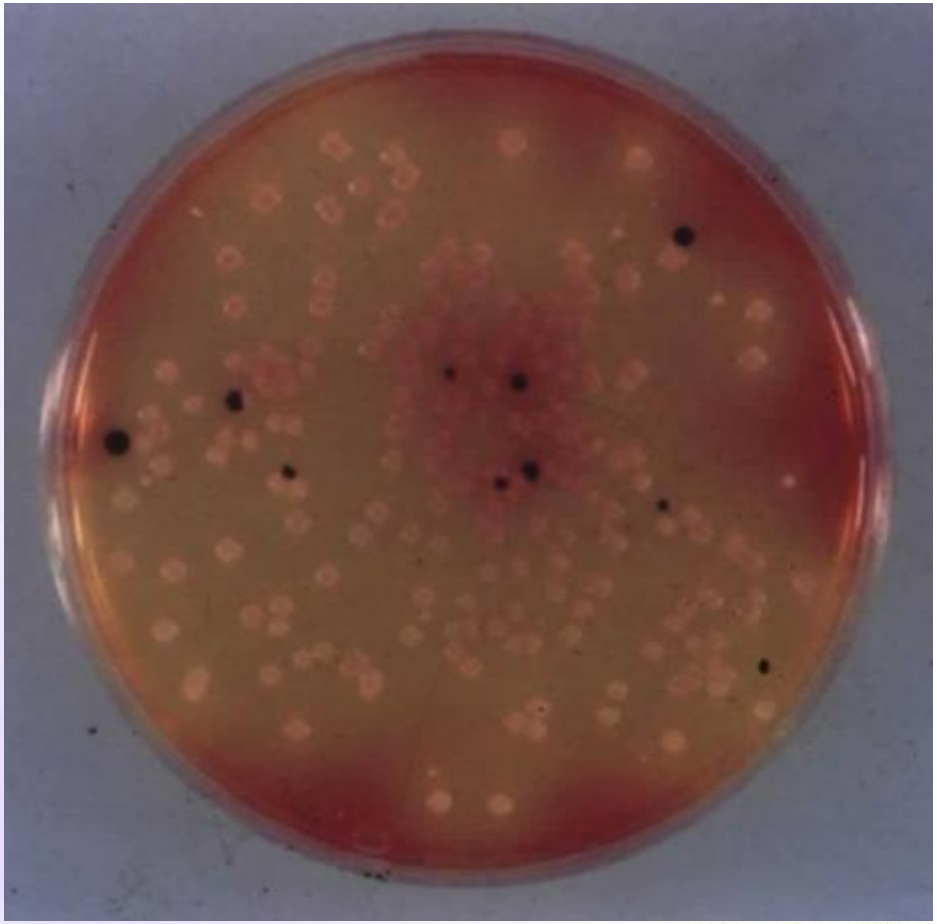
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One-Step Thin Agar Layer Method

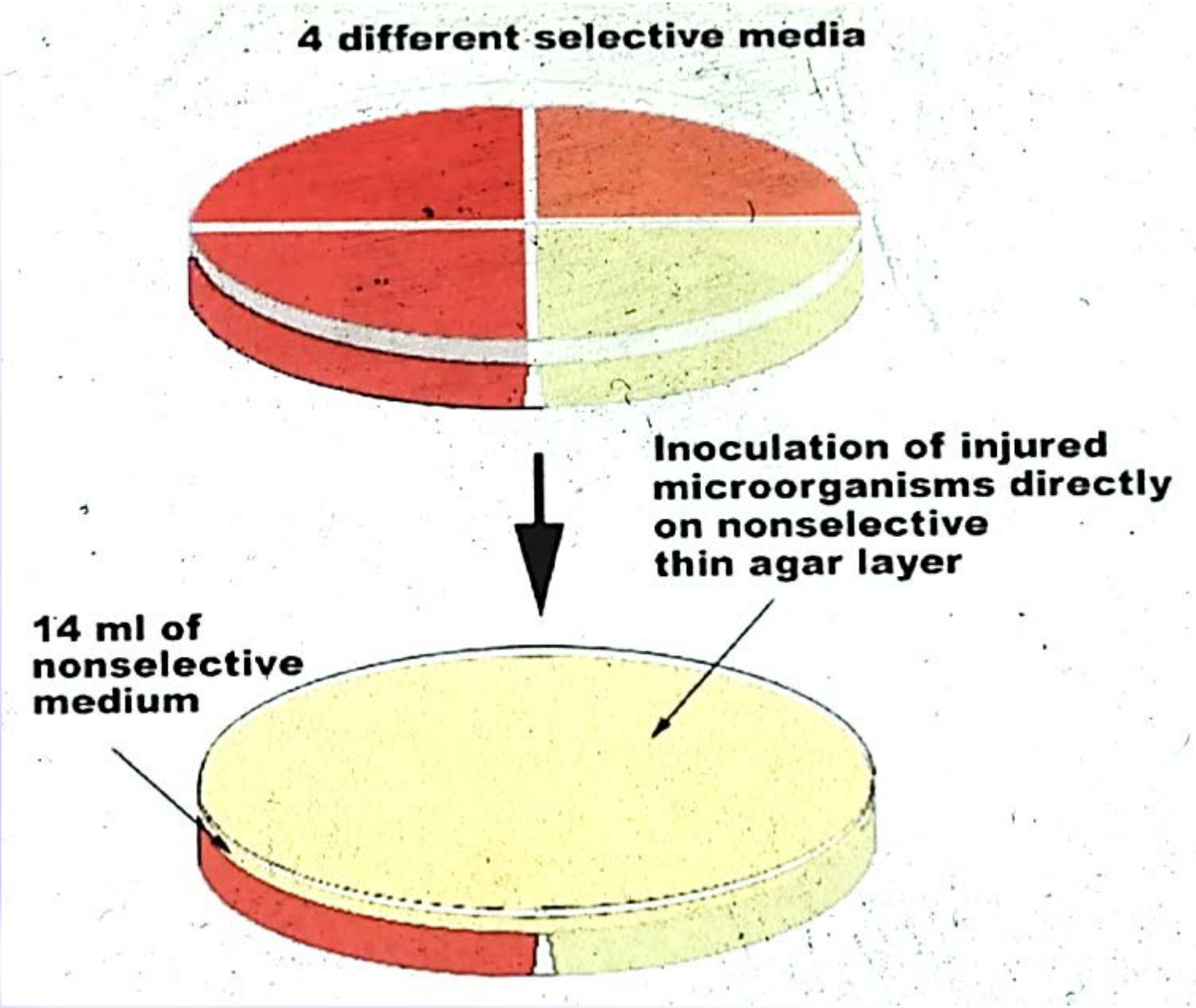


Injured cells recovered and migrated to selective agar and grew in selective agar

Salmonella typhimurium in Mixed Culture Using TAL



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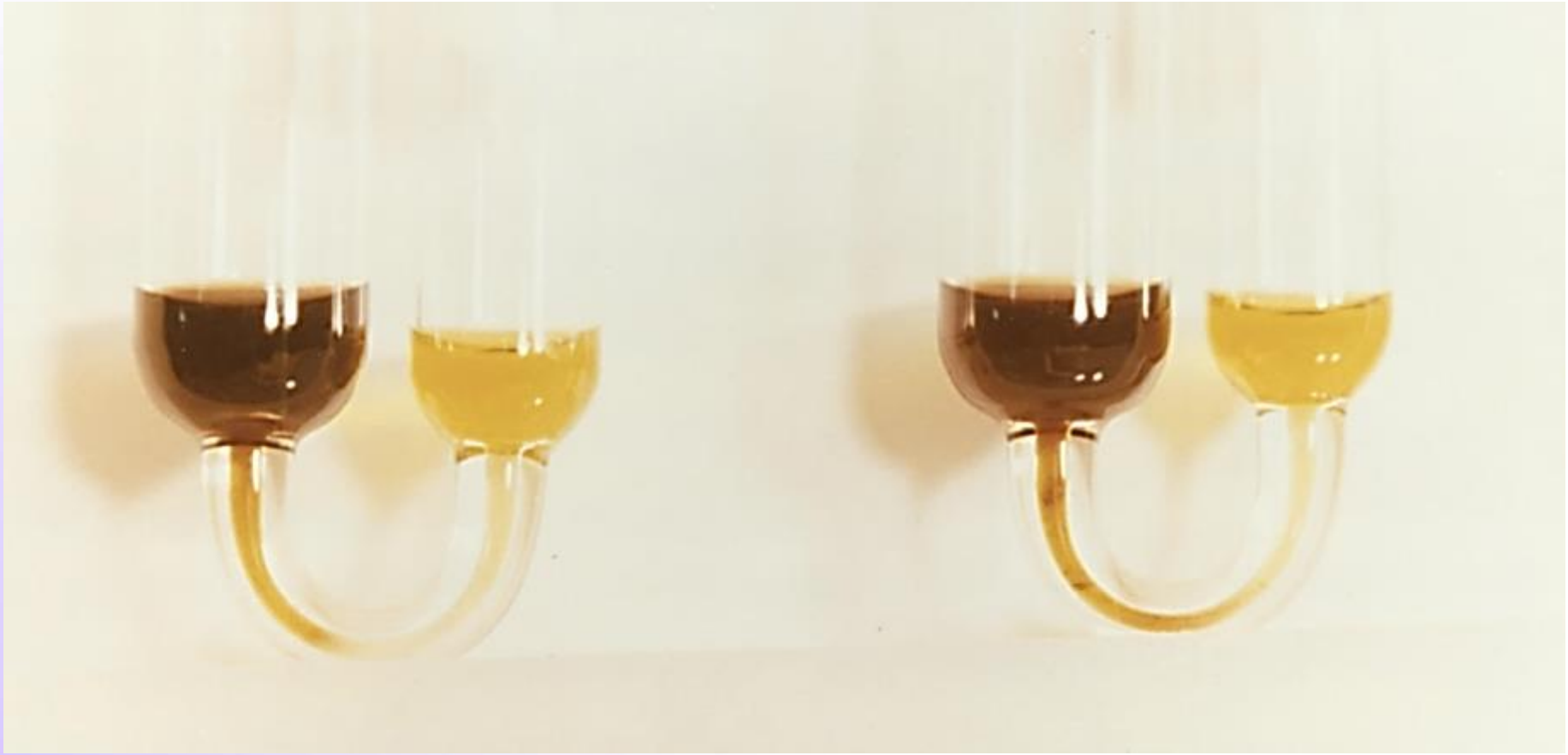


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Oxyrase Research at Kansas State University



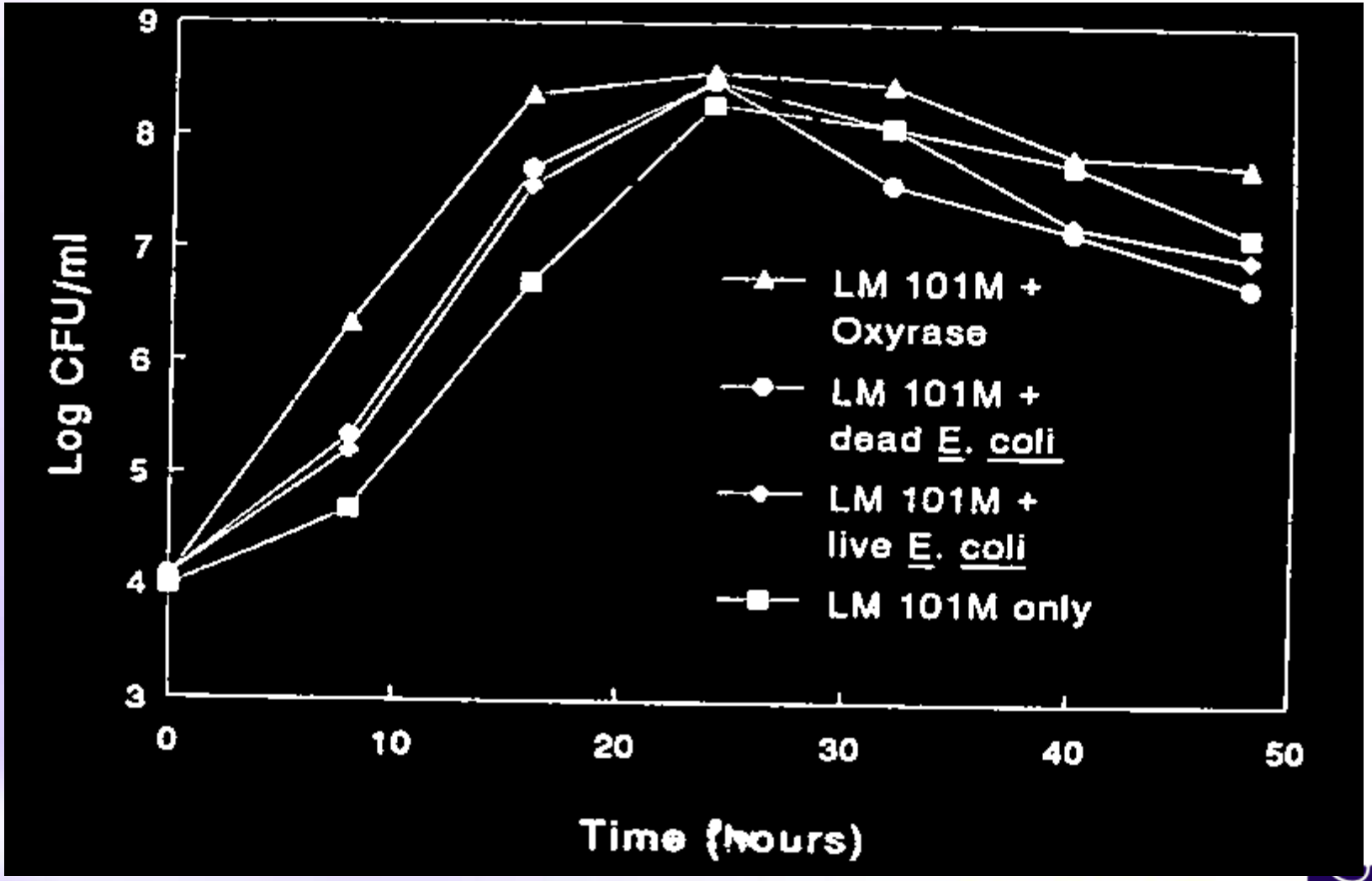




The semisolid agar started to change the color in the left and changed color at mid-point of the column in the right.

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Growth of *L. monocytogenes* LM 101M in the Presence of *E. Coli* or Oxyrase™ in Fraser broth at 35° C

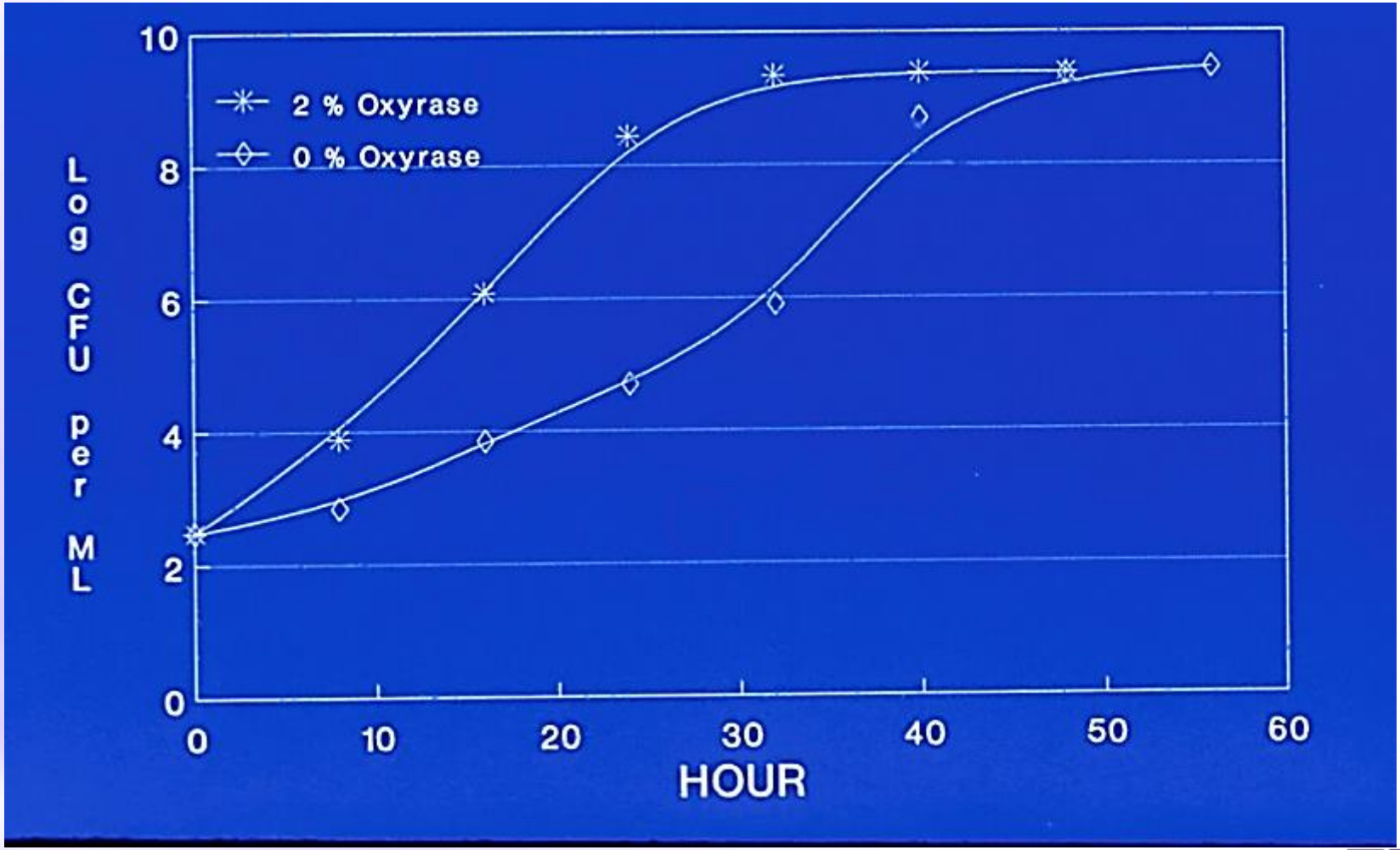


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SIGMA
Isotemp

Campylobacter coli 43474 –

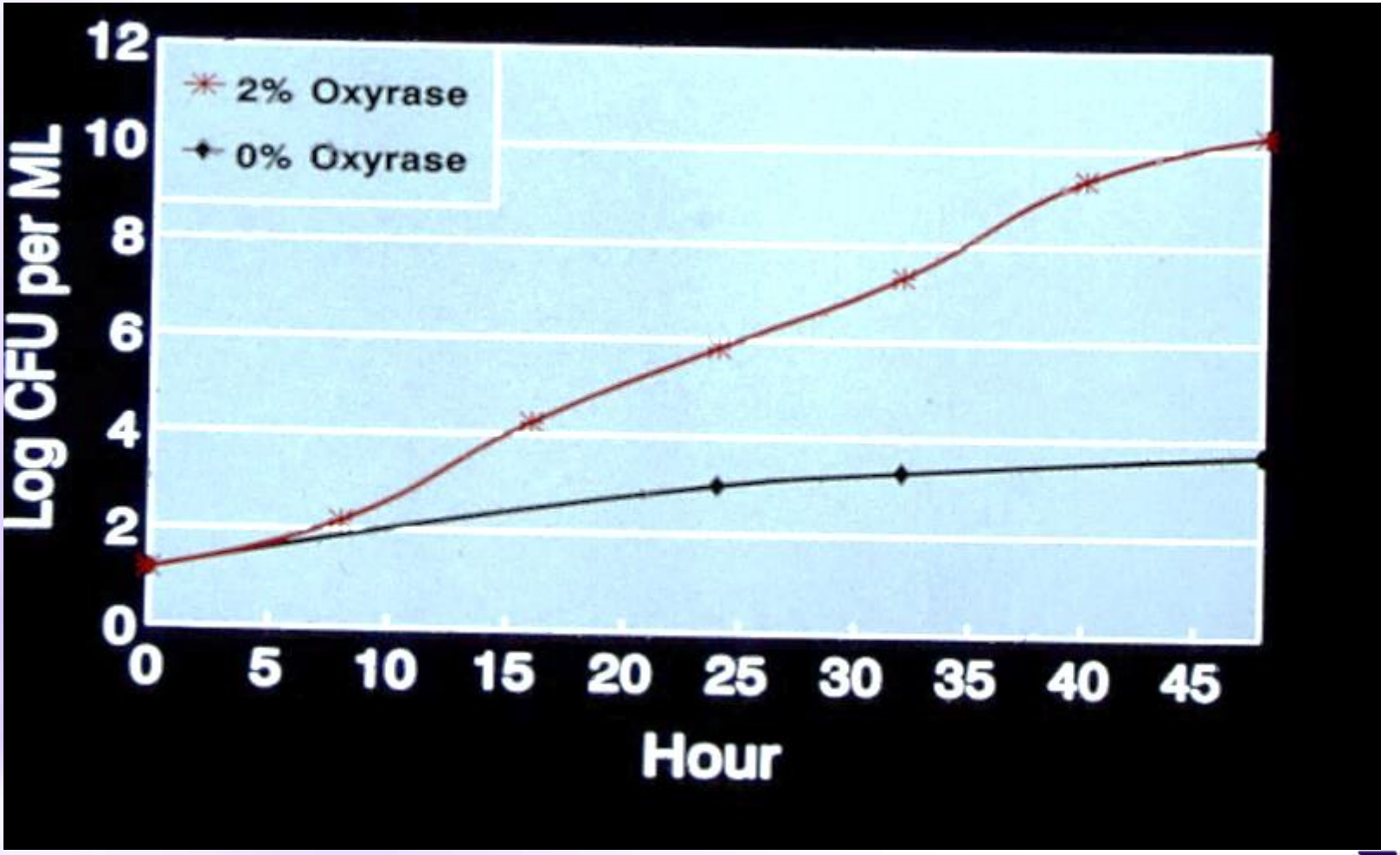
42°C with 2 and 0% Oxyrase



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Campylobacter jejuni 43429 –

42°C with 2 and 0% Oxyrase



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Application of Membrane Fractions in Food Safety

Test organisms:

- *Listeria monocytogenes,*
- *Salmonella typhimurium,*
- *Yersinia enterocolitica,*
- *Escherichia coli O157:H7,*
- *Clostridium perfringens.*

Tested by the OmniSpec™ Bioactivity method:

- *Campylobacter jejuni,*
- *Campylobacter coli.*

Tested using the methods described by Niroomand and Fung (1992 a,b, 1993)

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Membrane Bound Enzymes

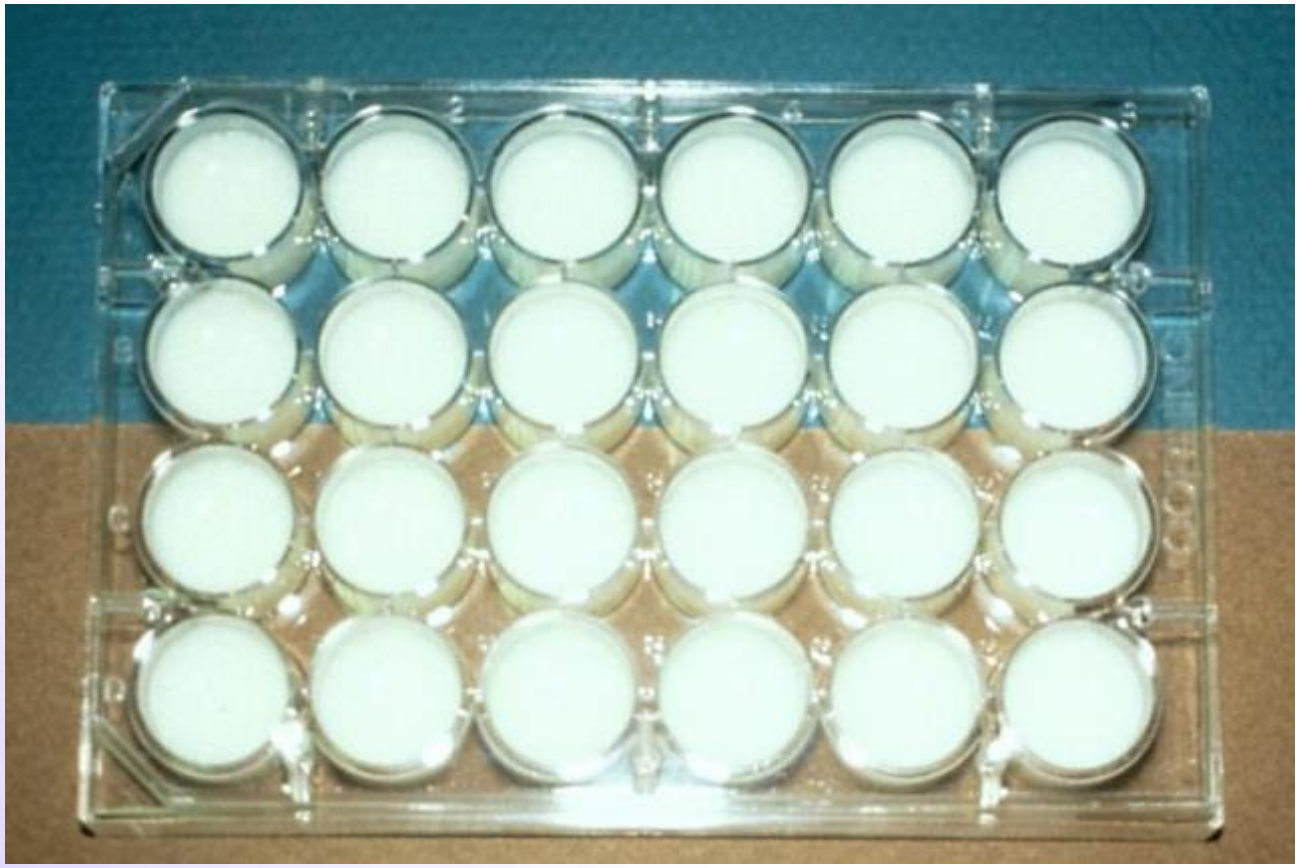
- Non-food grade
  - Oxyrase – Commercial (*Escherichia coli*)
  - E-8 – *E. Coli* E-8
- Food grade
  - ACE – *Acetobacter xylinum*
  - GLU – *Gluconobacter oxydans*

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Food Fermentation Considerations

- All membrane fractions stimulated starter culture activities
  - *Streptococcus thermophilus*
  - *Lactobacillus bulgaricus*
  - *Lactobacillus lactis*
  - *Lactobacillus cremoris*
  - *Lactobacillus plantarum*
  - *Lactobacillus acidophilus*
  - *Pediococcus acidilactici*
  - *Propionibacterium acidipropionici*
  - *Saccharomyces cerevisiae*

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Yogurt and Buttermilk fermentation

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Summer sausage

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Results (Oxyrase & Membrane Fractions)

- All membrane fractions accelerated the following fermentation processes:
  - Yogurt
  - Buttermilk
  - Wine
  - Beer
  - Bread
  - Summer sausage

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Instantaneous Results – Seconds

- Catalase and enzyme tests
- Food residual tests
- Biosensor

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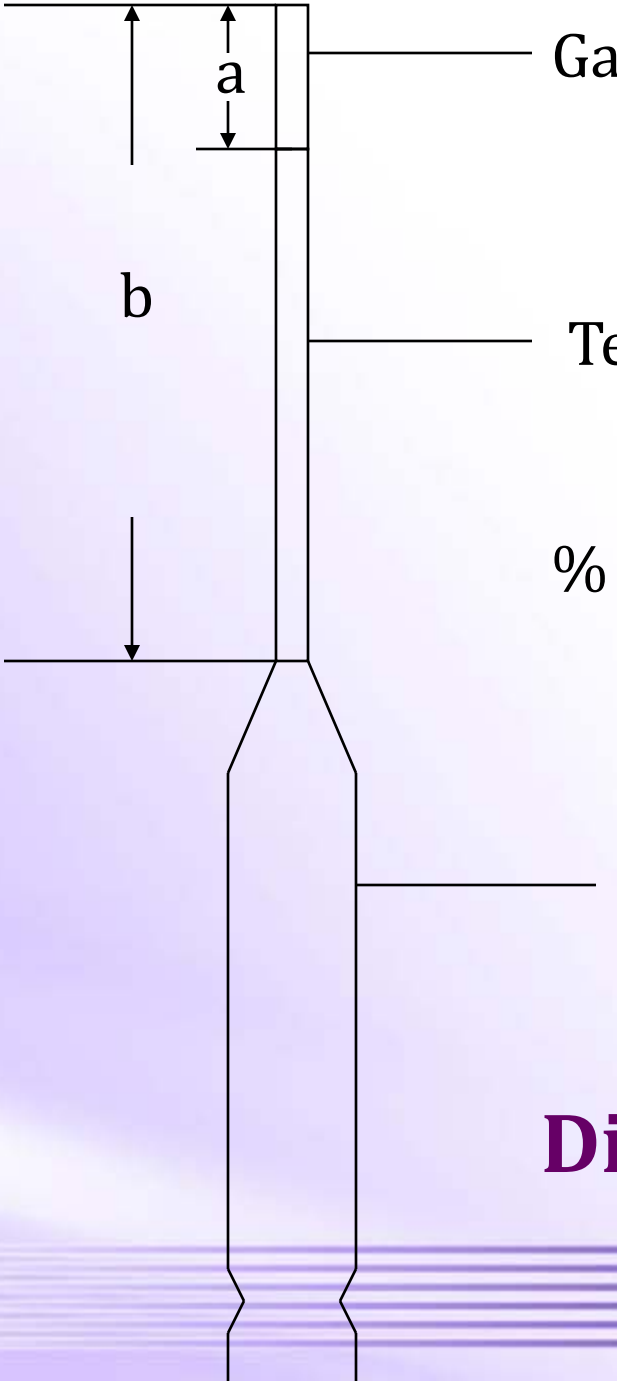
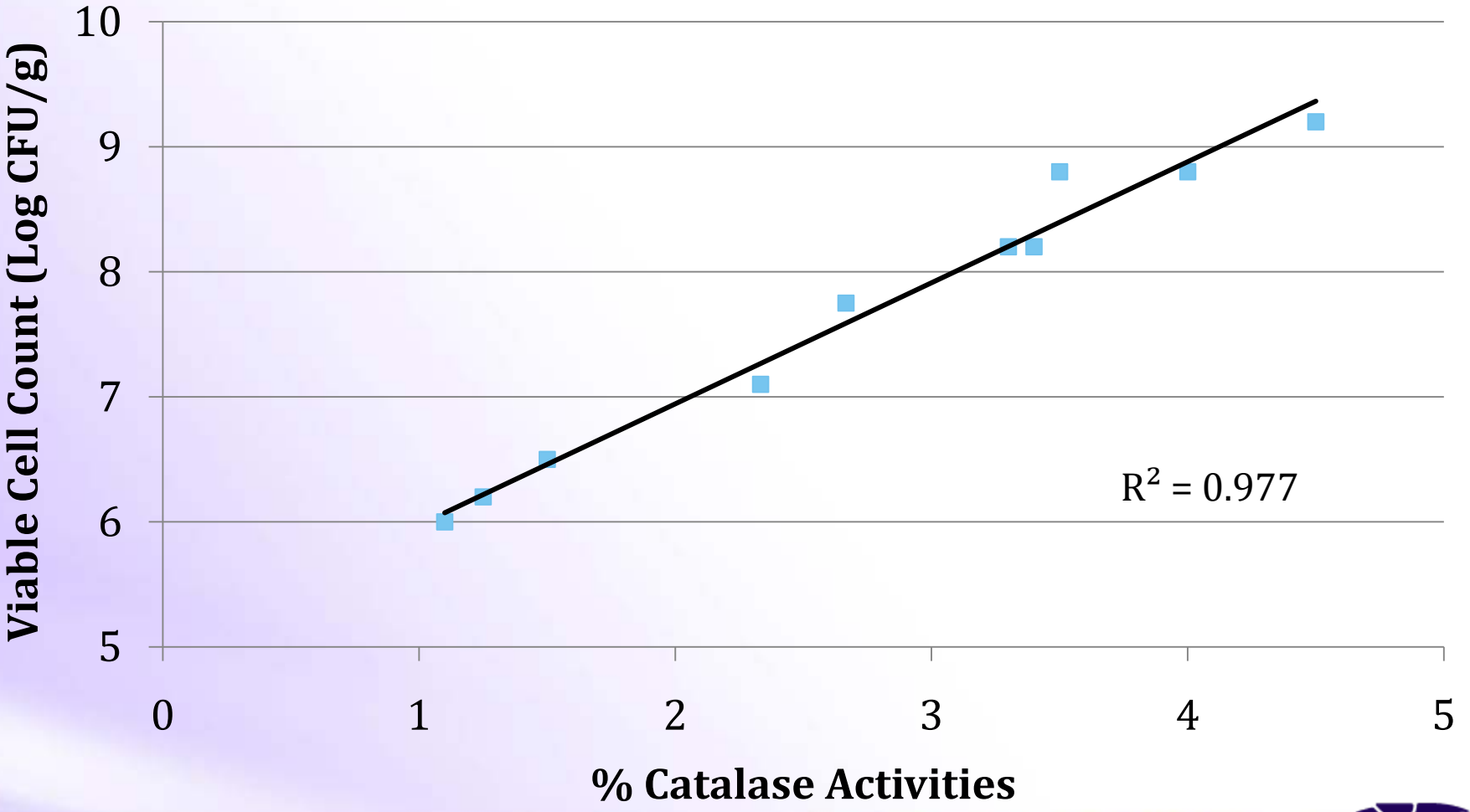


Diagram of Gas Column Method

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The Percentage of Catalase Activities and Viable Cell Count in Rainbow Trout "Meat" During 7 Days at 7°C



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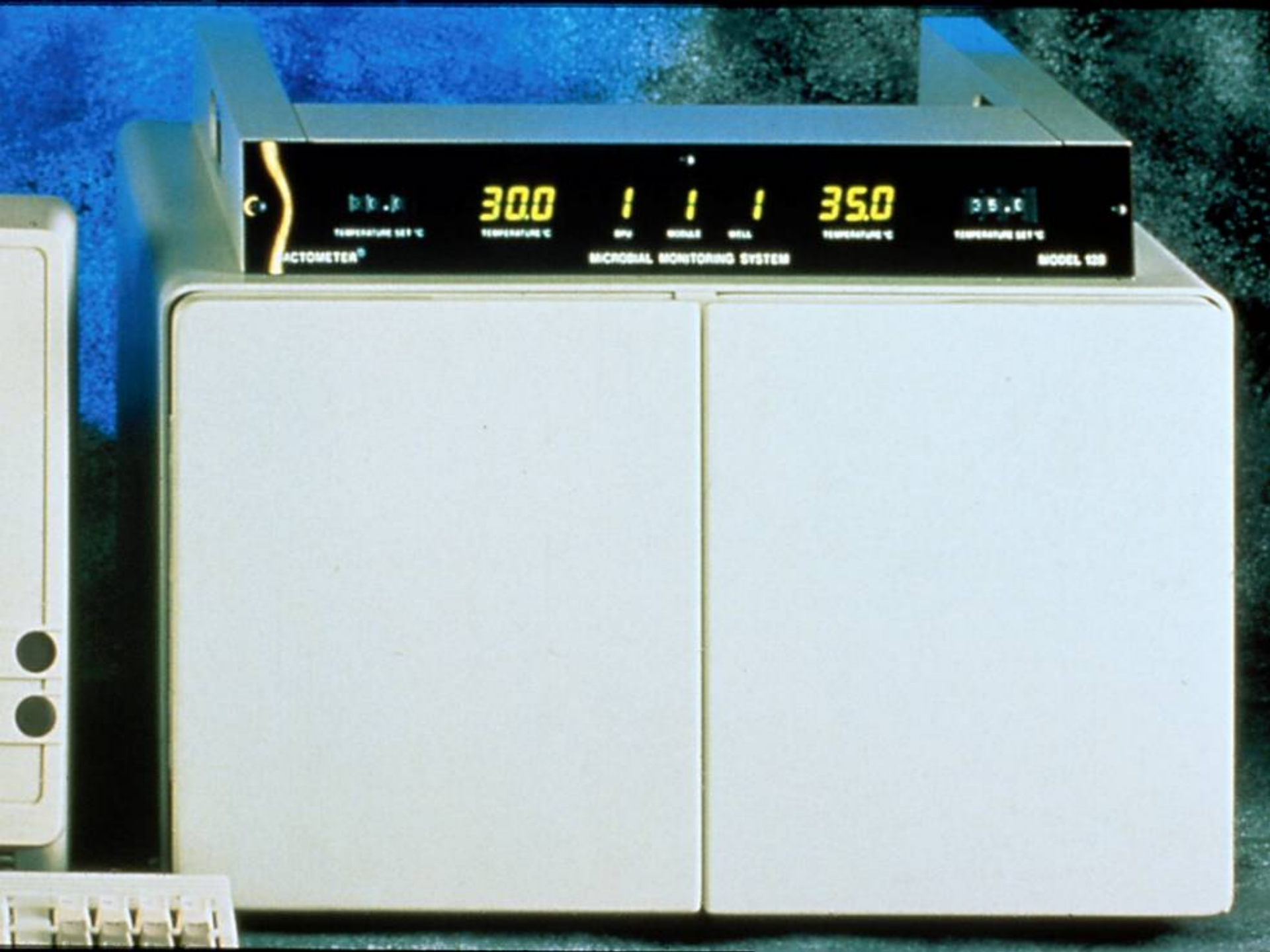
Semi-Quantitative Evaluation of Protein Residues



Automated Instruments Can Monitor Microbial Activities with Ease

- Conductance-Malthus
- Impedance-Bactometer, RABIT
- Bac T/Alert
- Omnispec
- BioSys

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30.0
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1
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35.0
MICROBIAL MONITORING SYSTEM

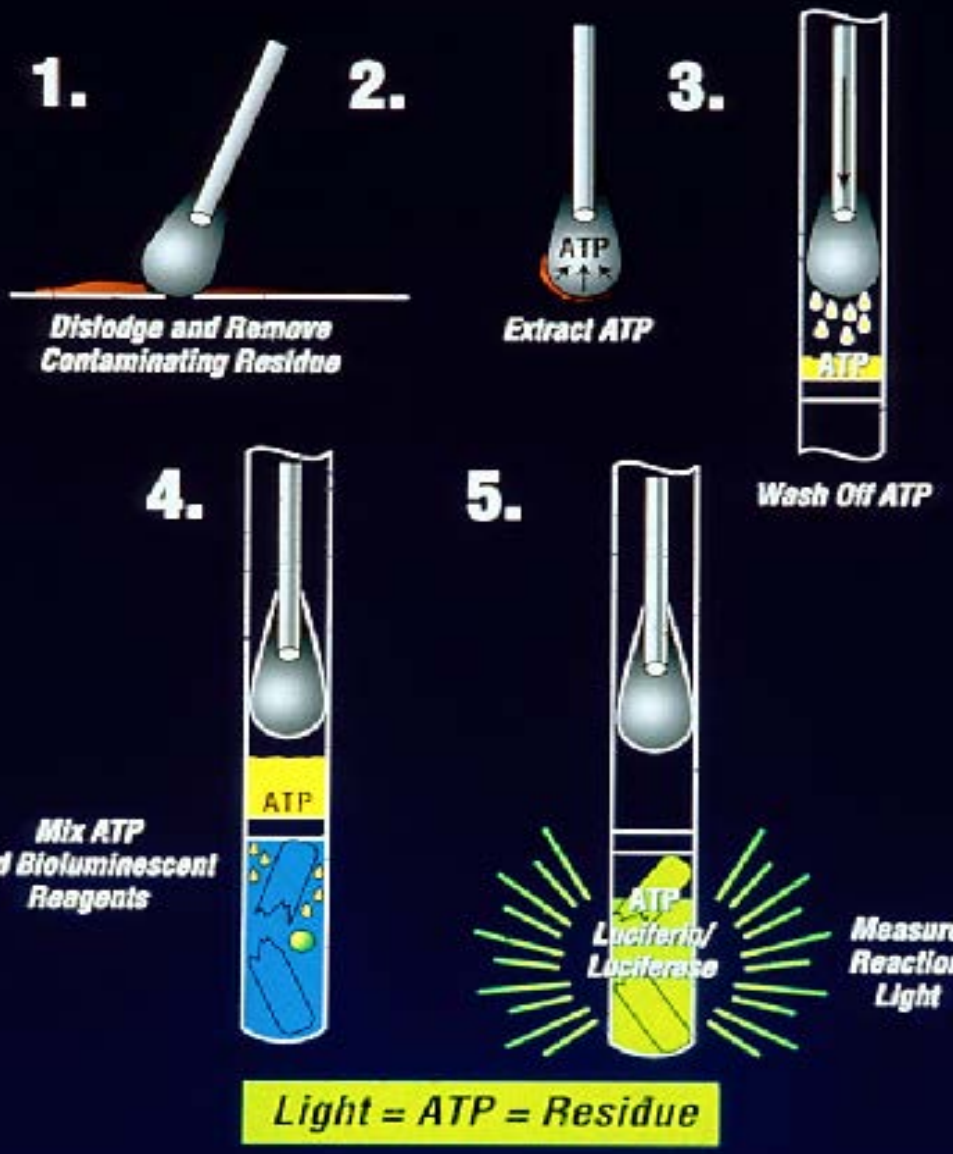
Bioluminescence

- A unique type of chemiluminescent reaction catalyzed by an enzyme.



LIGHTNING™

Swab Device Function



Light = ATP = Residue

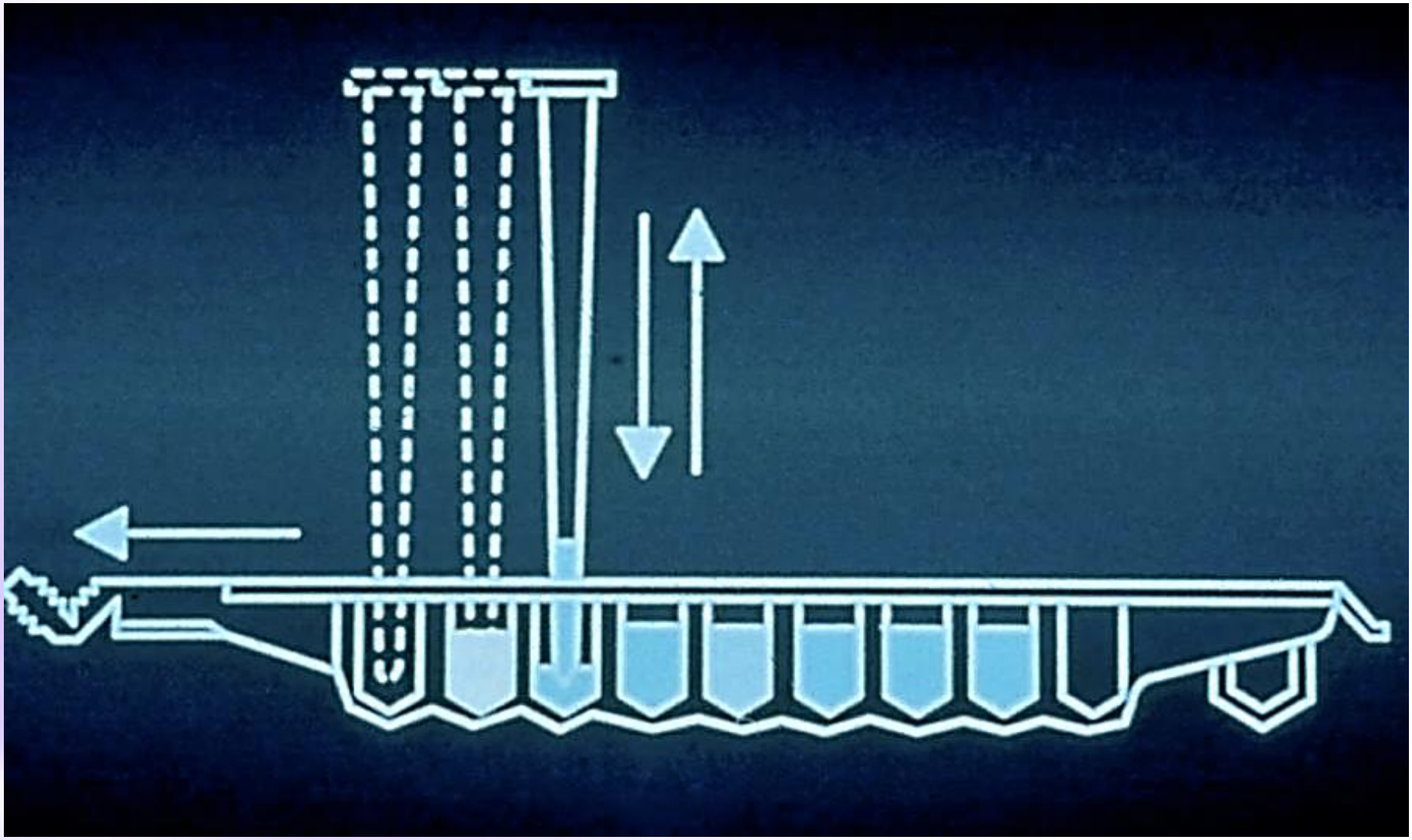
Advances in Immunological Testing

- ELISA tests, VIDAS
- Diffchamb, Detex system
- Lateral Migration immunoassays
- Immunomagnetic separation technologies

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bioMérieux VIDAS®





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isteria AFNOR APPROVED



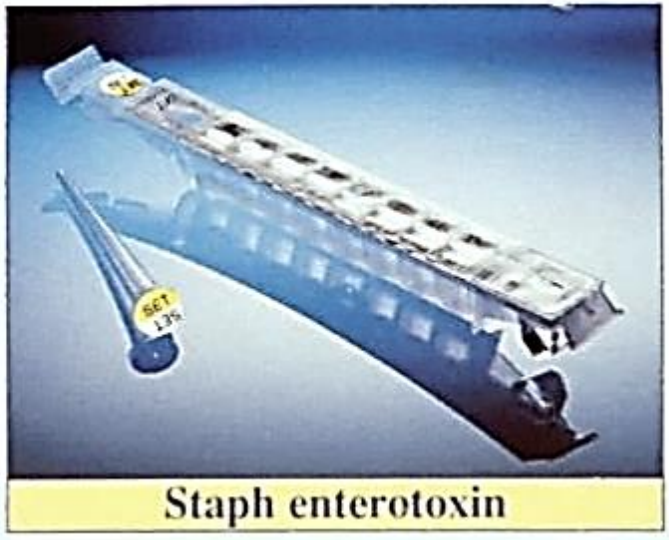
Listeria monocytogenes



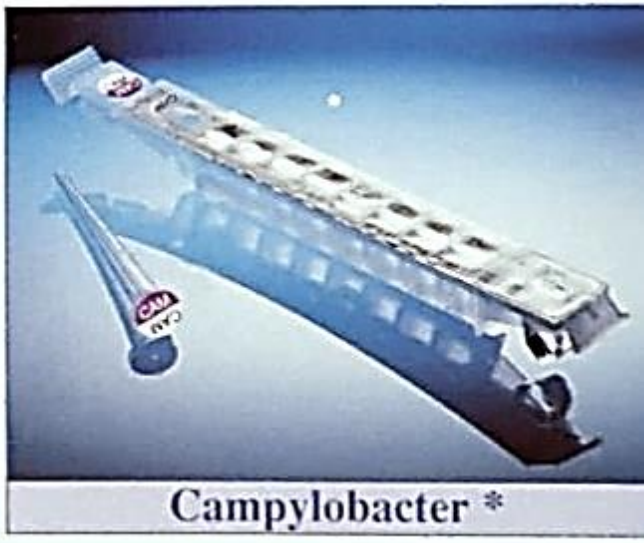
Salmonella AFNOR APPROVED



E. coli O157

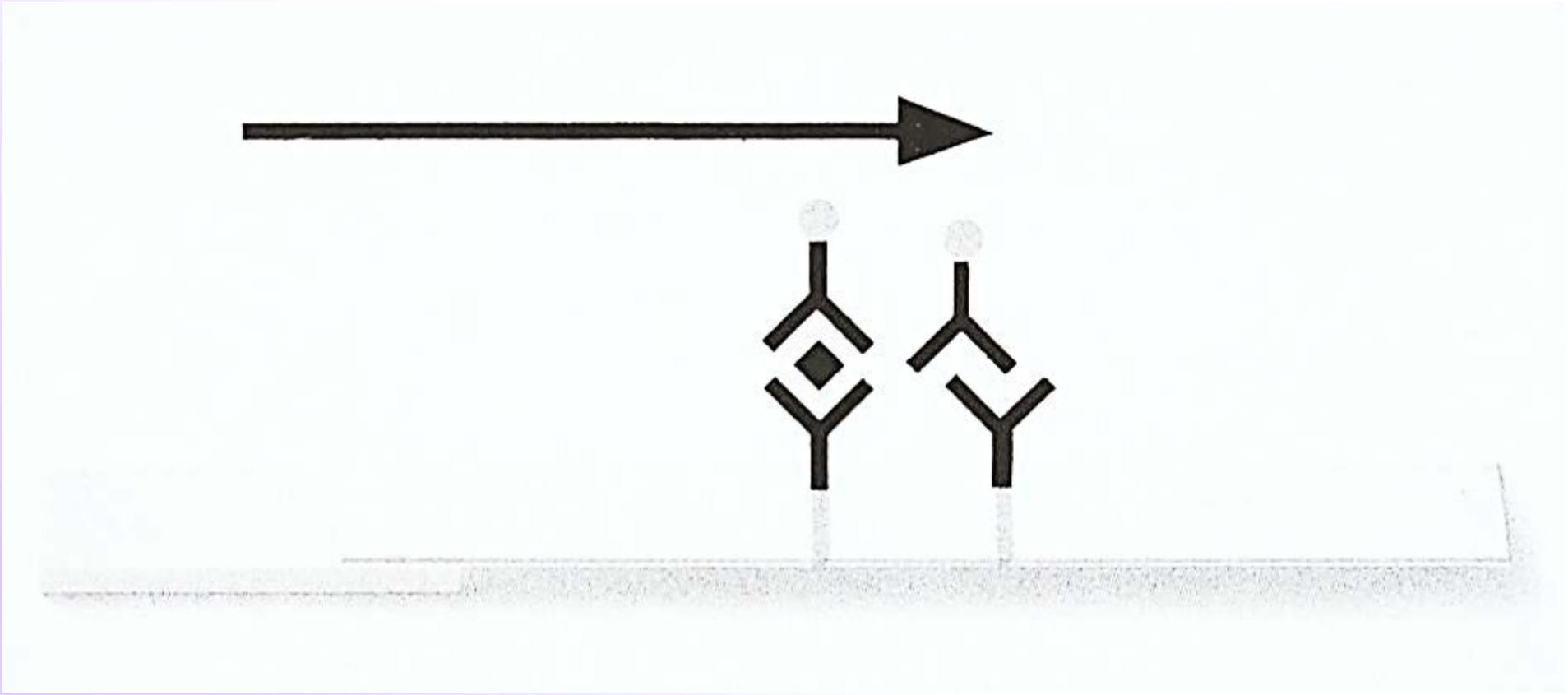


Staph enterotoxin

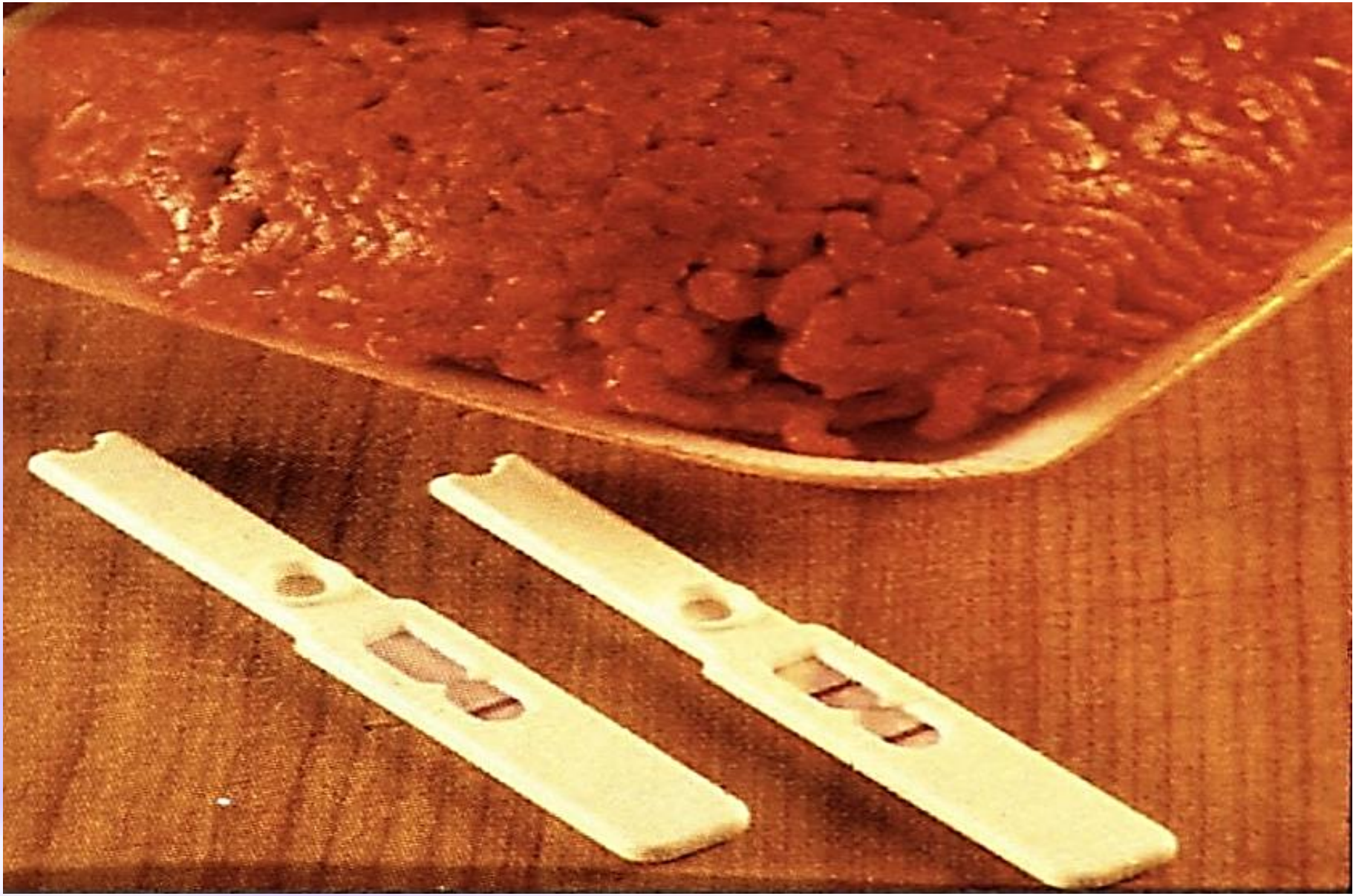


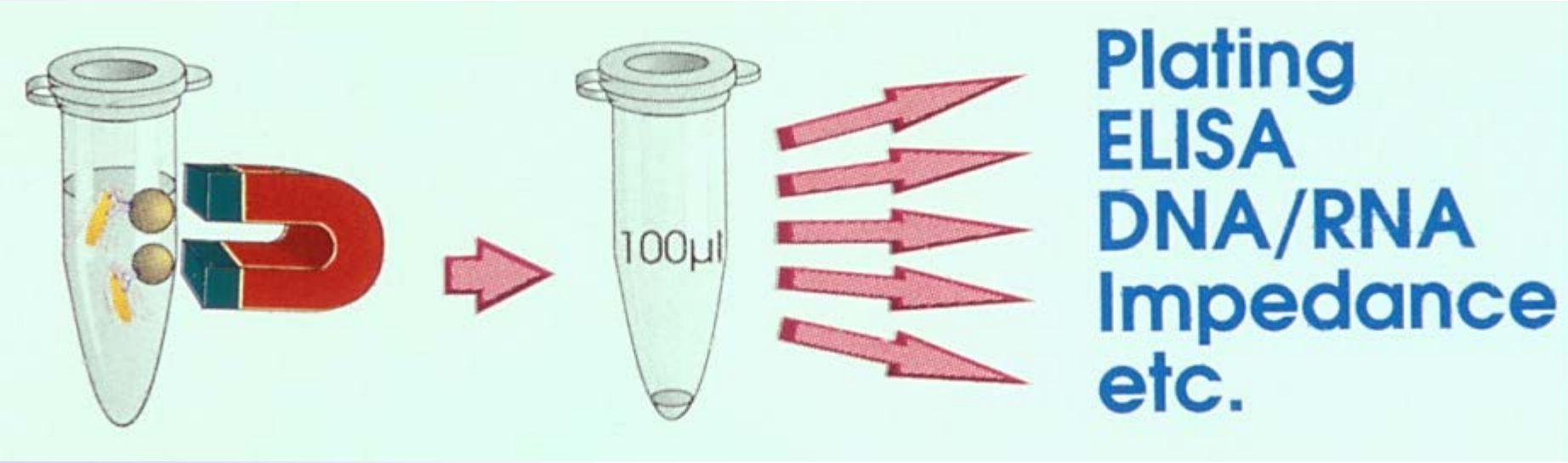
Campylobacter *

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Washing,
Separation,
& Concentration

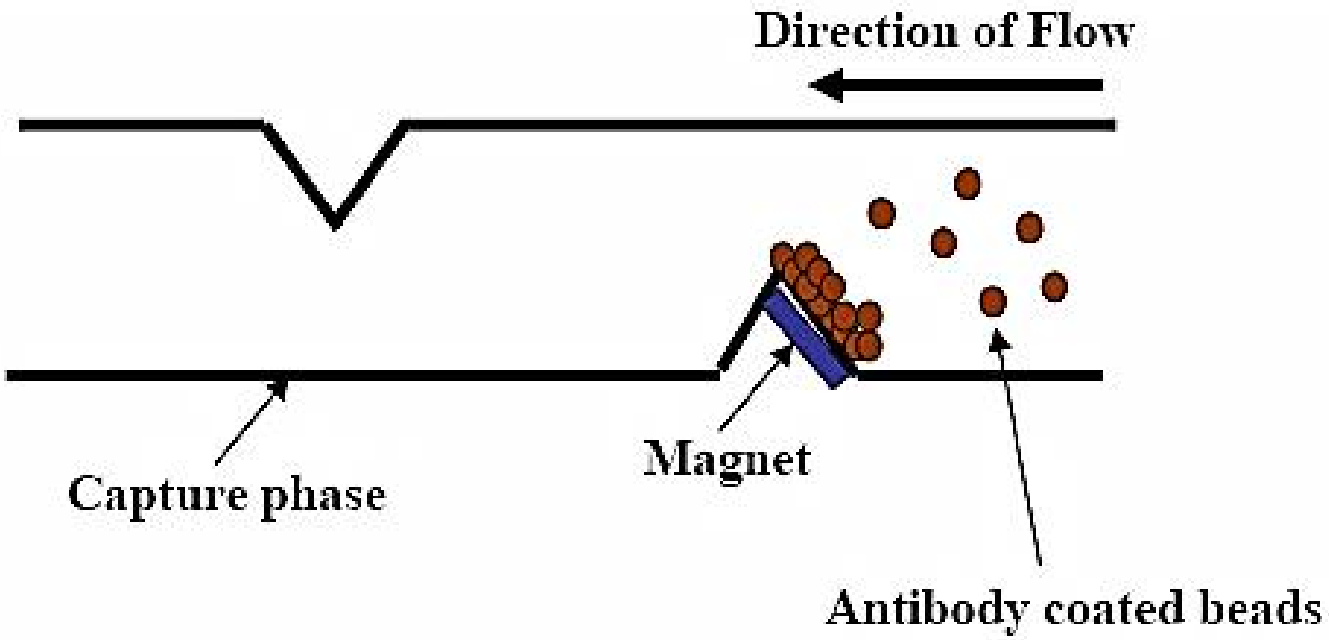
Reconstitution

Detection

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Pathatrix

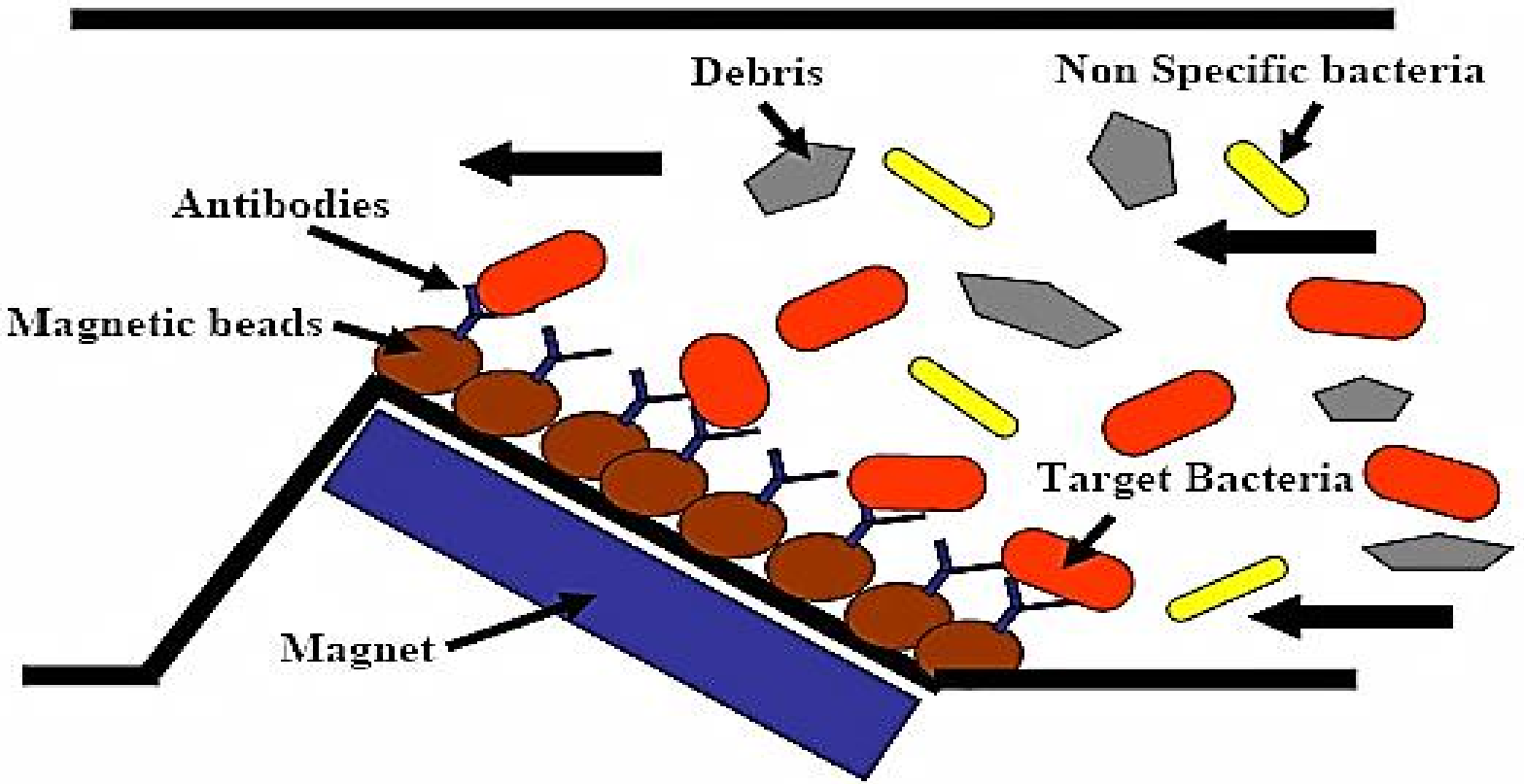
Antibody coated beads capturing on surface of capture phase



The beads are added to the consumable immediately prior to circulating the sample.

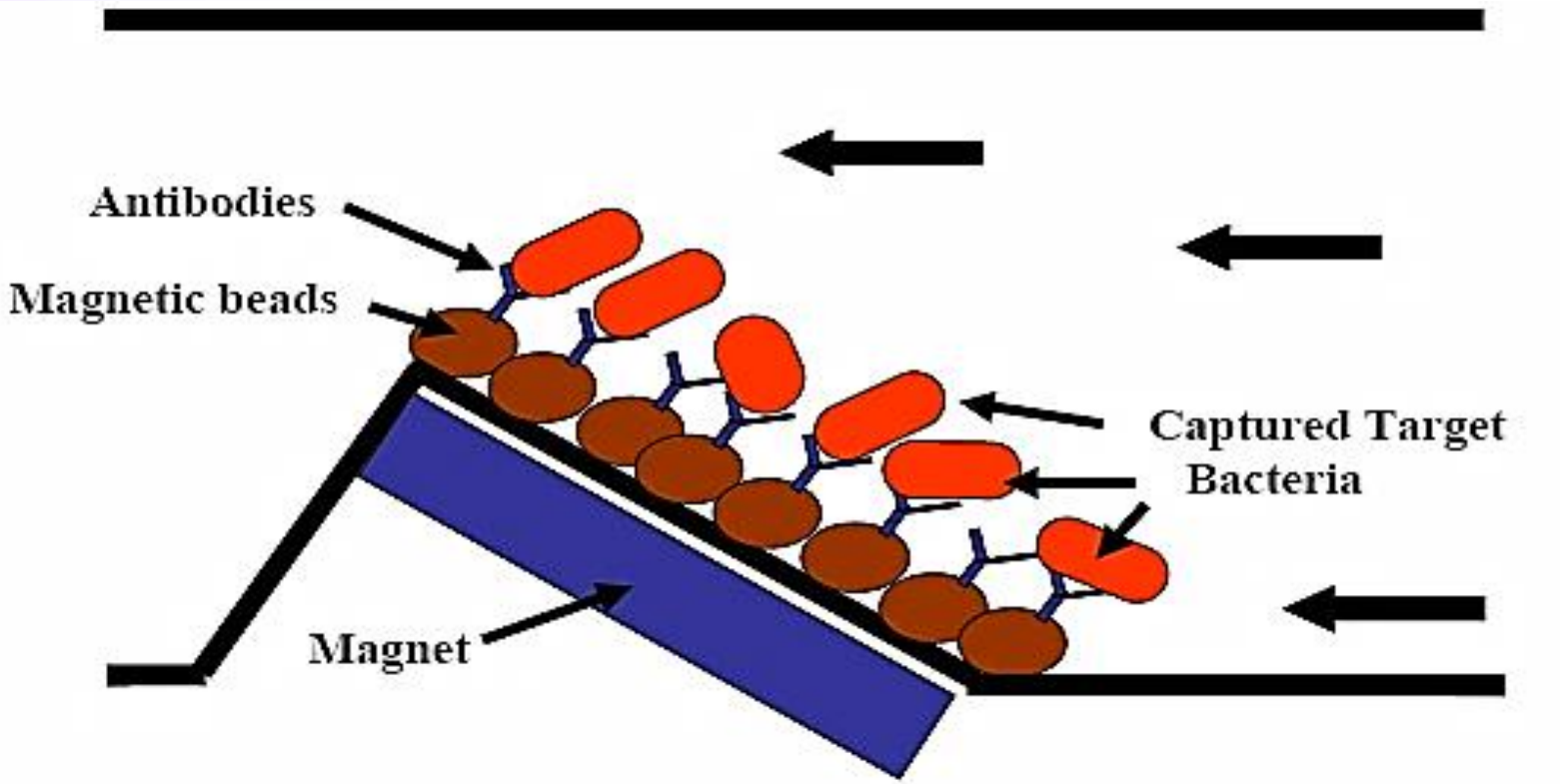
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Capture of Target in Food



The sample is re-circulated repeatedly across the capture phase with the whole 250 mL sample passing over the phase approximately twice every minute.

Captured Target Bacteria After Wash



When the re-circulation is complete, the captured bacteria (bound to the magnetic particles) can be washed extensively.

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Current State of Microbiological – Genetic Tests

- **DNA/RNA hybridization**
  - Needs 6 log CFU/ml, g, cm^2 for reaction
- **Polymerase chain reaction and related technologies**
  - Needs enrichment to ensure monitoring of viable cells and dilute inhibitors
- **Microarray, biochips, proteomics, geonomics**
  - Needs sample preparation before application
- **Biosensors**
  - Needs concentration of target cells before detection

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Genetic Methods

- DNA/RNA Hybridization
- PCR –BAX
- Molecular Beacon Technology
- Probelia
- Riboprinting and Pulse Net Systems

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Products for Microbial Analysis



Pre-Enrichment

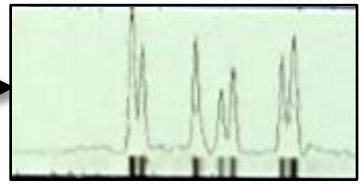
Screen for it

Positive

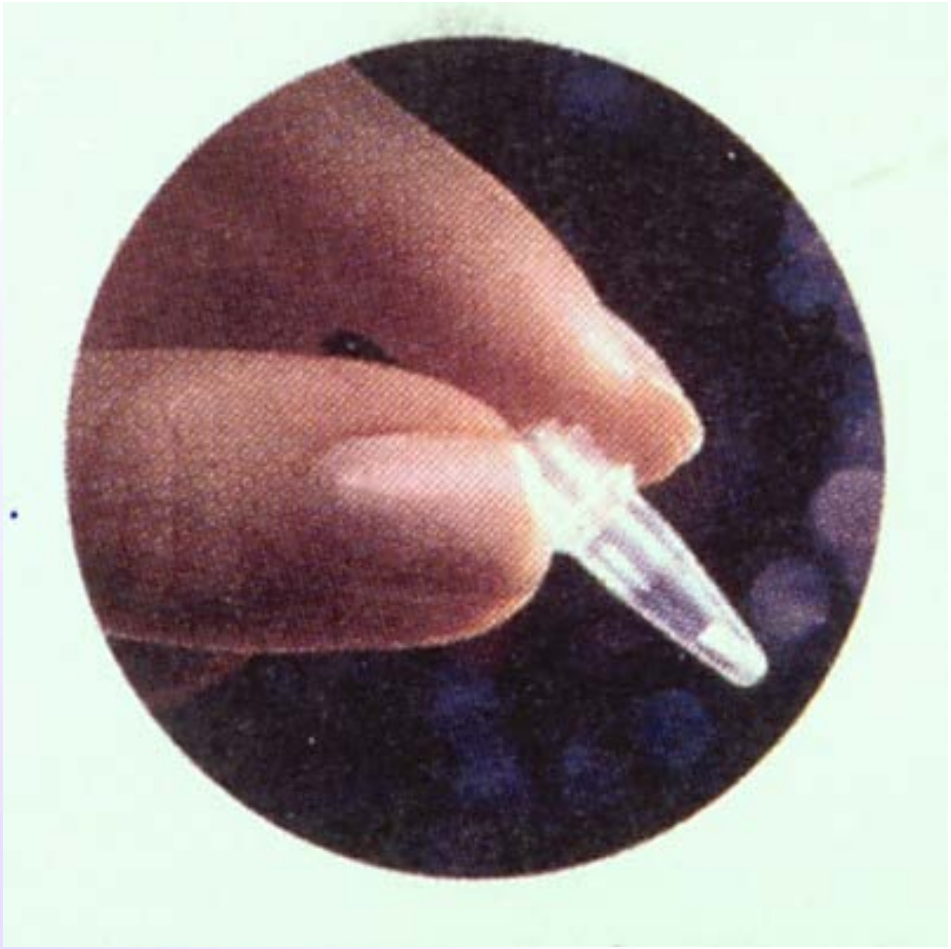
Negative

Microbe Isolation

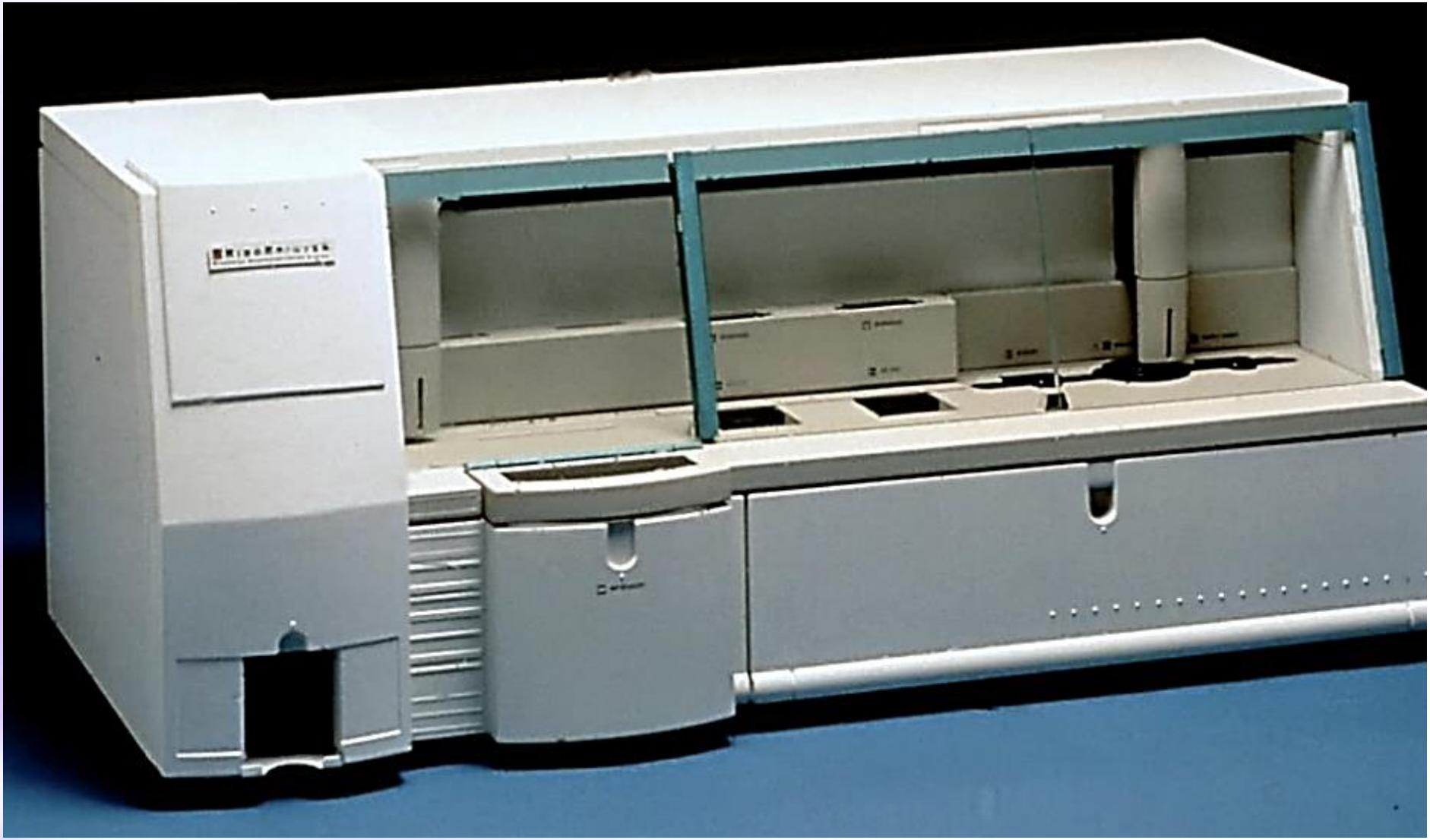
Characterize & Identify it



RiboPrint™ pattern (fingerprint)




BAX System
BAX
Qualicon



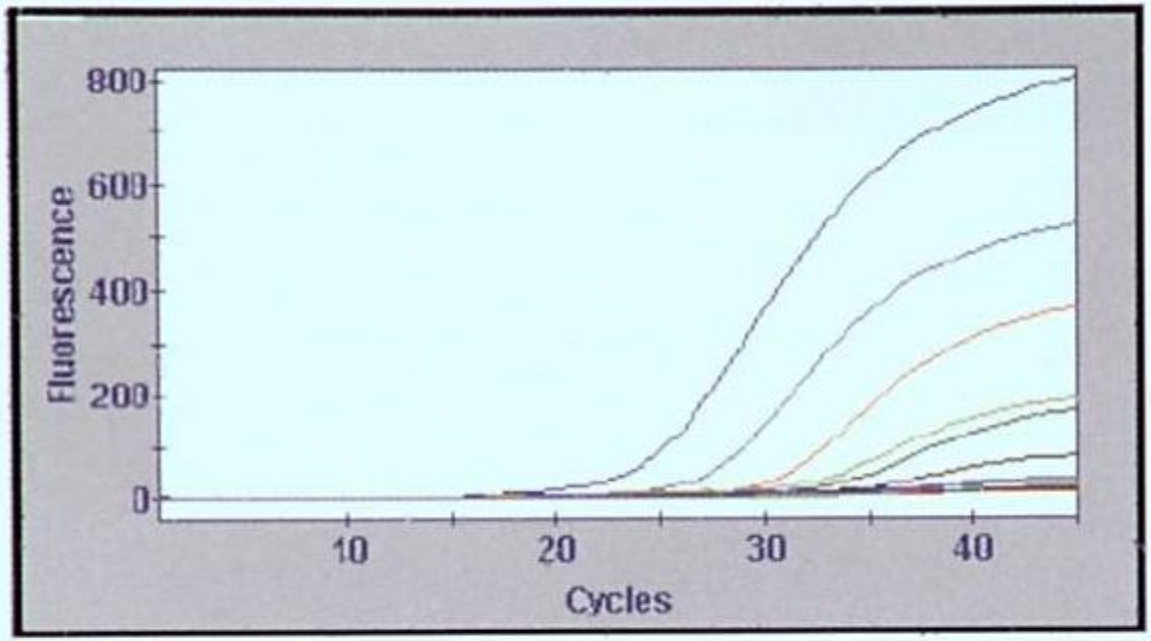
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R.A.P.I.D.



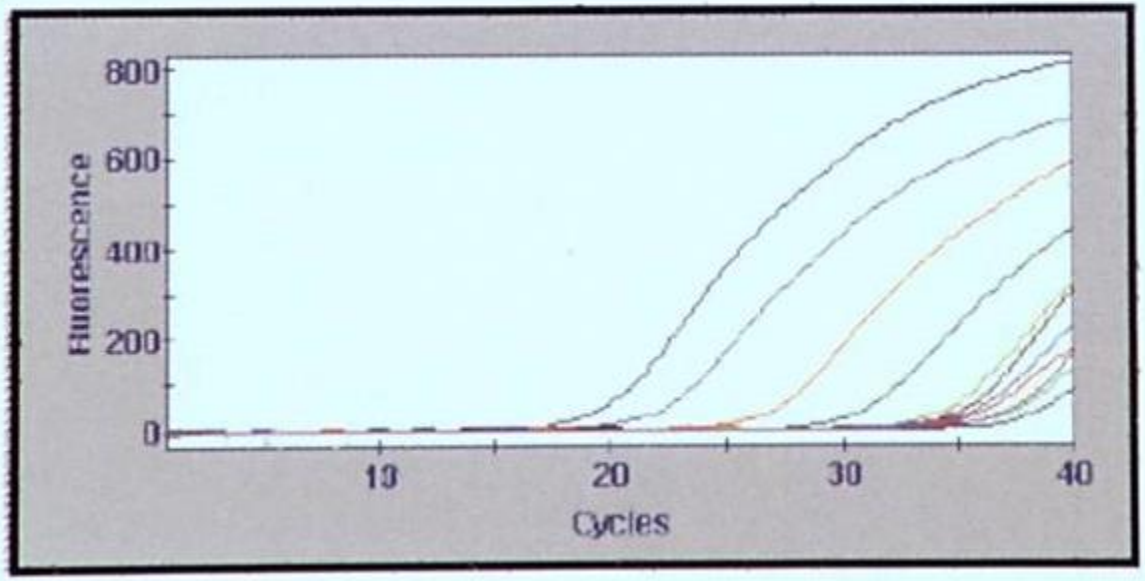
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A



10 ng
1 ng
100 pg
10 pg
1 pg
100 fg
no DNA control

B



10 ng
1 ng
100 pg
10 pg
1 pg
100 fg
10 fg
1 fg
0.1 fg
no DNA control

k does not include agent specific reagents. Those
purchased separately.

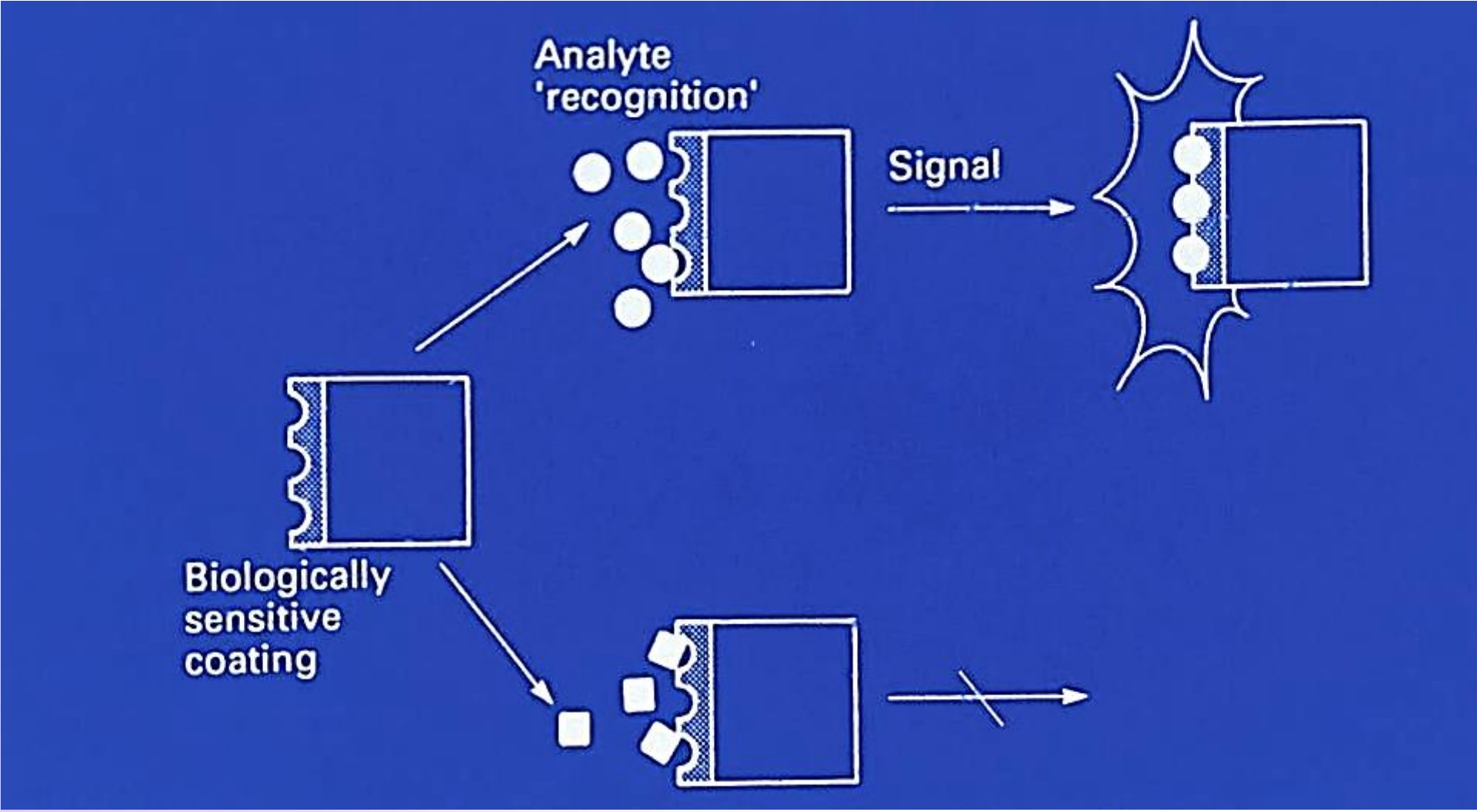
Manuals / Software CD	1 Set



Advances in Biosensors

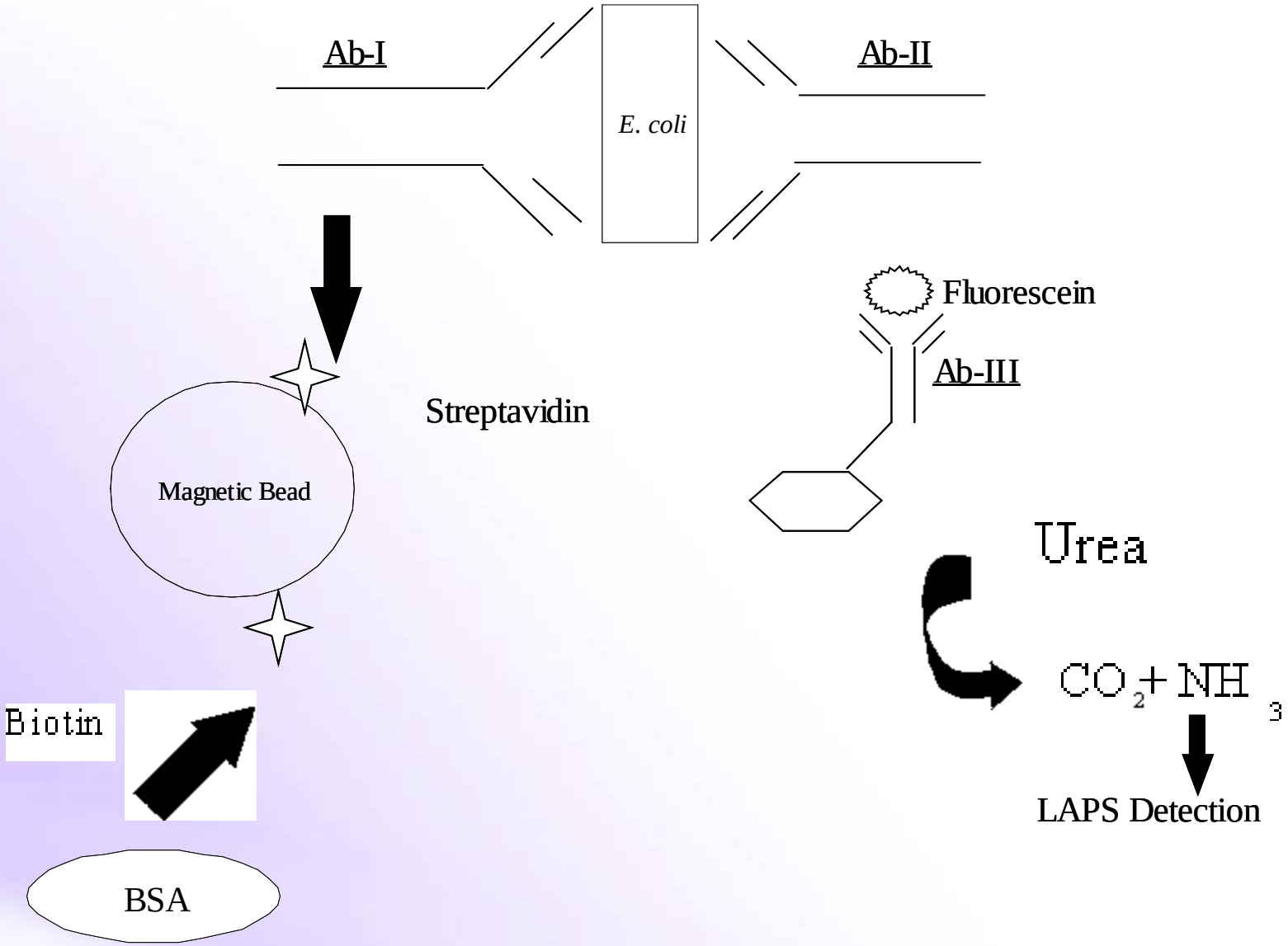
- Microarrays, biochips
- Nanotechnology
- Sampling clean up and extractions
- Viability and sensitivities of cells

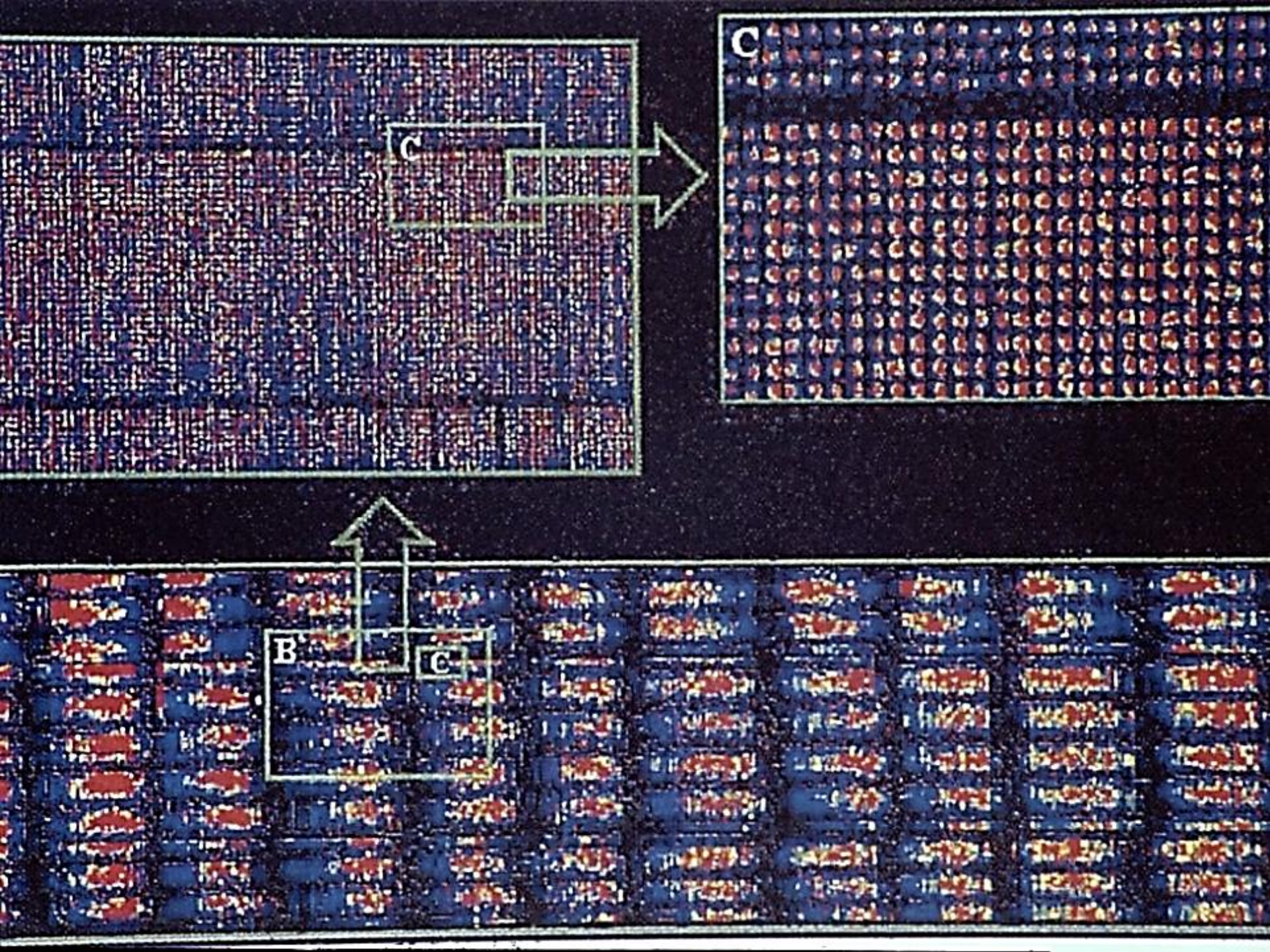
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The biosensor: surface-modified transducer which is reactive towards a specific chosen analyte.

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Ab-I
Ab-II
E. coli
Fluorescein
Ab-III
Streptavidin
Magnetic Bead
Urea
$CO_2 + NH_3$
LAPS Detection
Biotin
BSA
Nitrocellulose Membrane (0.45 µ)


C
C
B
C

Nanotechnology: Why Size Matters

Gold nanoparticles can emit intense heat

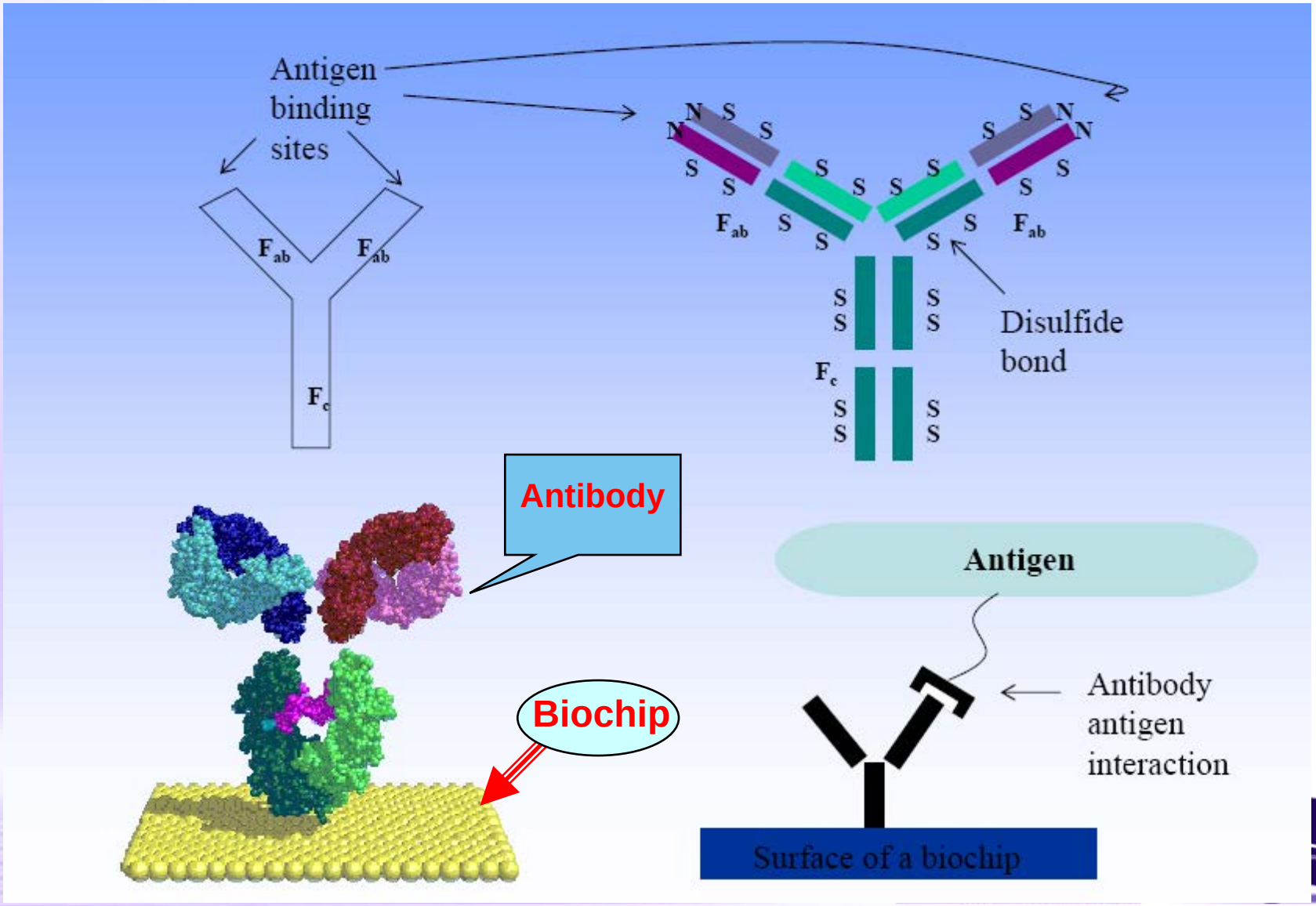


A cluster of gold nanoparticles 50 nanometers in diameter created a much larger crater in the ice sample.

www.physorg.com/printnews.php?newsid=63003999

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Microbial Nanosensors on a Chip





Food Micro – 2008 - 2013

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Food Microbiology Market Summary

1. This report focuses on the microbiology testing practices/diagnostics used by the Food Processing sector to meet its fundamental objective: produce safe, wholesome food products that meet label claims.

2. The Food Microbiology market (The Market) in 2008 is sizable and represents almost 740 million tests performed globally in the Food Processing Industry by the estimated 40,000 plants having over 25 employees. Historically, this market has been growing reasonably quickly, stimulated to a certain extent by the frequent food safety headlines attributed to this market.

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Food Microbiology Market Summary, Cont'd

3. These estimates are based on all of the samples collected at the 40,000 food processing plants regardless of where they are analyzed (at the plant, at corporate labs sited at a different location, or at outside private labs).

3. The total worldwide market value for all microbiology tests performed in 2008 is estimated to be over $2.0 billion.

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Food Plants with >25 Employees	40,000

Tests/Plant/Year

Routine	15,005
Pathogen	3,453
Total	18,458

Total Tests (Millions)

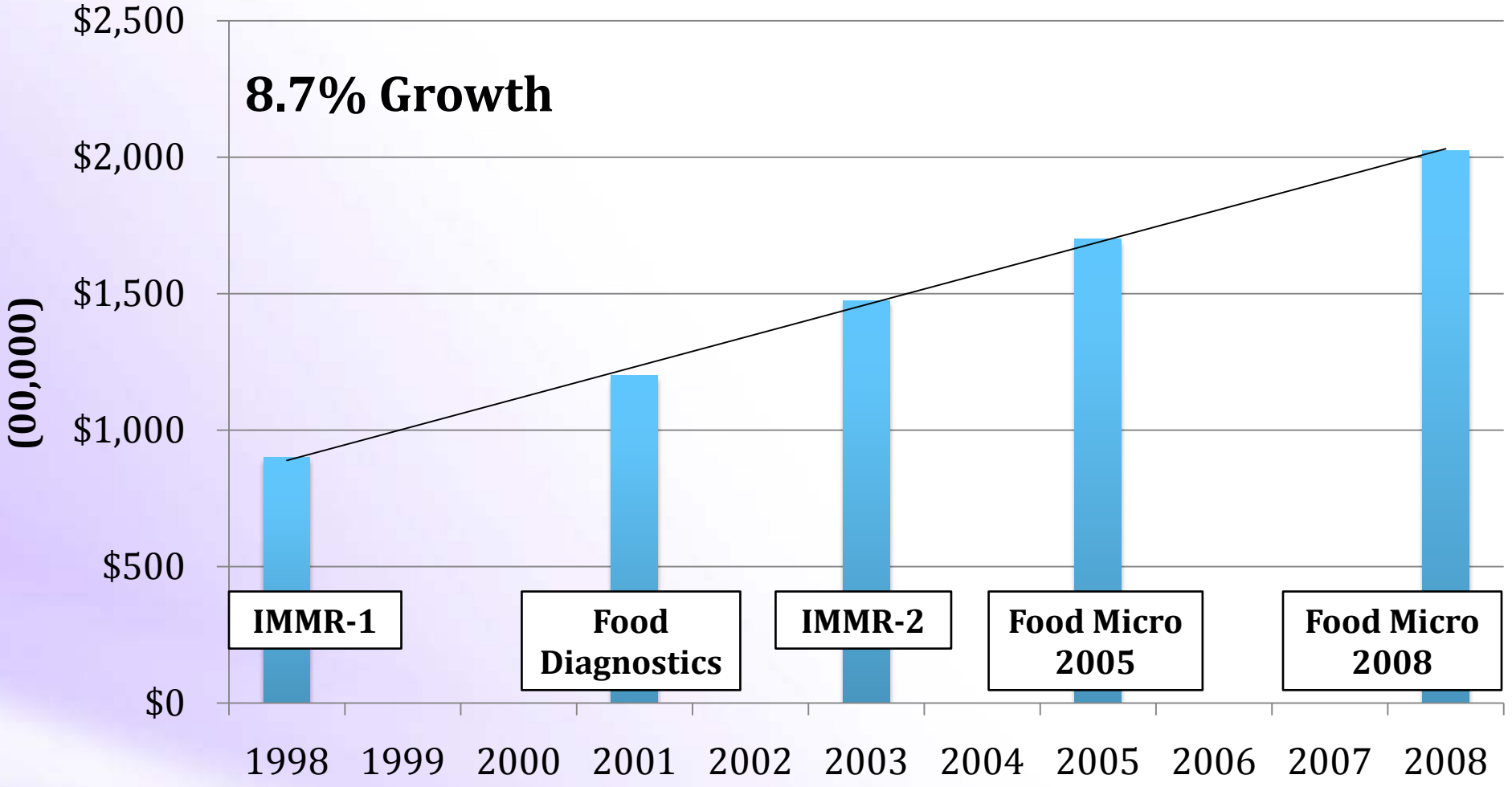
Routine	600.2 M
Pathogen	138.1 M
Total	738.3 M

Market Value ($$ Million)

Routine	$1,050.0 M
Pathogen	$1,007.4 M
Total	$2,057.4 M

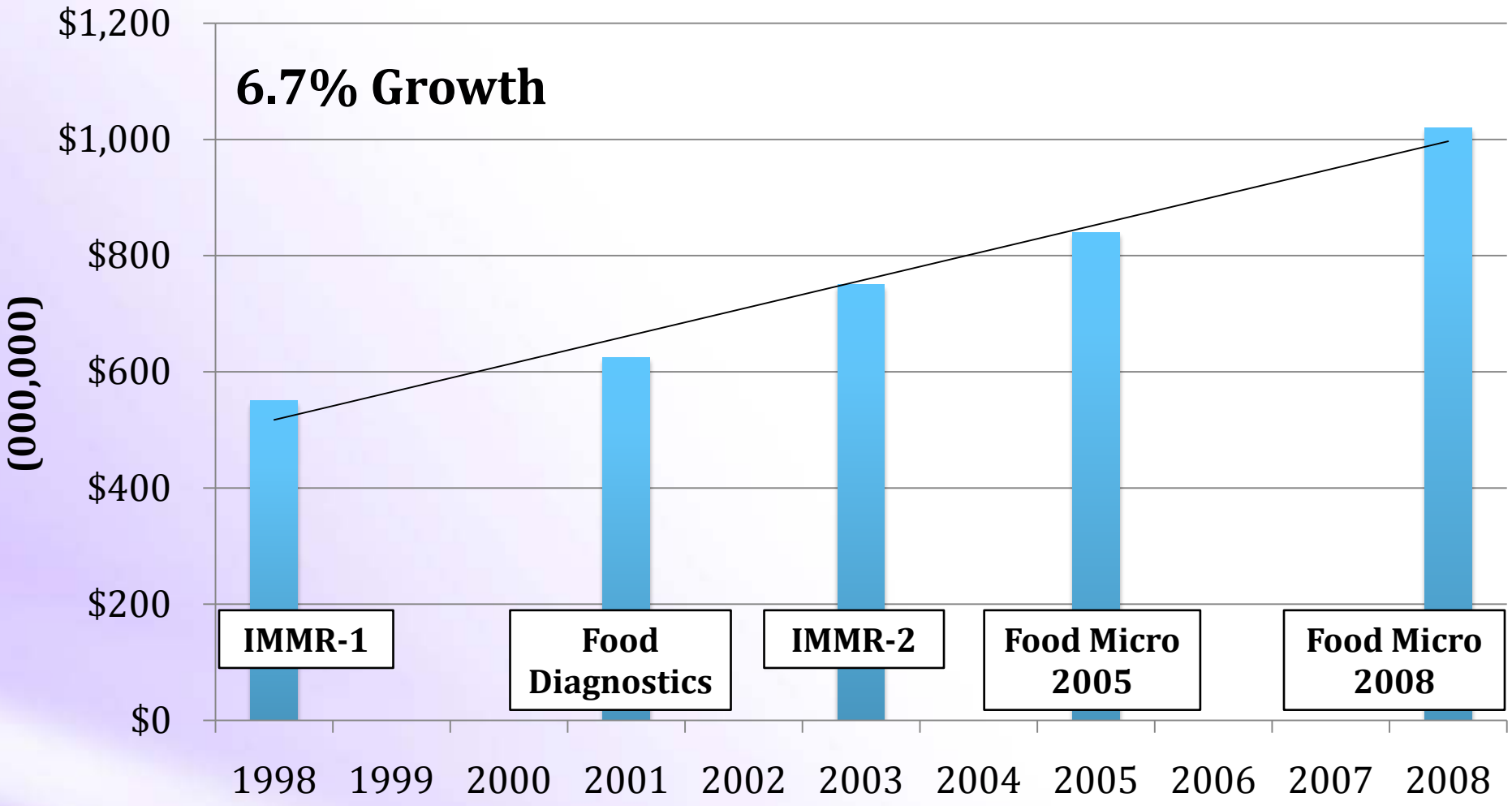
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Microbiology Testing – Market Value (1998-2008)



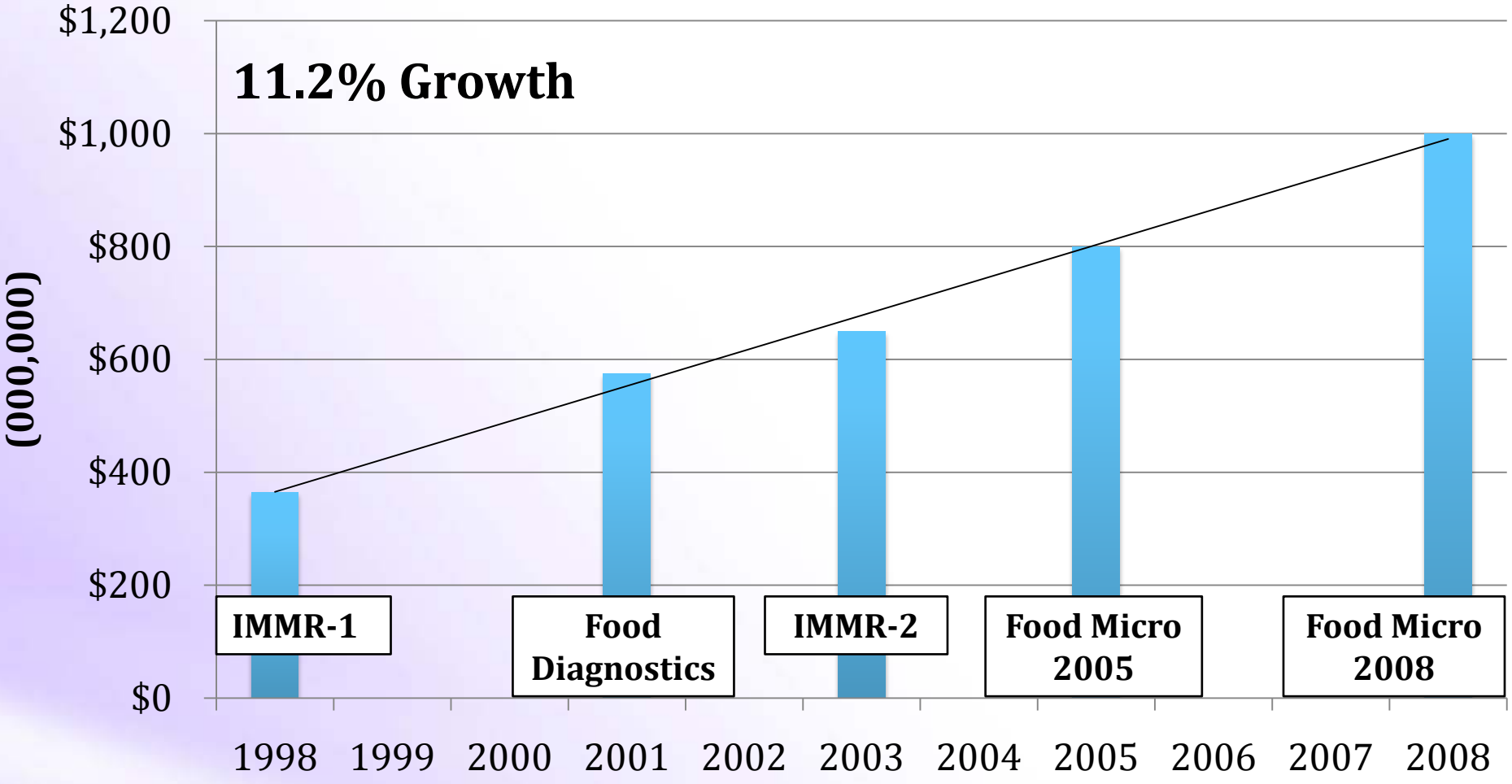
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Routine Micro Tests – Market Value(1998-2008)



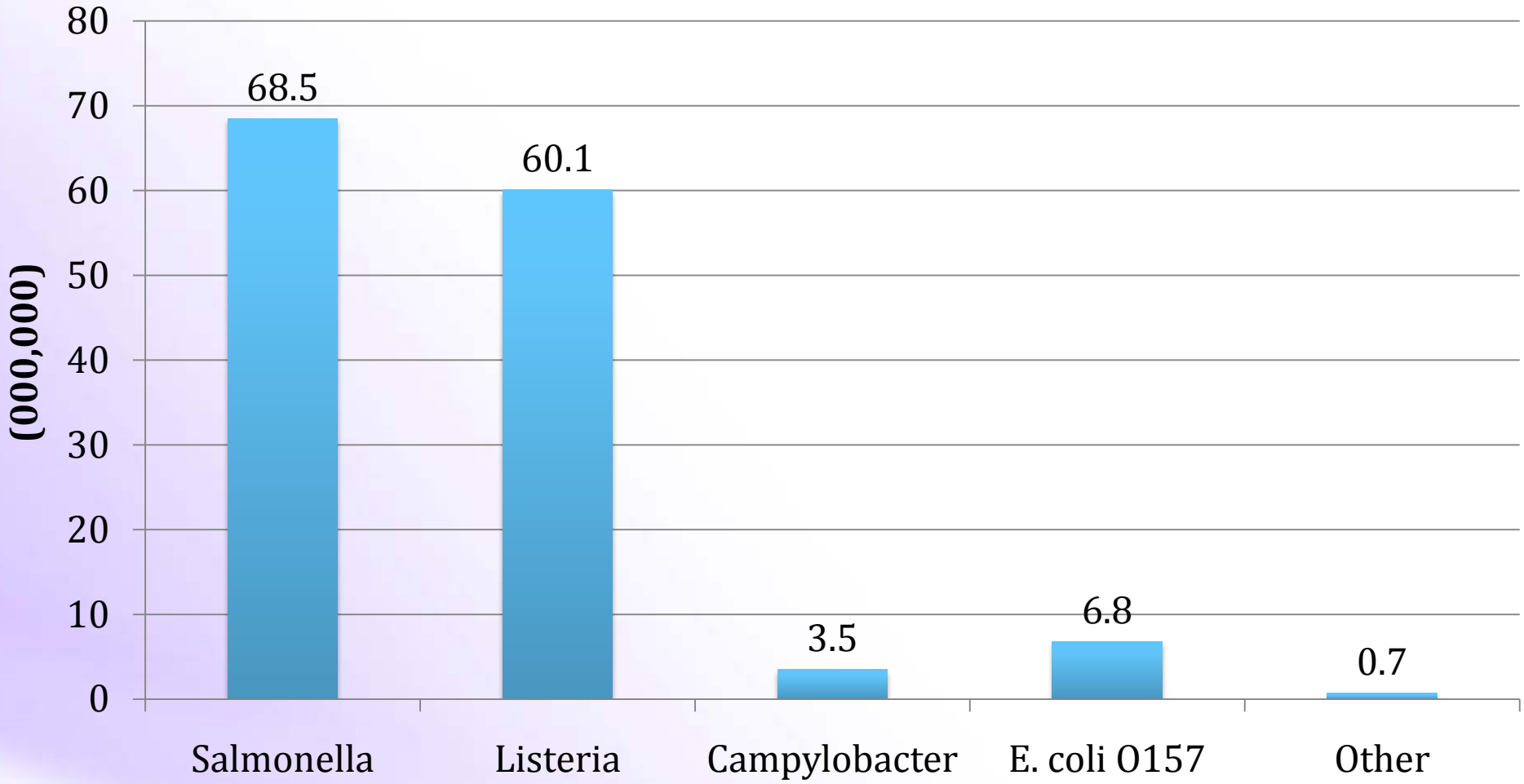
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Pathogen Tests – Market Value(1998-2008)



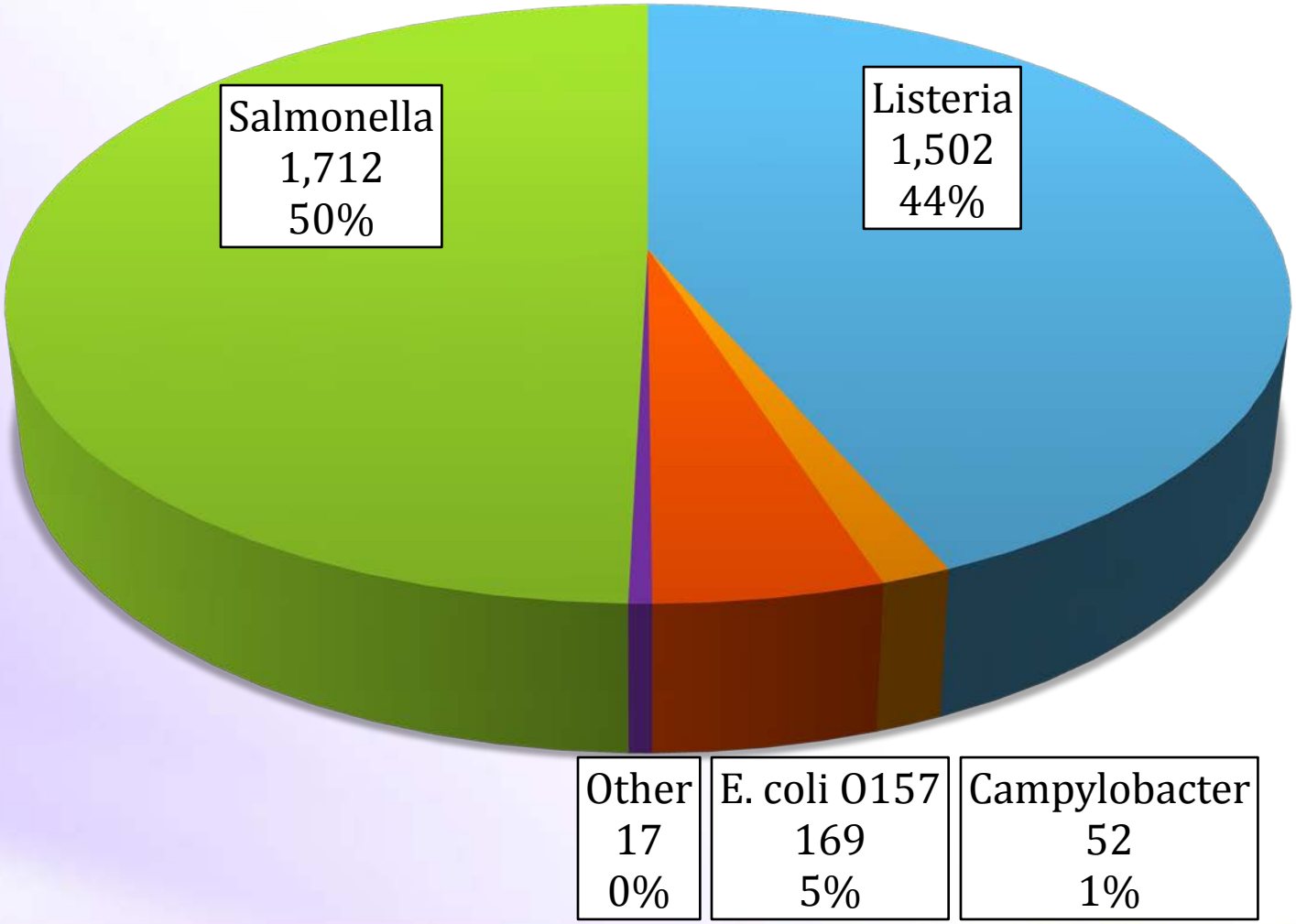
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Pathogen Tests by Organism (2008)



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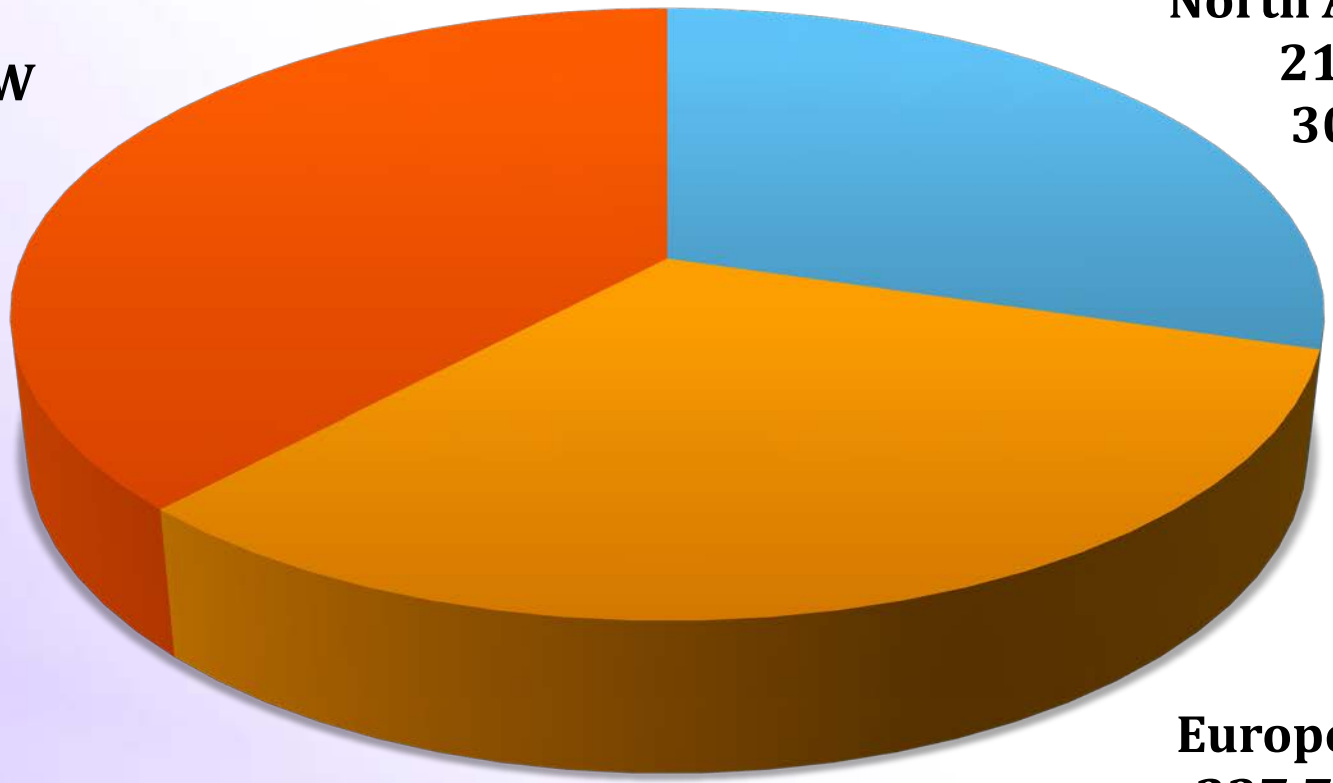
Pathogen Testing Breakdown (000,000)



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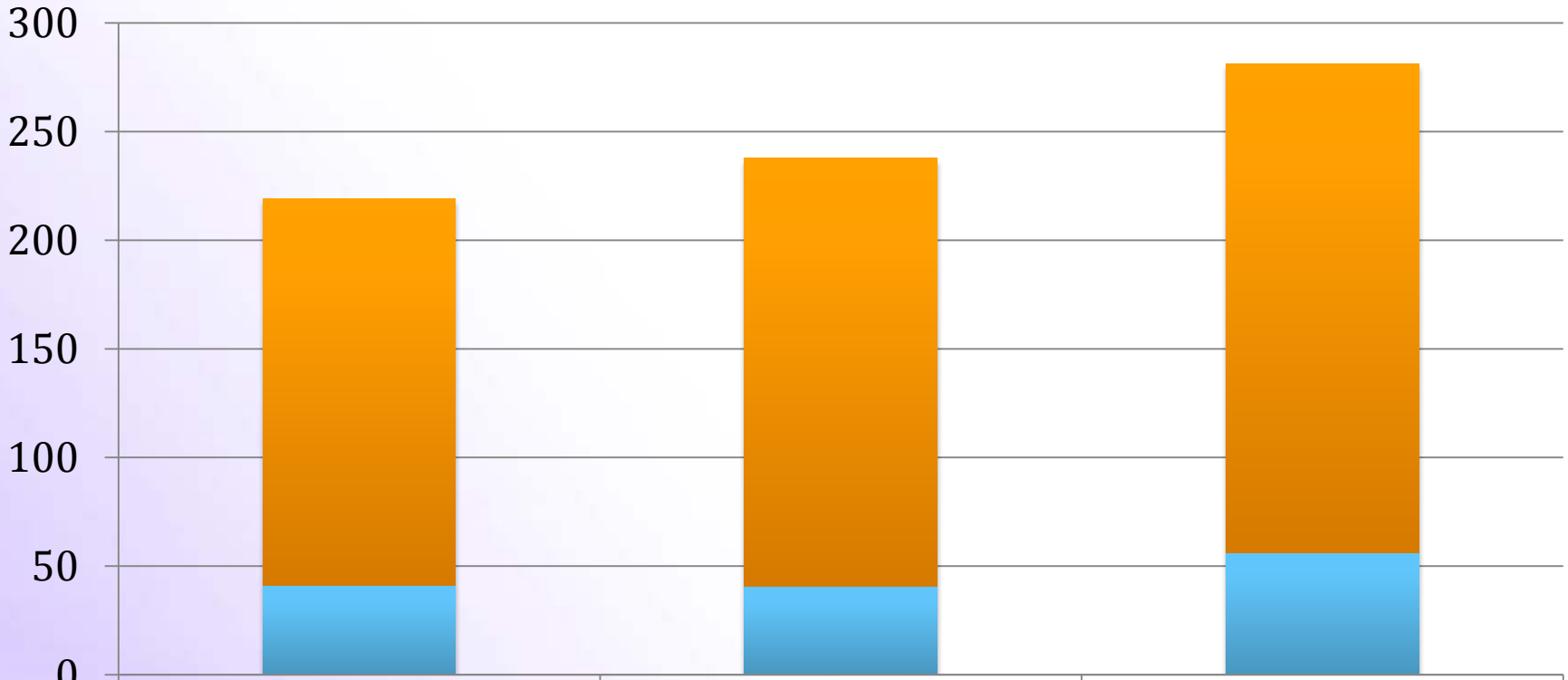
2008 Micro Tests by Geographic Region

(000,000)



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2008 Geographic Review – Organisms Tested

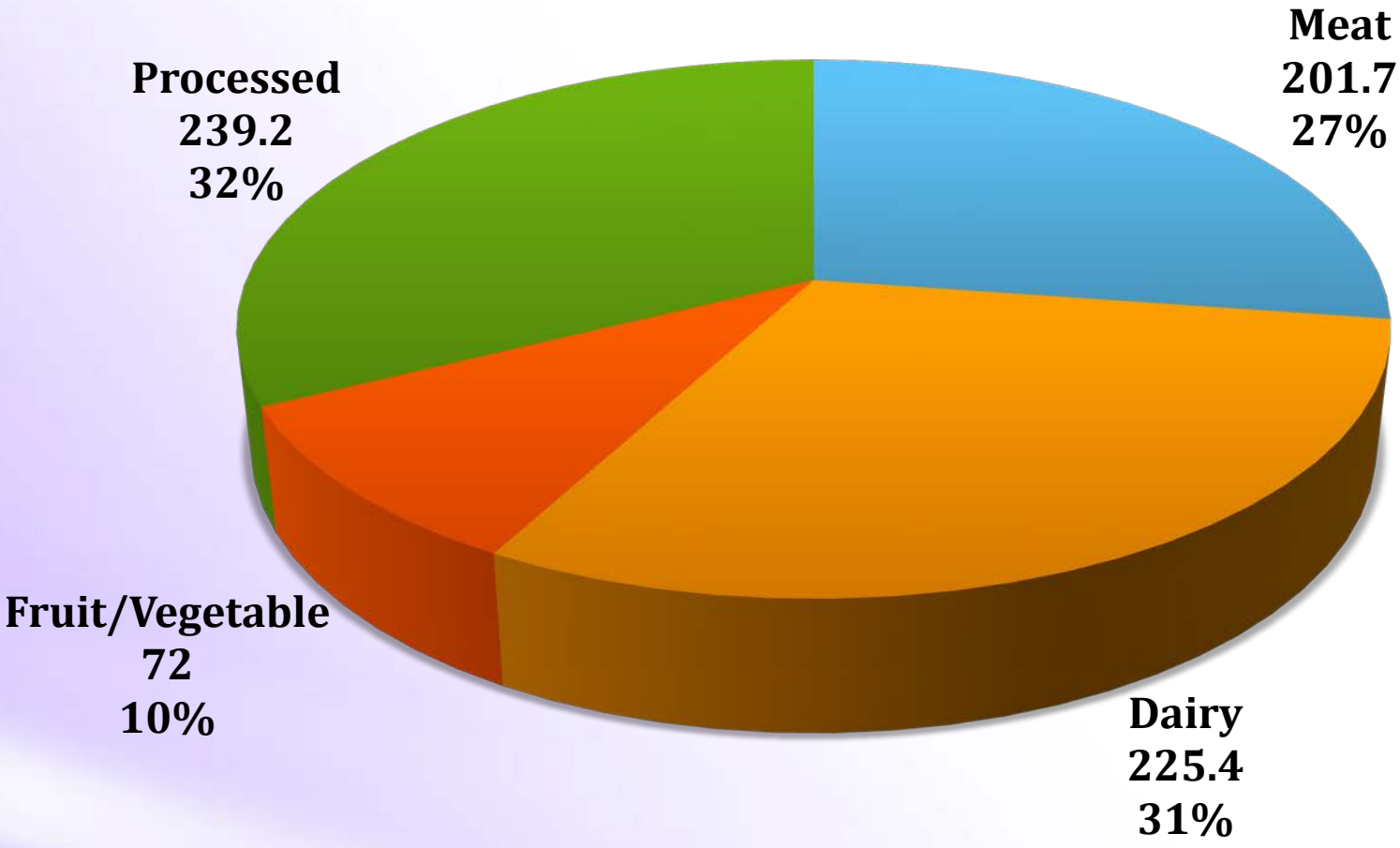


	North America	Europe	AP/ROW
Routine	178.1	196.9	225.2
Pathogen	41.1	40.9	56.1

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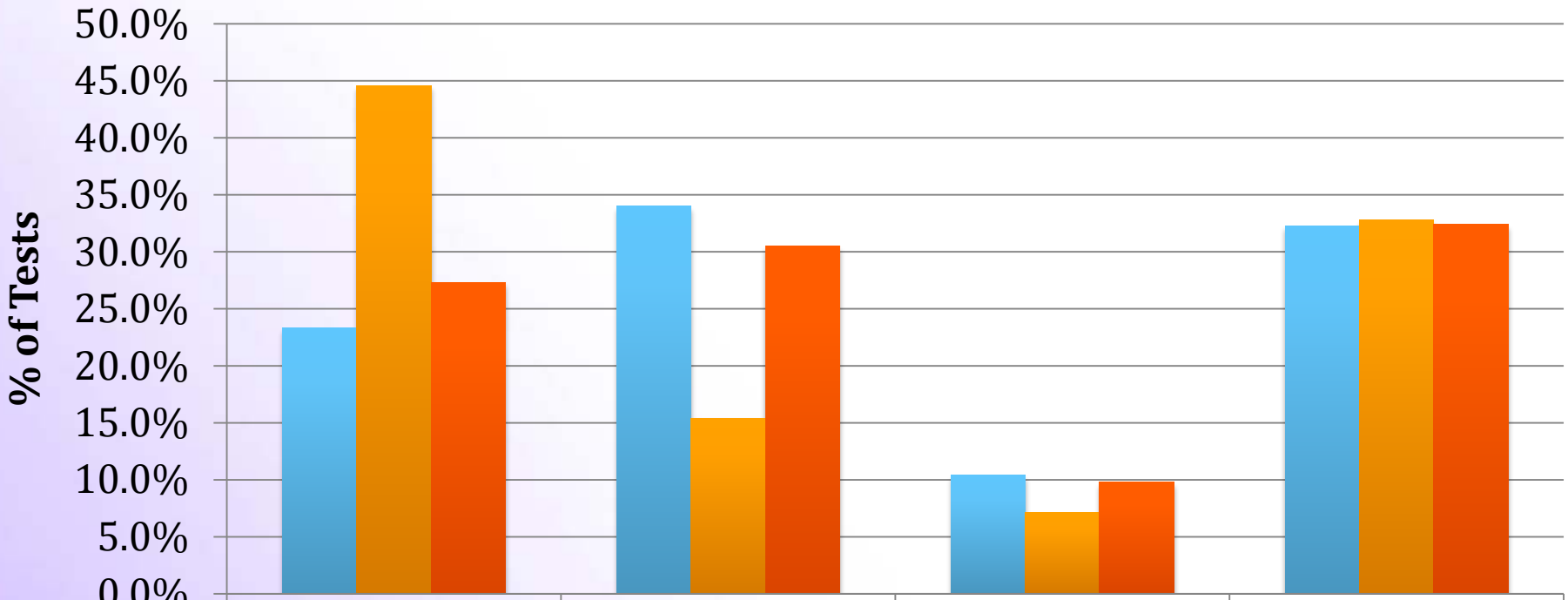
Sector Comparison Summary – 2008

Microbiology Tests by Food Sector (000,000)



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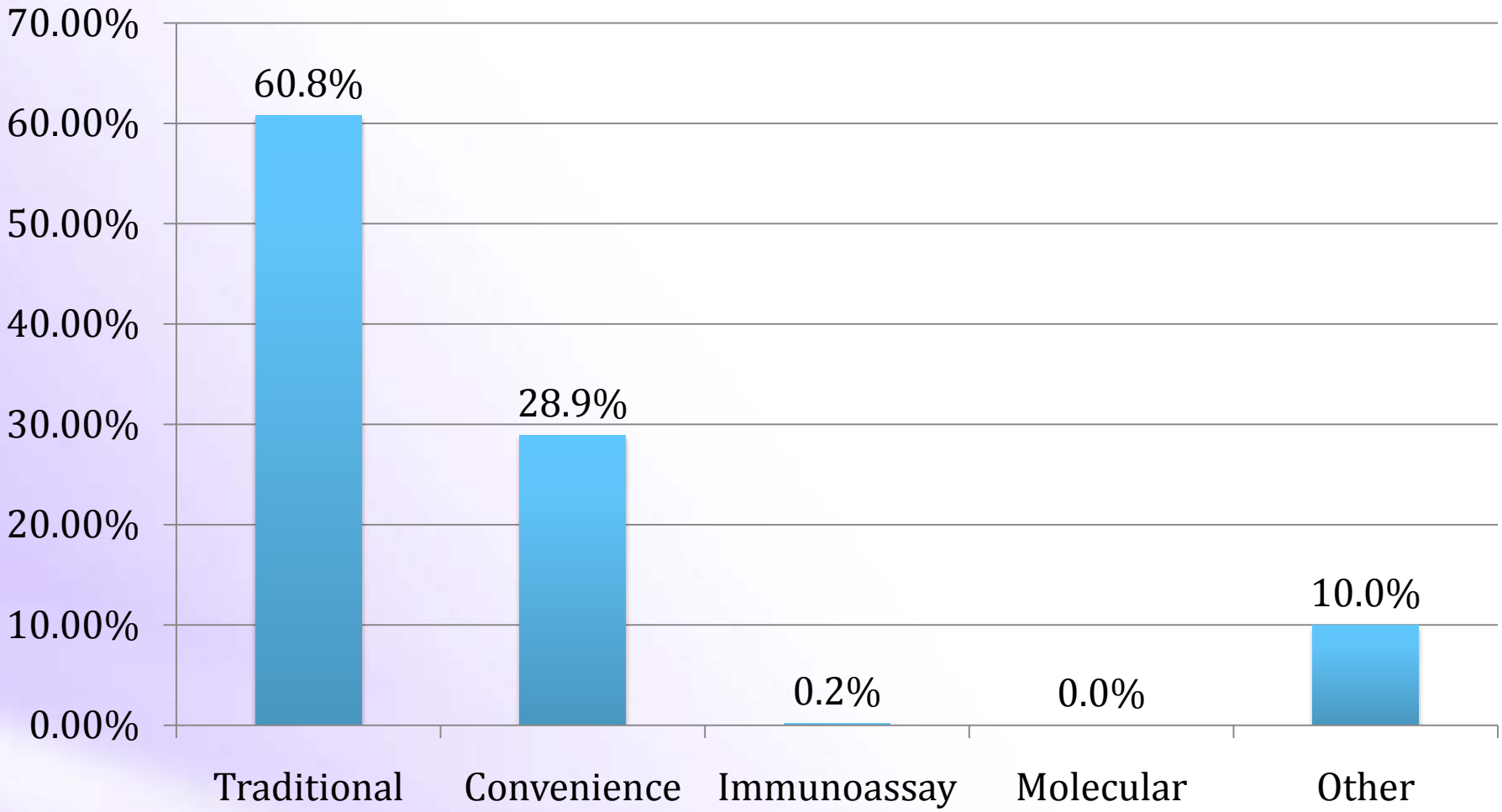
Microbiology Testing by Food Sector



	Meat	Dairy	Fruit/Veg	Processed
Routine	23.3%	34.0%	10.4%	32.3%
Pathogen	44.6%	15.4%	7.1%	32.8%
Total	27.3%	30.5%	9.8%	32.4%

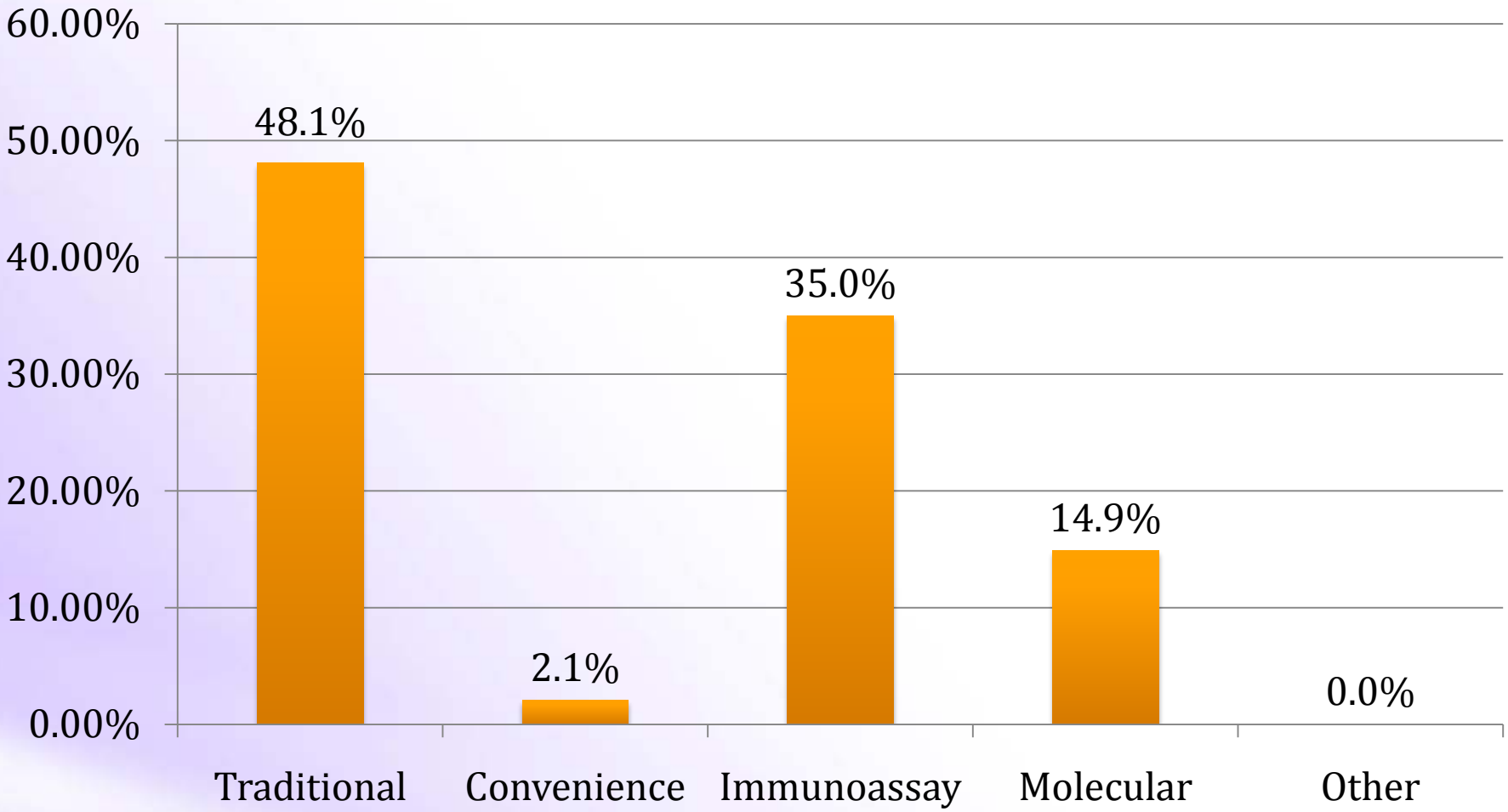
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Routine Microbiology Testing – Method Used

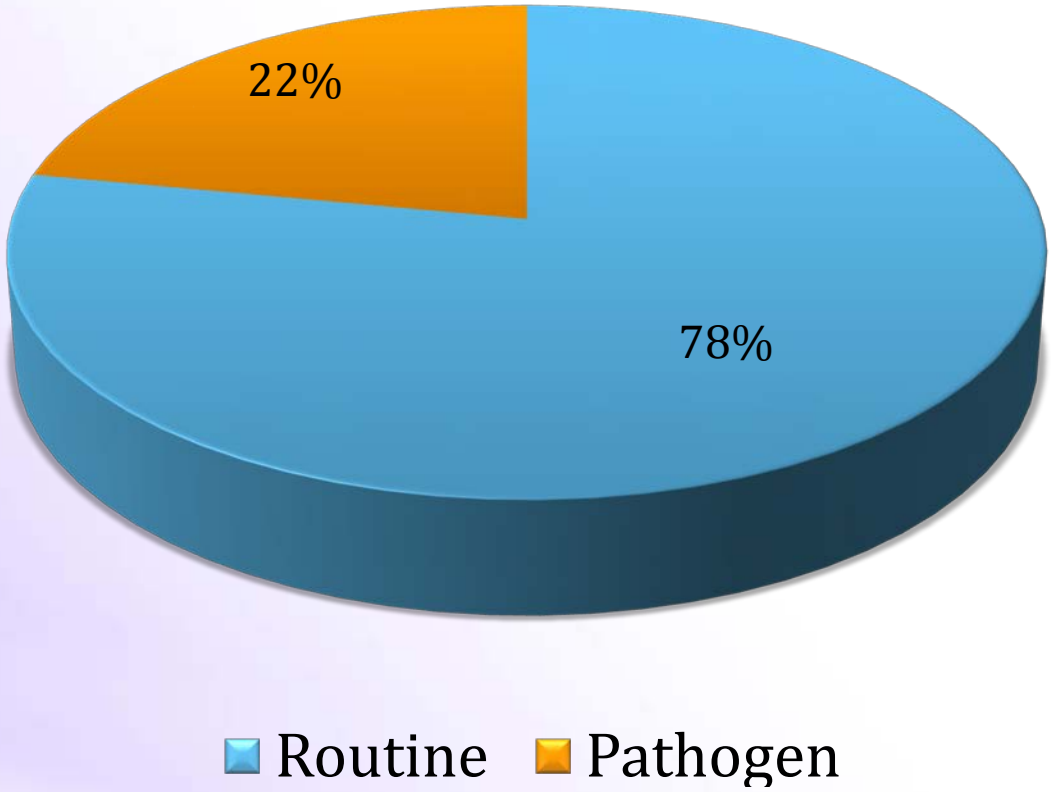


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Pathogen Testing – Method Used

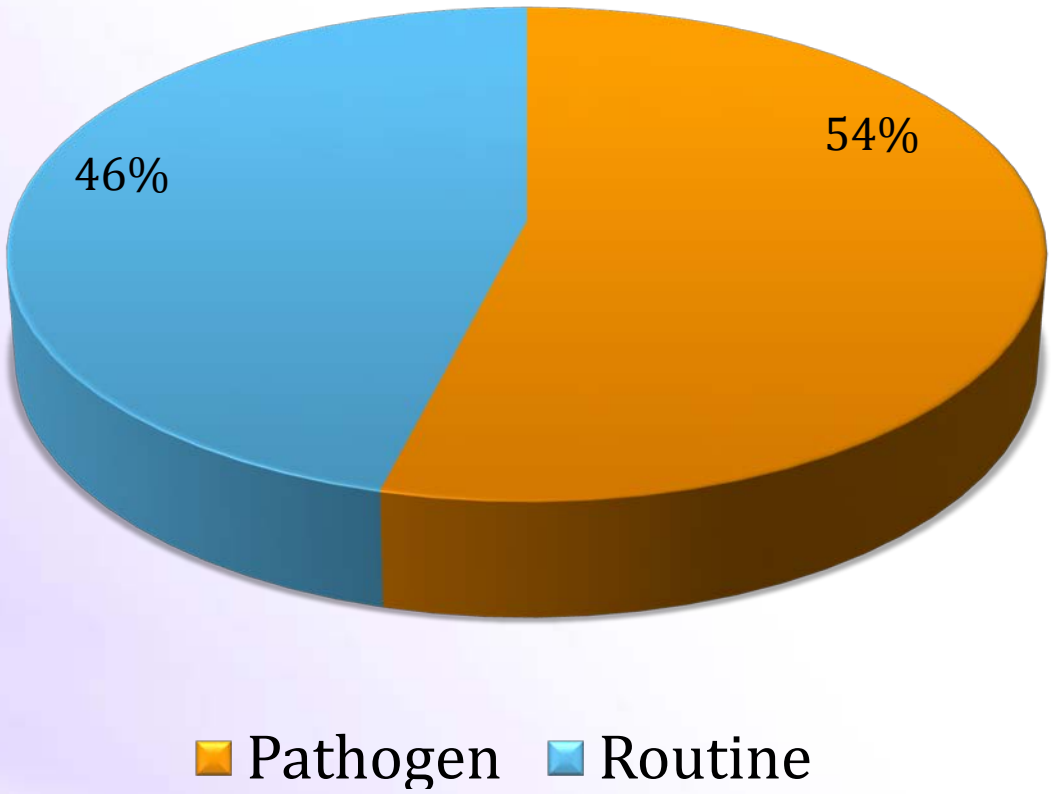


Food Micro Test Volume, 2010



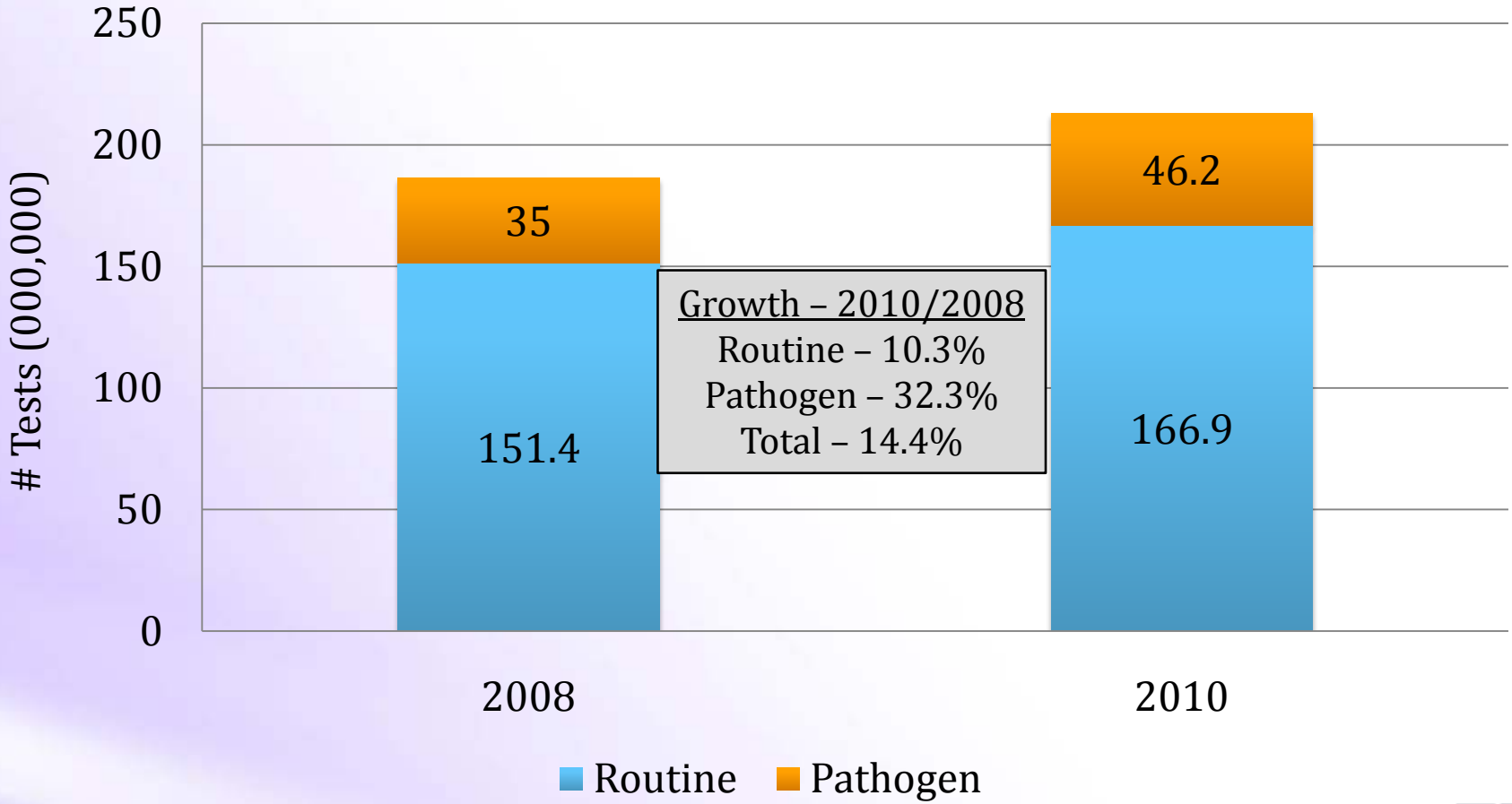
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Food Micro Market Value, 2010



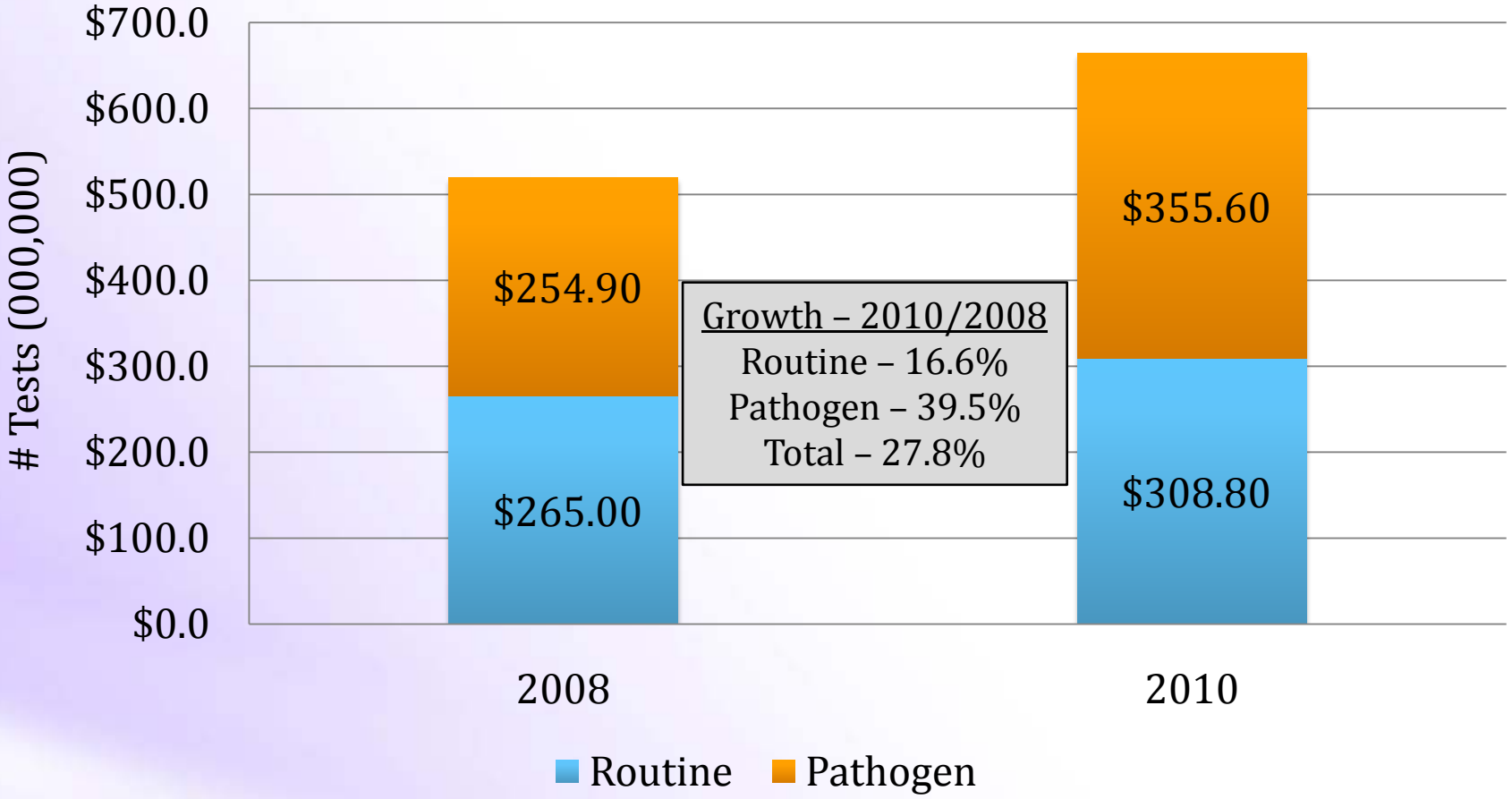
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US Food Micro Market – Test Volume



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US Food Micro Market – Market Value



Food Microbiology Growth Model – 2010

Testing Volume

= (Volume of Commodity Produced) x (Rate of Testing per Unit of Commodity)

Base Commodity Growth per Year – 1.5%	Annual Change in Testing per Unit of Commodity – 5.5%

…results in an Average Testing Volume Increase of **7.0%**

Market Value of Testing

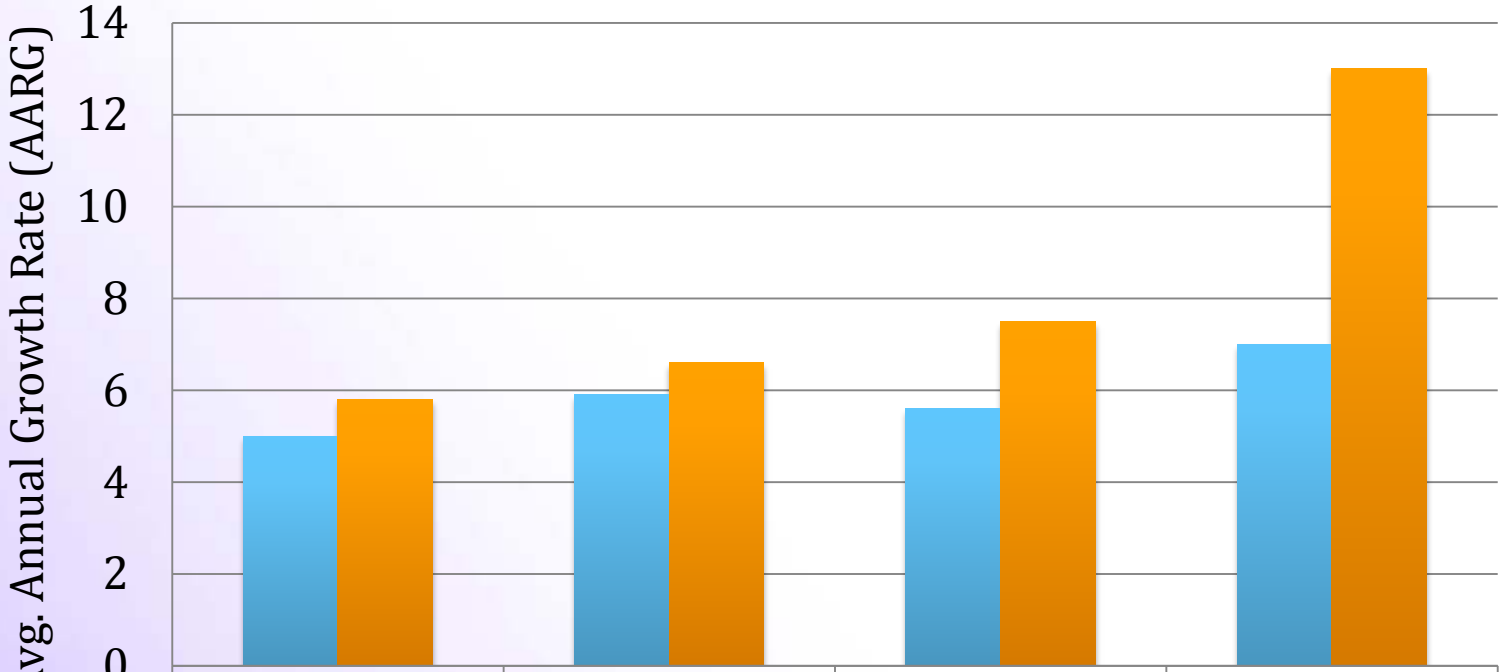
= (Testing Volume) x (Average Cost per Test)

Yearly testing Volume– 7.0%	Yearly Change in ACT (constant dollars) – 6.0%

…results in an Average Market Growth per Year of **13.0%**

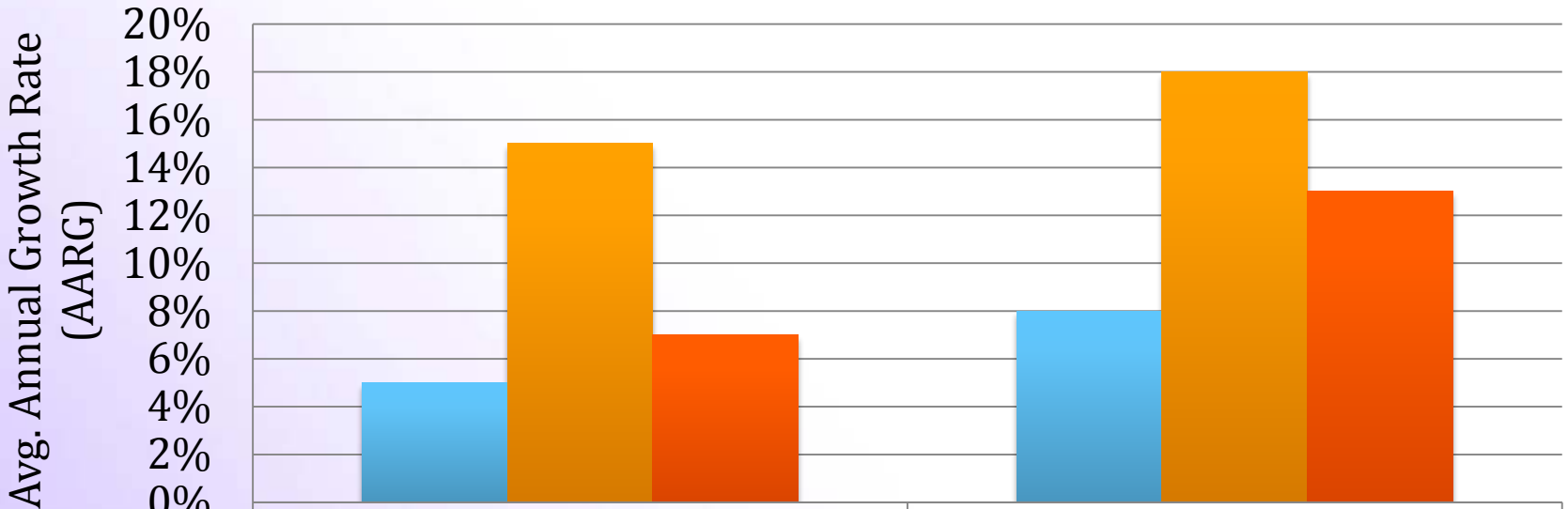
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AARG Comparison - # of Tests vs. Market Value



	1993-1998	1998-2003	2003-2008	2008-2010
# of Tests	5	5.9	5.6	7
Market Value	5.8	6.6	7.5	13

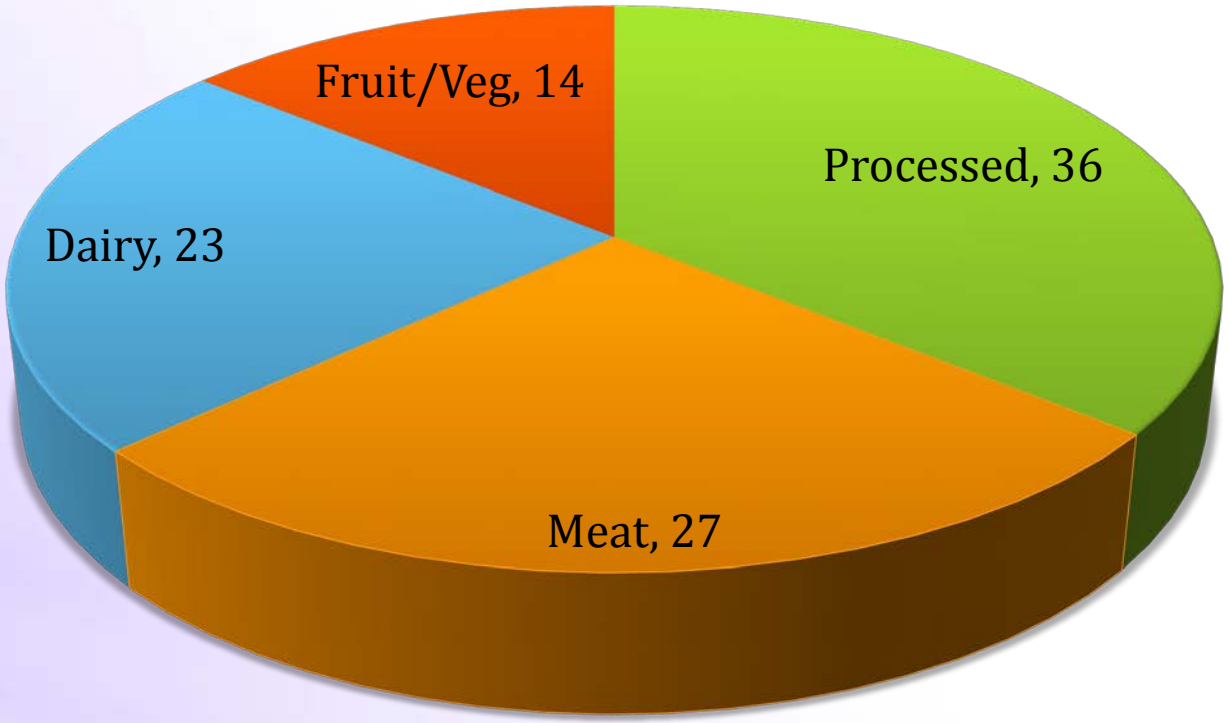
AARG in US Food Micro Market, 2008-2010



	Test Volume	Market Value
Routine	5%	8%
Pathogen	15%	18%
Total	7%	13%

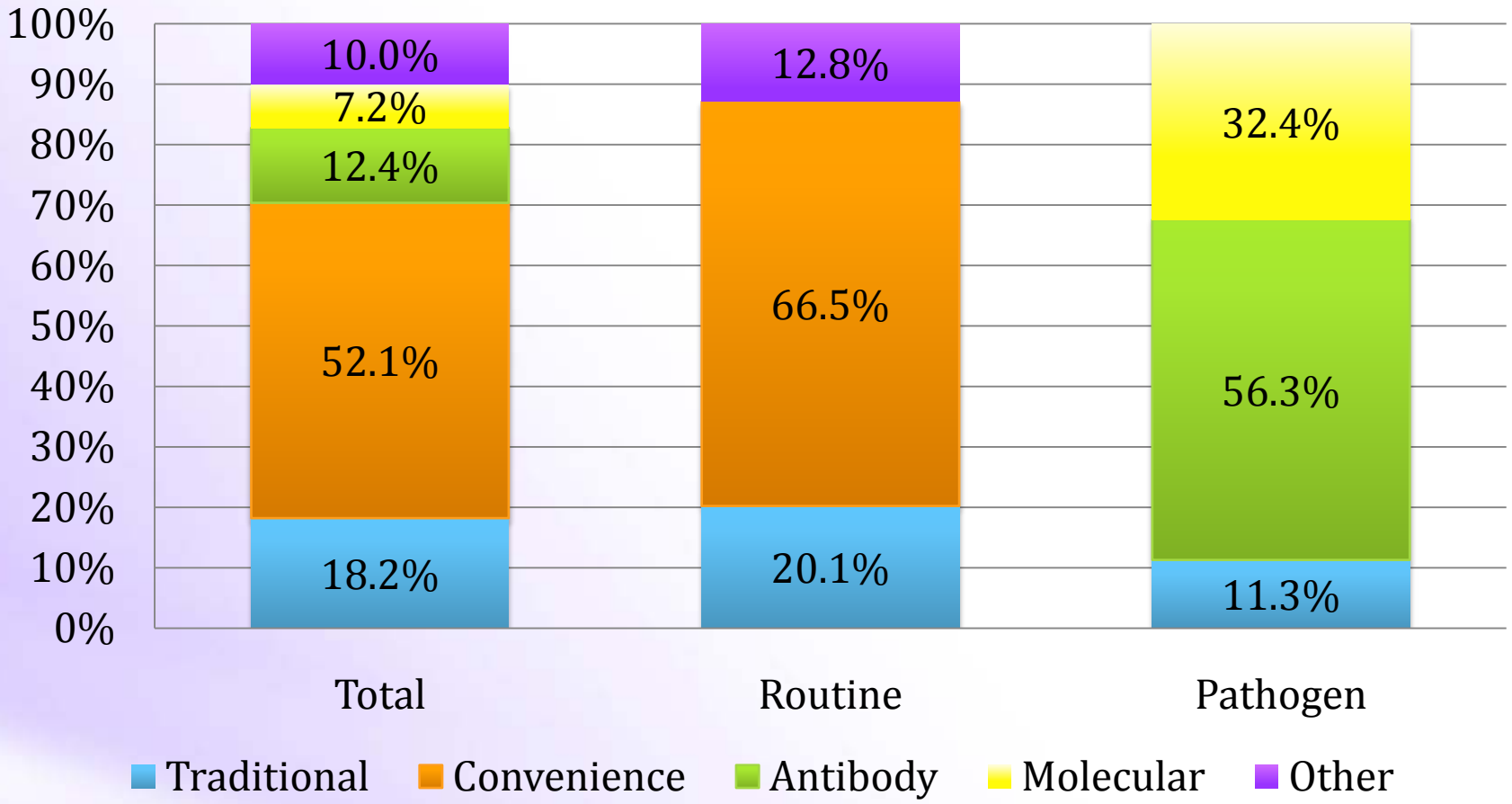
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Microbiology Tests by Food Segment



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2010 Methods Used



Comparative Analysis of Sampling Methods in Ground Beef, Ground Pork, and Raw Milk by Pearson Correlation Coefficient

Method	APC	Redigel	Petrifilm	Spiral P.	Isogrid
APC	1.000	0.999	0.999	0.999	0.999
Redigel	0.999	1.000	0.999	0.999	0.999
Petrifilm	0.999	0.999	1.000	0.999	0.999
Spiral P.	0.999	0.999	0.999	1.000	0.999
Isogrid	0.999	0.999	0.999	0.999	1.000

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Total Cost Analysis per Plate (Per viable cell count[3])

Method	Material and Media Cost	Labor Costs	Total Cost
APC	$2.06 (12.36)	.21 (1.26)	2.27 (13.62)
Redigel[1]	1.16 (6.96)	.21 (1.26)	1.37 (8.22)
Petrifilm[1]	1.16 (6.96)	.21 (1.26)	1.37 (8.22)
Isogrid[2]	3.01 (3.01)	.32 (.32)	3.33 (3.33)
Spiral Plate System*	2.06 (2.06)	.21 (.21)	2.27 (2.27)

Notes:

* Does not include initial cost of equipment (Spiral Plate System ranges from $11,700 to $12,500 including the plater, vacuum system, and colony counter; Isogrid ranges from $2,500 to $4,000 including the line counter, vacuum system, 12 filter heads, 3 clamps, and 100 filters. Approximate costs as of 3-1-88).

1. Cost per plate is reduced by quantity purchased.
2. Does not reflect possible enzyme pretreatment before filtration- cost averages 30 cents per sample for enzyme treatment.
3. Assumes an average of six plates for one viable cell count and necessary dilutions.

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Rapid Microbiological Methods and Demonstrating a Return on Investment: *It's Easier Than You Think*!

By Michael J. Miller
President, Microbiology Consultants, LLC.
American Pharmaceutical Review. **Vol 12. Issue 5. July/August 2009. PP 42-47.**
Russell Publishing Company, Indianapolis, MN.

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Example of Operating Costs for the Conventional Method (CM) and the Rapid Microbiological Method (RMM) for Airborne Particles

	CM	**RMM** Year 1	**RMM** Year 2
Number of tests per year	70,000	14,000	14,000
Total sampling, testing, data handling and documentation resource time per test (hours)	1.00	0.10	0.10
Calculated annual labor (hr)	3,500,000	70,000	70,000
Total Annual Costs	$ 3,675,000	$250,000	$ 466,000

CM used agar base technology. **RMM** used Mie-scattering technology which can detect, size and quantitate both viable and nonviable particles

Miller, Michael J. 2009. **Rapid Microbiological Methods and Demonstrating a Return on lnvestment :It's Easier Than you Think**. *American Pharmaceutical Review*. Vol 12 Issue 5 July/August 2009. Pp. 42-47. Russell Publishing Company. Indianapolis, MN.

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Predictions (1995)

1. Viable cell counts will still be used
    a. Early sensing of viable colonies on agar 3-4 hrs.
    b. Electronic sensing of viable colonies under microscope 2-3 hrs.
    c. Improvement of vital staining to count living cells
    d. Early sensing of MPN

2008 (+) on target

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Predictions (1995)

2. Real time monitoring of hygiene will be in place
    a. ATP
    b. Catalase
    c. Sensors for biological materials
    d. Sensors for chemical materials

2008 (+) on target

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Predictions (1995)

3. PCR, ribotyping, genetic tests will become reality in food laboratories. (+)
4. ELISA and immunological tests will be completely automated and widely used. (+)
5. Dip Stick technology will provide rapid answers. (+)

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Predictions (1995)

6. Biosensors will be in place in HACCP programs. (?)
7. Microarrays, biochips, nanotechnologies will be widely used. (+)
8. Effective separation and concentration of target cells will greatly assist rapid identification. (+)

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Predictions (1995)

9. Microbial alert systems will be in food packages. (+/?)
10. Consumers will have rapid alert kits for pathogens at home. (?)

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Future Developments of Rapid Methods and Automation in Food : A Microbiology Prediction

A. There will be a lot more microbiological systems at molecular levels for identification of normal and defective food samples.

B. More instruments to analyze microbial samples in the food industries.

C. Greater sensitive of information to the molecular level.

D. Less human manipulations and more automation in sample handling.

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Future Developments of Rapid Methods and Automation in Food : A Microbiology Prediction

E. Need to train more scientists and technicians on sampling foods and analyzing food for pathogenic and spoilage microorganisms.

F. Automation in analysis of food samples and reporting data.

G. Instruments to decide pass-fail of food samples for human consumption.

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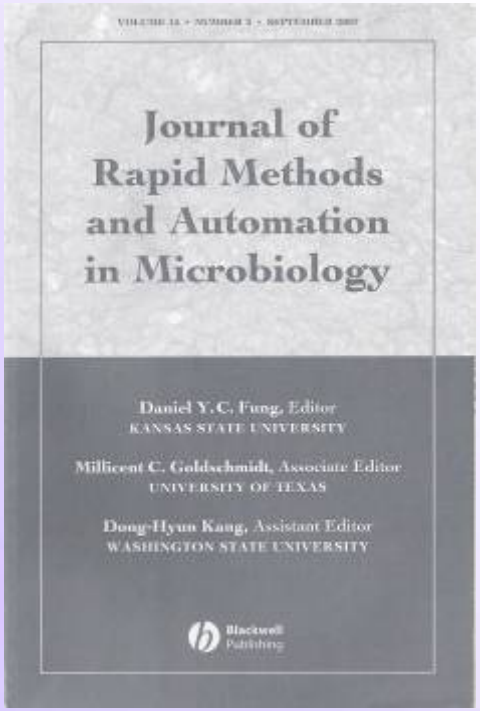
Future Developments of Rapid Methods and Automation in Food : A Microbiology Prediction

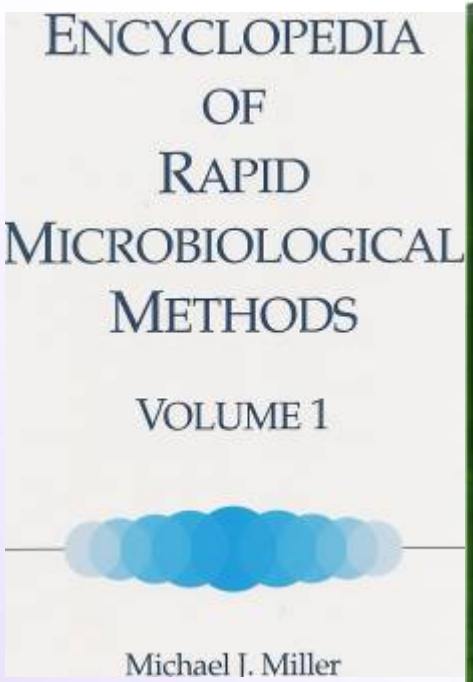
H. More harmonization of microbial protocols among nations.

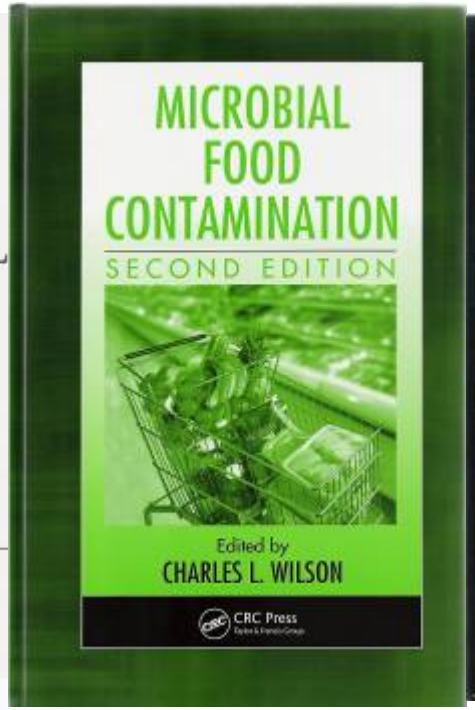
I. More international cooperation in methodology developments and usage.

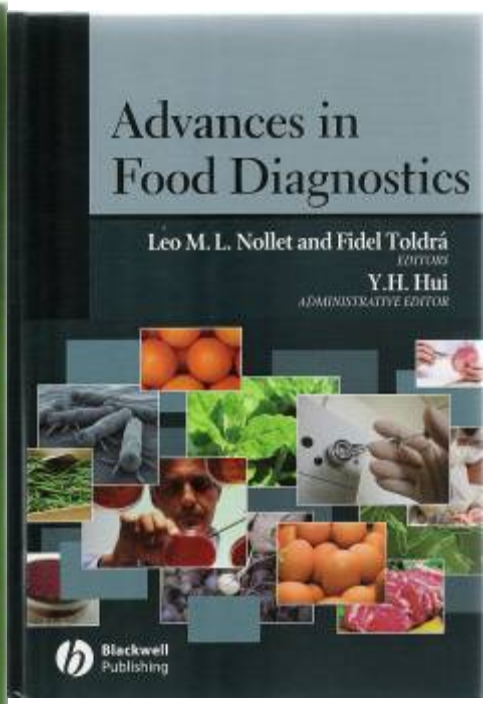
J. More sophisticated consumers who demand safer food and drink supplies internationally.

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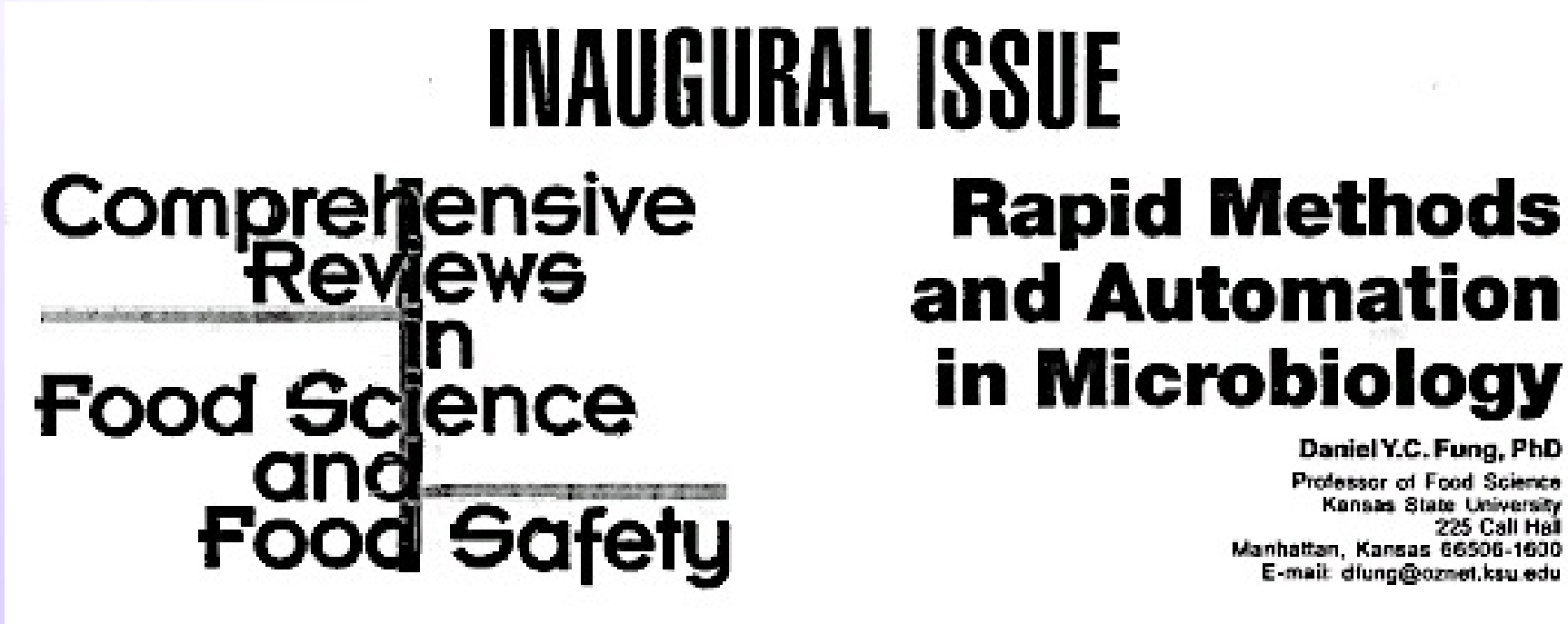








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As of March 2005 the website of Fung's paper received 2,967 individual 'hits'!

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Konza Night at the Rapid Methods Workshop



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