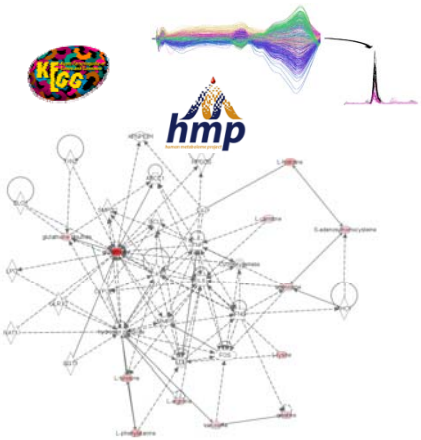
Foodómica: Principios y aplicaciones

Alejandro Cifuentes ***a.cifuentes@csic.es***
Carolina Simó ***c.simo@csic.es***
Virginia García-Cañas ***virginia.garcia@csic.es***



Laboratorio de Foodómica
Instituto de Investigación en Ciencias de la Alimentación (CIAL)
Consejo Superior de Investigaciones Científicas (CSIC)
Nicolás Cabrera 9, 28049 Madrid, España

I Jornadas sobre Foodómica, CIAL, Noviembre 2011

Retos actuales en Ciencia y Tecnología de Alimentos

-Aproximación global a la seguridad, calidad y trazabilidad de alimentos.

-Desarrollo, producción y monitorización de nuevos alimentos (p.ej., transgénicos).

-Producción de nuevos alimentos funcionales (con base científica) para mejorar la salud y/o prevenir enfermedades.

-Estudiar y comprender los efectos de la interacción alimentos-genes sobre la salud (Nutrigenómica).

-Entender las diferentes respuestas de los individuos a los alimentos: dietas personalizadas (Nutrigenética).

Nuevas necesidades, nuevas respuestas: FOODÓMICA

-Aproximación global a la seguridad, calidad y trazabilidad de alimentos.

-Desarrollo, producción y monitorización de nuevos alimentos (p.ej., transgénicos).

-Producción de nuevos alimentos funcionales (con base científica) para mejorar la salud y/o prevenir enfermedades.

-Estudiar y comprender los efectos de la interacción alimento-genes sobre la salud (Nutrigenómica).

-Entender las diferentes respuestas de los individuos a los alimentos: dietas personalizadas (Nutrigenética).

Foodomics

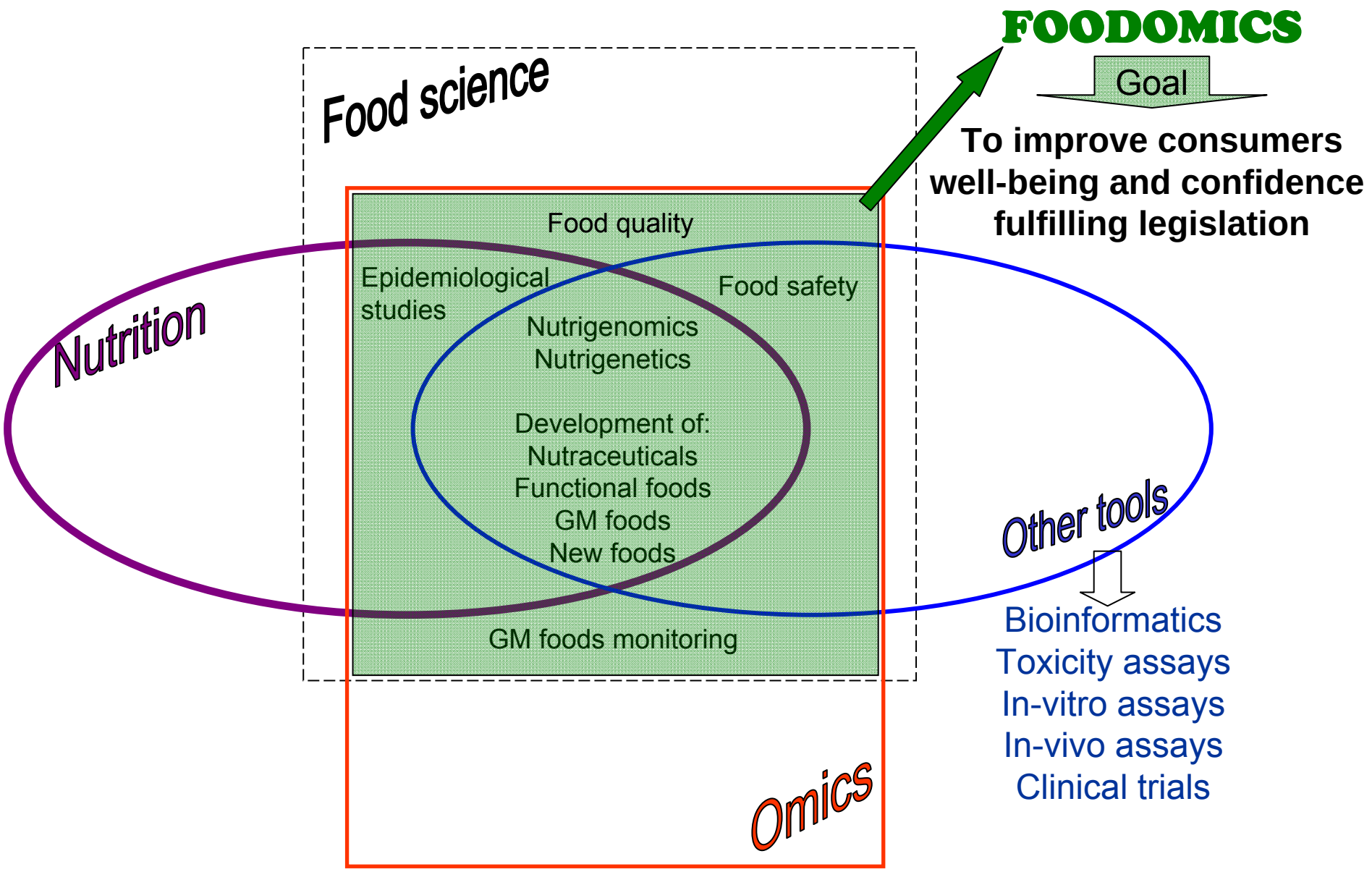
Nuestro grupo ha acuñado el término **Foodomics (Foodómica)** y lo ha definido por primera vez en una revista SCI como: **una nueva disciplina que estudia los alimentos, incluyendo sus múltiples conexiones con la nutrición y la salud, mediante el empleo de técnicas ómicas con el fin de mejorar la salud y la confianza del consumidor.**

(Cifuentes et al.; *J. Chromatogr. A* 1216 (2009) 7109; *Electrophoresis* 31 (2010) 205; *Mass Spectrom. Rev.* 2011, DOI 10.1002/mas).

El interés en Foodomics coincide con una clara tendencia en medicina y biociencias hacia la prevención de enfermedades futuras.

MEJORAR EL BIENESTAR Y LA CONFIANZA DE LOS CONSUMIDORES Y ASEGURAR EL CUMPLIMIENTO DE LA LEGISLACIÓN

Foodomics: A new omics for a new food era



Foodomics papers from our group

-A. Cifuentes
"Food Analysis and Foodomics"
J. Chromatogr. A 1216 (2009) 7109-7110.

-M. Herrero, V. García-Cañas, C. Simo, A. Cifuentes
"Recent advances in the application of CE methods for food analysis and foodomics"
Electrophoresis 31 (2010*) 205-228*

-C. Simó, E. Domínguez-Vega, M.L. Marina, M.C. García, G. Dinelli, A. Cifuentes
"CE-TOF MS analysis of complex protein hydrolyzates from genetically modified soybeans. A tool for Foodomics"
Electrophoresis 31 (2010) 1175–1183

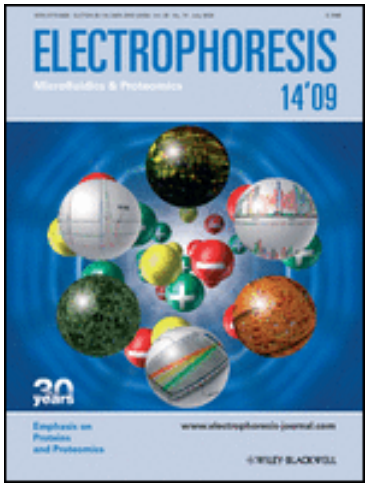
-M. Herrero, C. Simó, V. García-Cañas, E. Ibáñez, A. Cifuentes
"Foodomics: MS-based strategies in modern Food Science and Nutrition"
Mass Spectrom. Rev. 2011, DOI 10.1002/mas

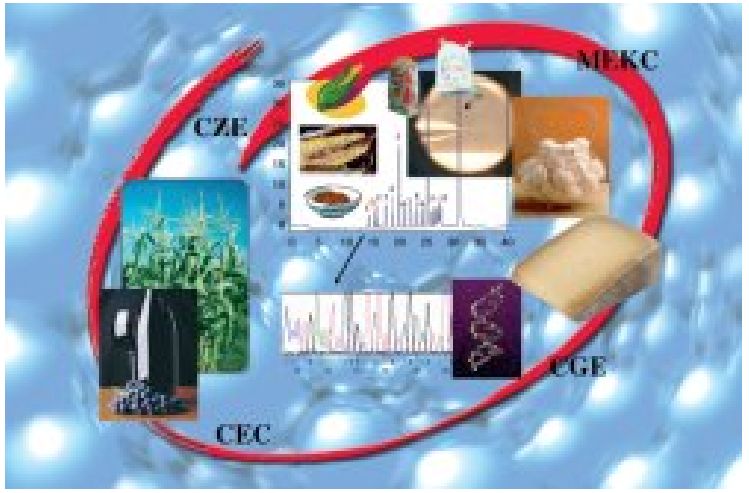
ELECTROPHORESIS

(impact factor: 3.569)

Special issue on:

"Advanced Food Analysis and Foodomics"





Editor: *Alejandro Cifuentes*
a.cifuentes@csic.es

(to be published in summer 2012)

WILEY-BLACKWELL

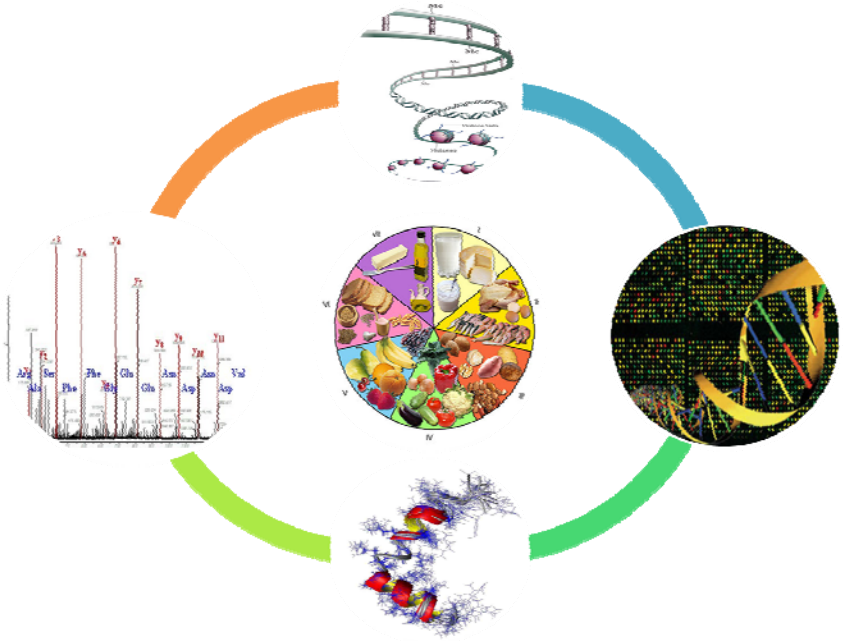
A book is now under preparation on:

"FOODOMICS: ADVANCED MASS SPECTROMETRY IN MODERN FOOD SCIENCE AND NUTRITION"

Editor: *Alejandro Cifuentes*
a.cifuentes@csic.es
(to be published in autumn 2012)

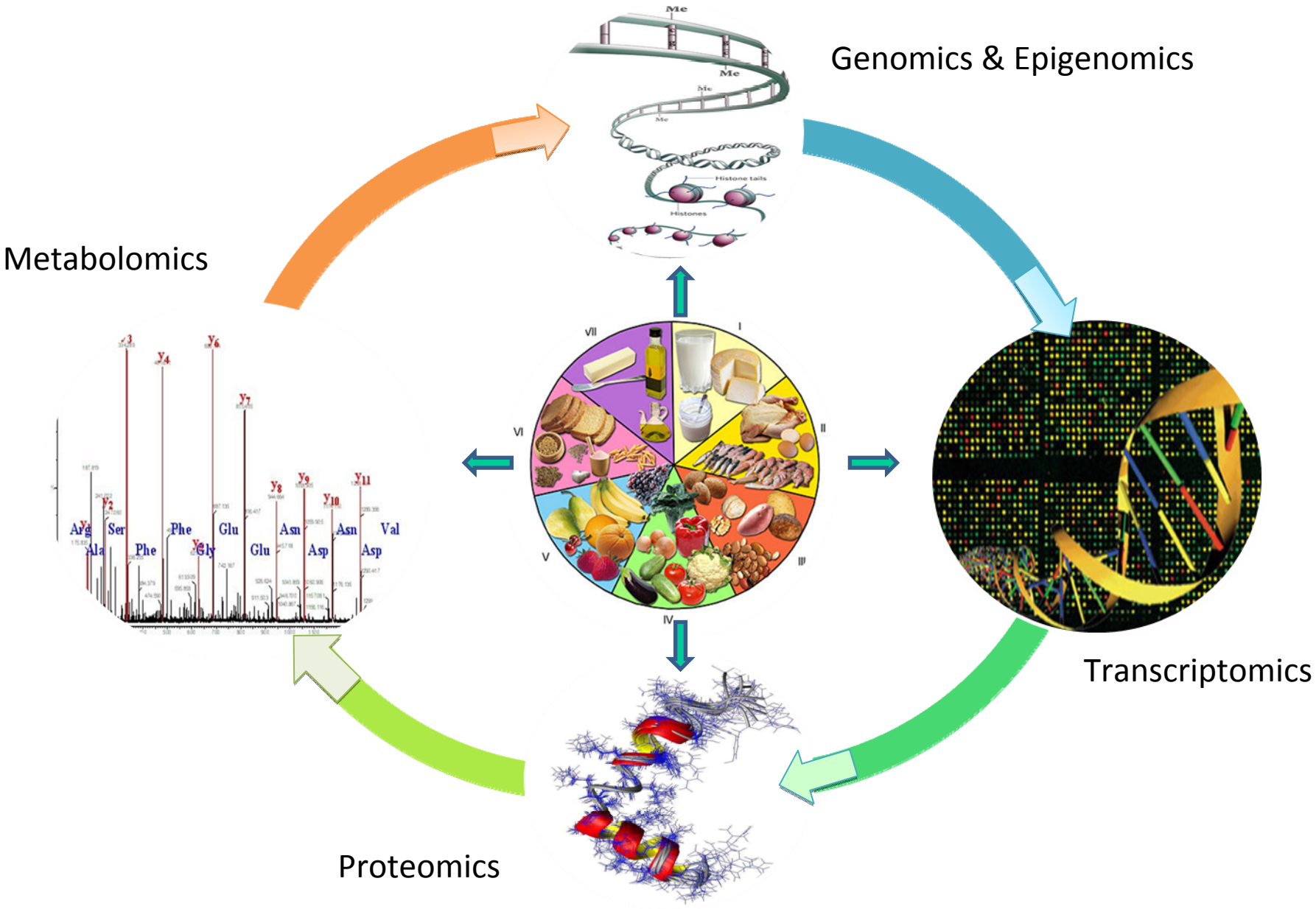
Creación de la Red de Foodómica

(con fecha 11 de Febrero de 2011)



PROYECTO CONSOLIDER
CSD2007-00063 FUN-C-FOOD

Foodomics


Genomics & Epigenomics
Transcriptomics
Proteomics
Metabolomics
Me
Histone tails
Histones
VII
I
II
III
IV
V
VI

Los alimentos del futuro: Algunos retos actuales en Ciencia y Tecnología de Alimentos

-Aproximación global a la seguridad, calidad y trazabilidad de alimentos.

-Desarrollo, producción y monitorización de nuevos alimentos (p.ej., transgénicos).

-Producción de nuevos alimentos funcionales (con base científica) para mejorar la salud y/o prevenir enfermedades.

-Estudiar y comprender los efectos de la interacción alimentos-genes sobre la salud (Nutrigenómica).

-Entender las diferentes respuestas de los individuos a los alimentos: dietas personalizadas (Nutrigenética).

Transgenic maize (Bt corn)

A new CryIA(b) gene (encodes for a *Bacillus thuringiensis* protoxin) is inserted by recombinant DNA techniques into the maize genome.

The new protoxin acts as insecticide against lepidopters.

Transgenic soybean (RR soybean)

A new CP4 EPSPS gene from Agrobacterium (that encodes for a CP4 5-enolpyruvylshikimate-3-phosphate sintase, CP4-EPSPS) is inserted by recombinant DNA techniques into the soy genome.

The new CP4-EPSPS enzyme allows to the GM plant to resist the effect of the herbicide glyphosate.

Can the new inserted genes give rise to other unintended effects?

The European Food Safety Agency (EFSA) recommends the development of profiling techniques to study these unexpected effects.

Second Generation GMOs

THEIR SUCCESS WILL DEPEND (AMONG OTHER FACTORS) ON PROVIDING STRONG SCIENTIFIC EVIDENCES ON:
-THEIR (HEALTH) BENEFITS FOR CONSUMERS
-THE EQUIVALENCE WITH THEIR NATURAL COUNTERPARTS
-NO ENVIRONMENTAL RISKS

Macronutrients:

- Proteins
  - Amino acid composition
  - Functionality, e.g. bread dough
- Carbohydrates
  - Starch composition, inulin, monosaccharides
- Vegetable oils
  - High-PUFA (e.g., oleic acid)

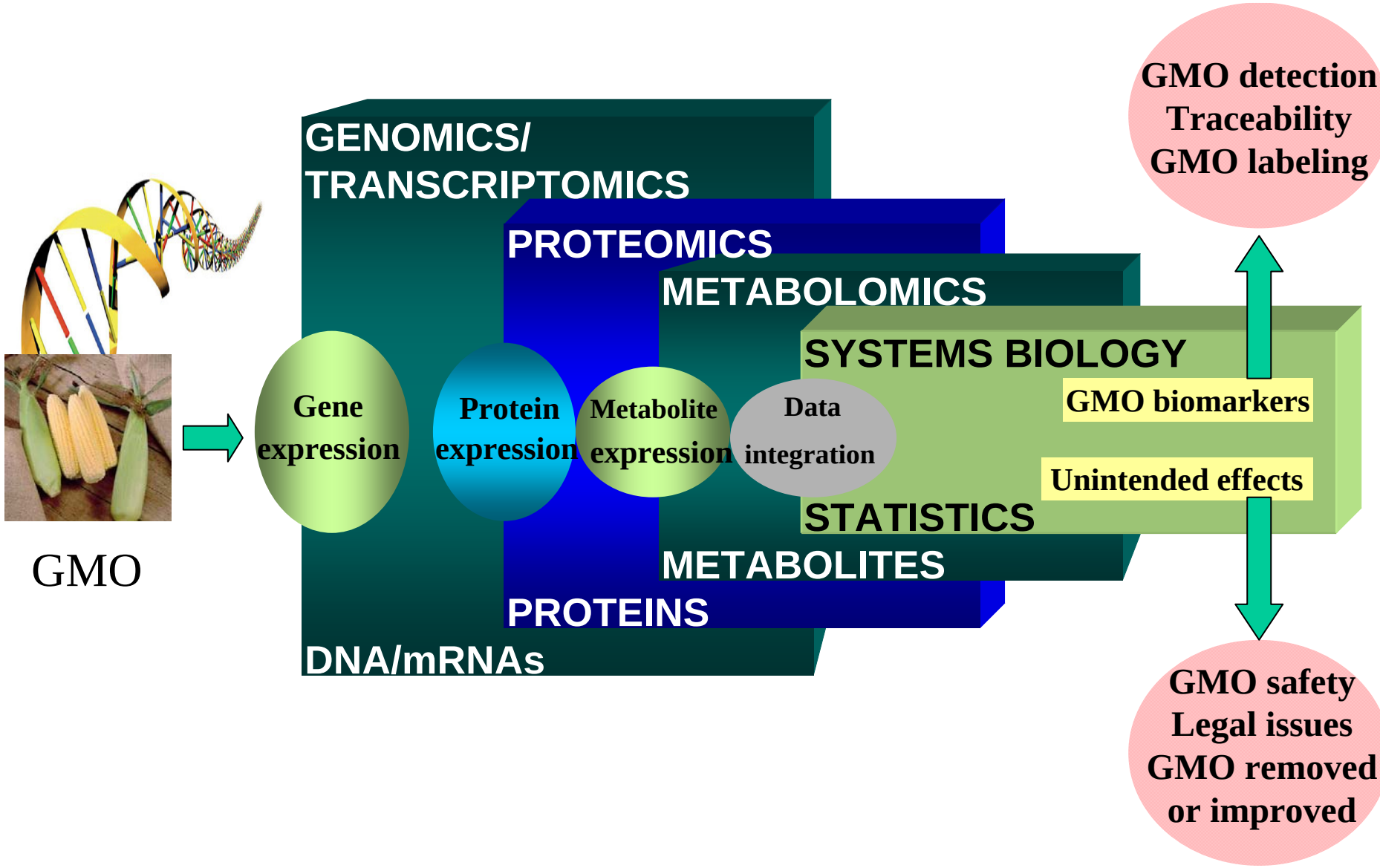
Micronutrients:

- Vitamins, anti-oxidants (Golden rice)
- Minerals (iron-fortified rice)

Miscellaneous:

- Hypoallergenic foods
- Drought tolerance
- Prolonged ripening

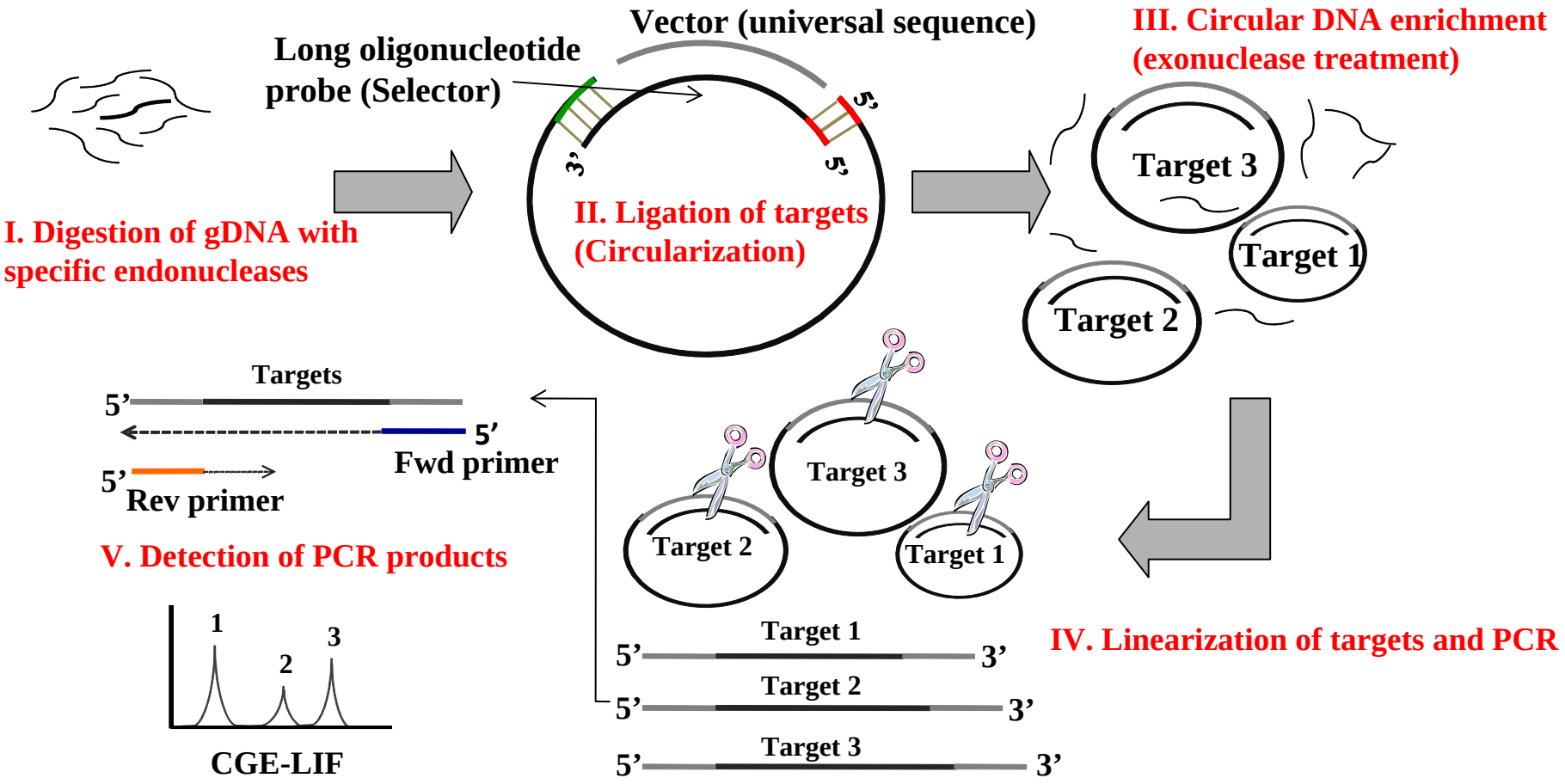
Ideal Foodomics platform for GMO analysis



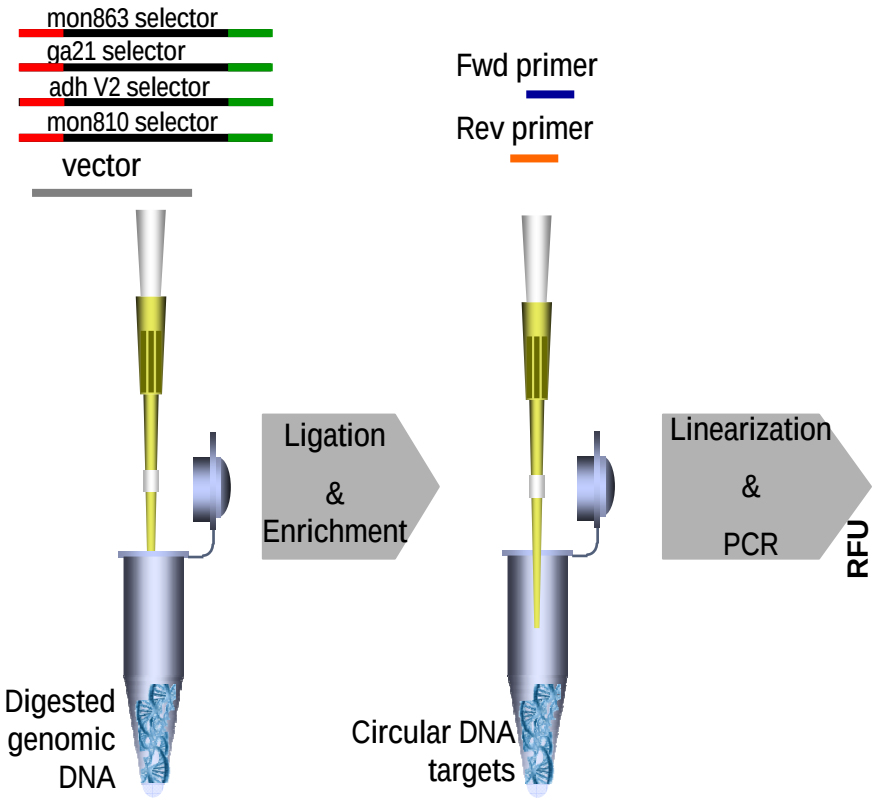
DNA analysis by CGE-LIF

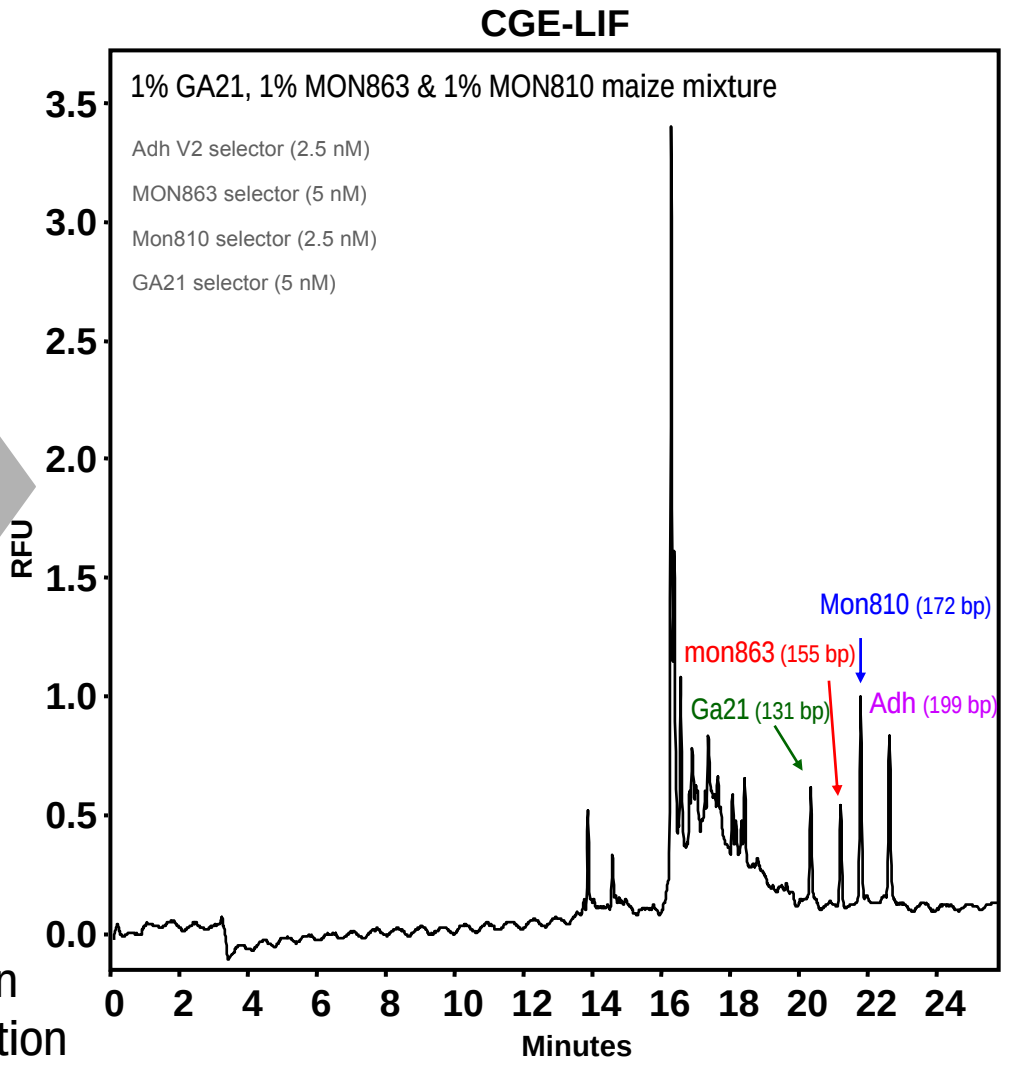
Development of a novel analytical methodology, based on MLGA-CGE-LIF, to simultaneously detect multiple GMOs in a single reaction

Multiplex ligation dependent genome amplification (MLGA)



Simultaneous detection of multiple GMOs with MLGA-CGE-LIF





MLGA is very flexible since the incorporation of new additional selector probes to the ligation step requires minor adjustments of the selector concentration to detect all the DNA target with LODs below 1%

Calculated LODs (S/N=3)

0.2% GA21 maize

0.3% MON863 maize

0.1% MON810 maize

SHOTGUN PROTEOMICS by CE-TOF-MS: GM vs. wild soybean

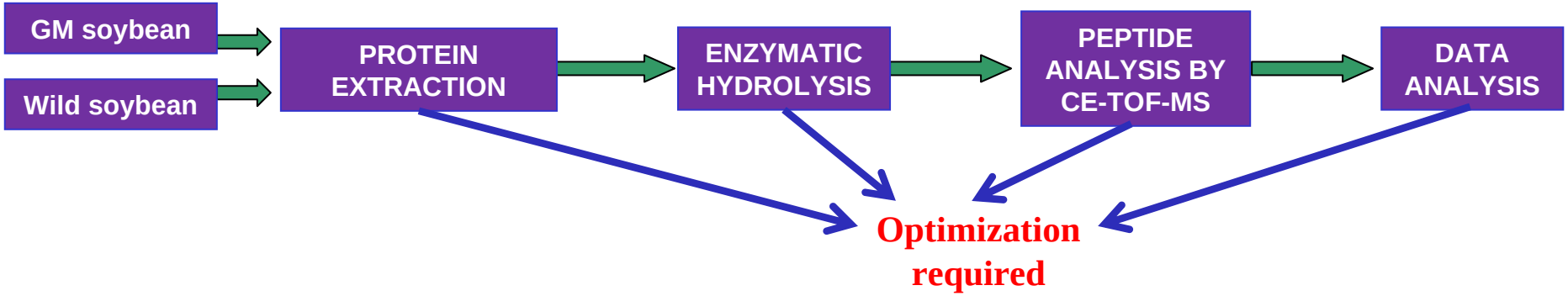
SOYBEAN → Protein content 40 %

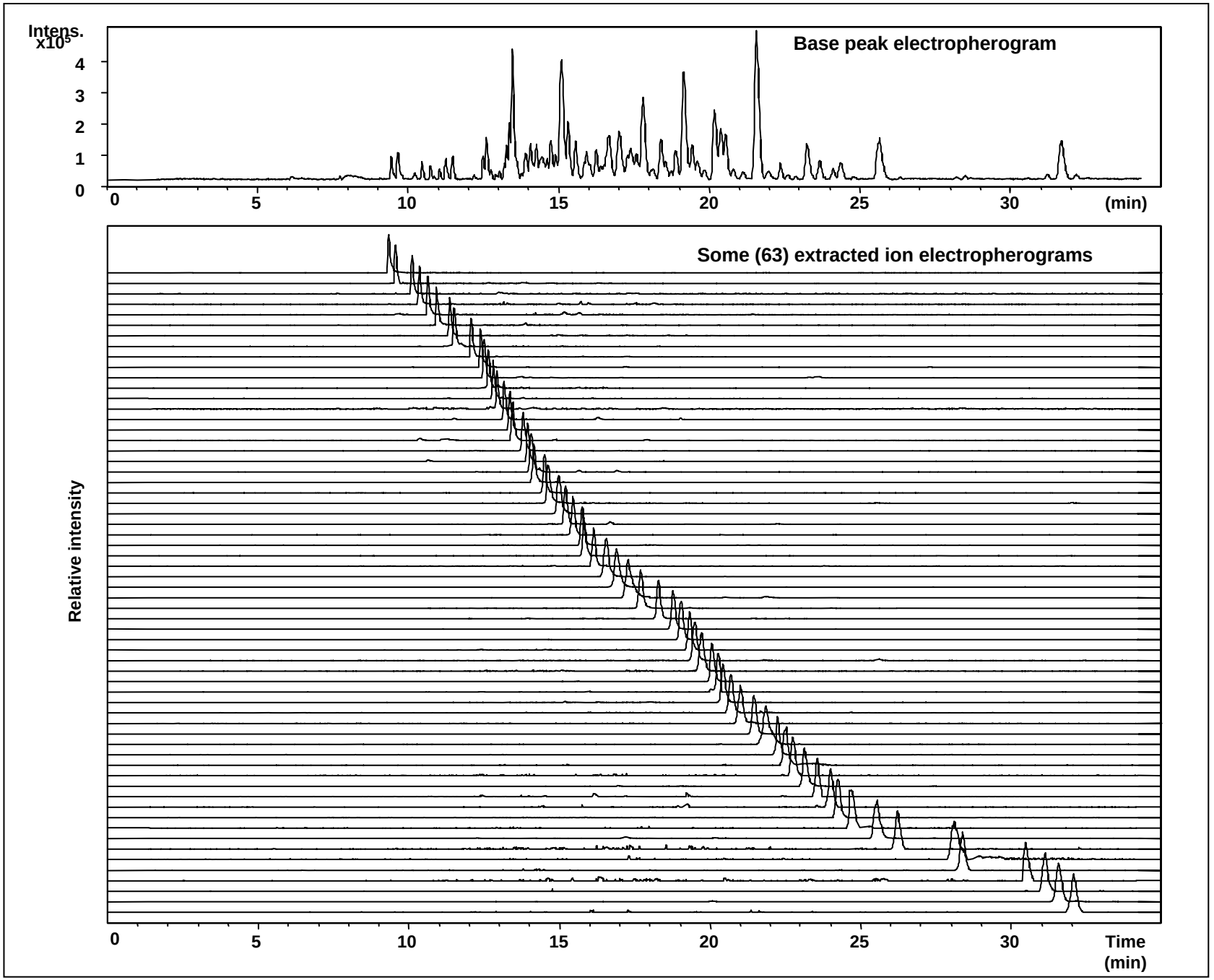
Well-known difficulties in protein separation:

- Different physico-chemical properties *(size, isoelectric point, hydrophobicity)* within a wide range of concentrations.
- Difficult to separate complex mixtures of proteins.
- Challenging identification of (large) proteins.

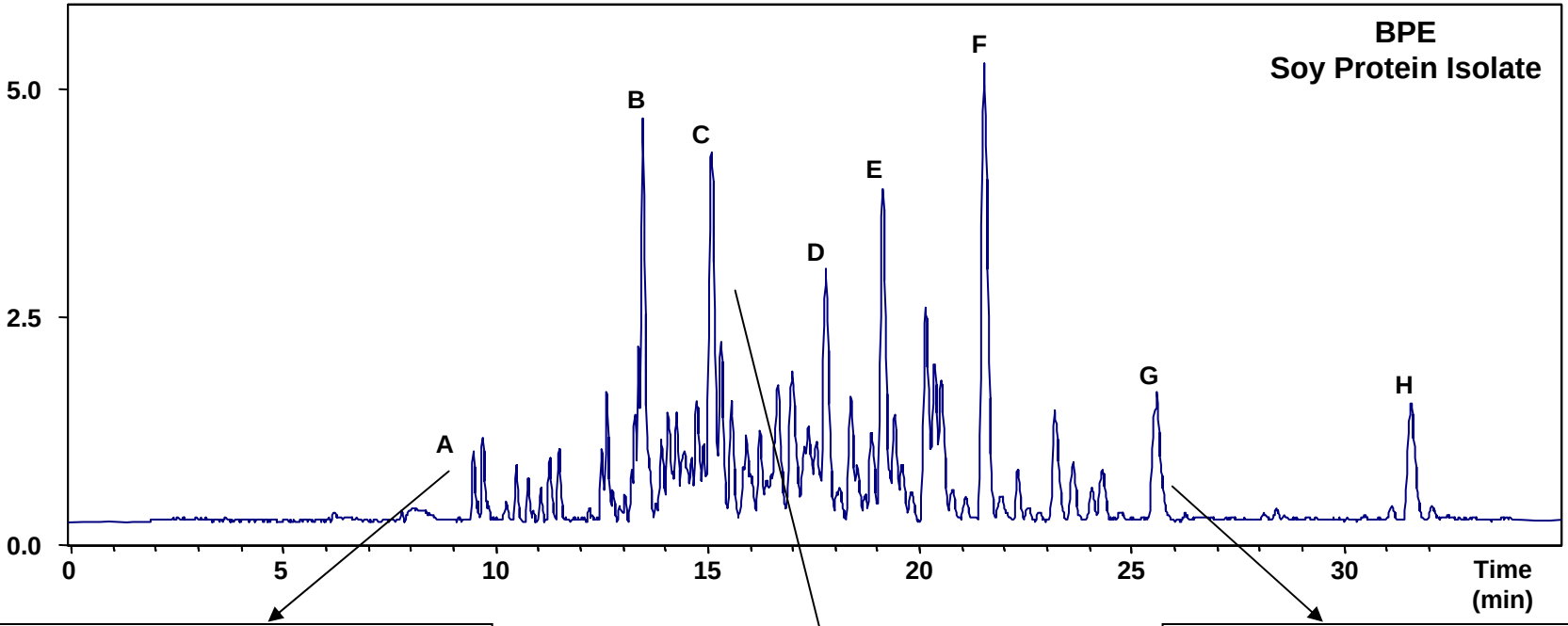
SHOTGUN PROTEOMICS by CE-TOF-MS

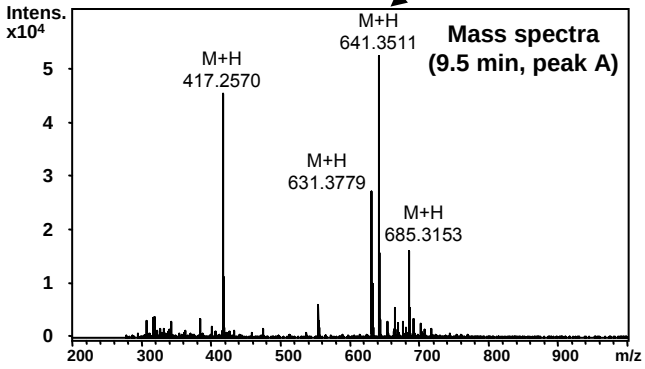
Analysis of peptides obtained after hydrolysis of complex protein mixtures

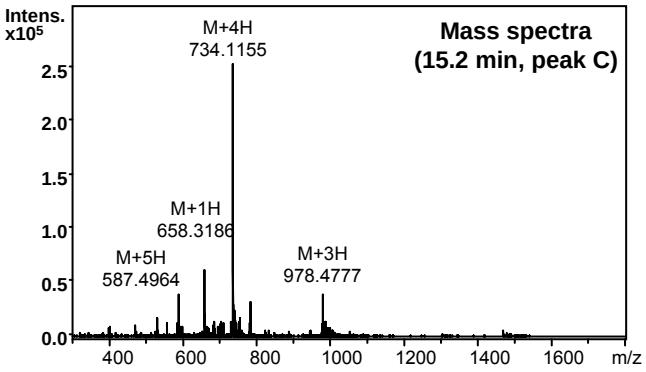


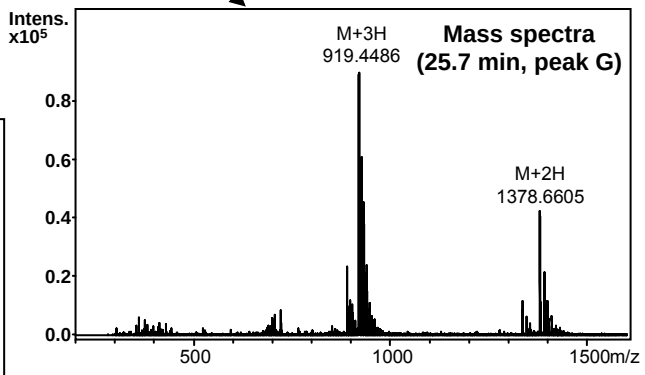

Intens.
x10^5
4
3
2
1
0
Base peak electropherogram
0
5
10
15
20
25
30
(min)
Some (63) extracted ion electropherograms
Relative intensity
0
5
10
15
20
25
30
Time
(min)

CE-TOF MS ANALYSIS UNDER SELECTED CONDITIONS









Complexity of the Peptidic Map

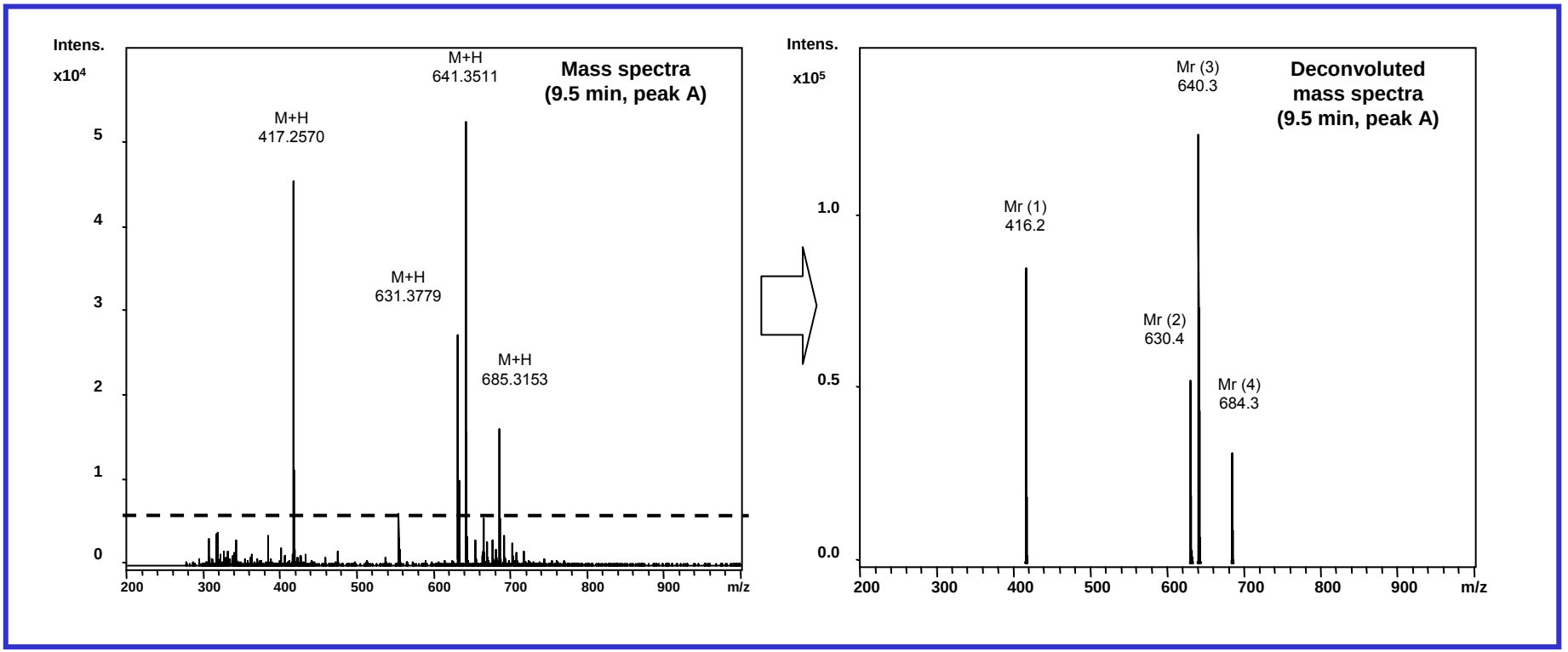
Automated interpretation

OPTIMIZATION OF AUTOMATED INTERPRETATION

Use of deconvolution tool → Study of the peptides obtained in 5 consecutive injections

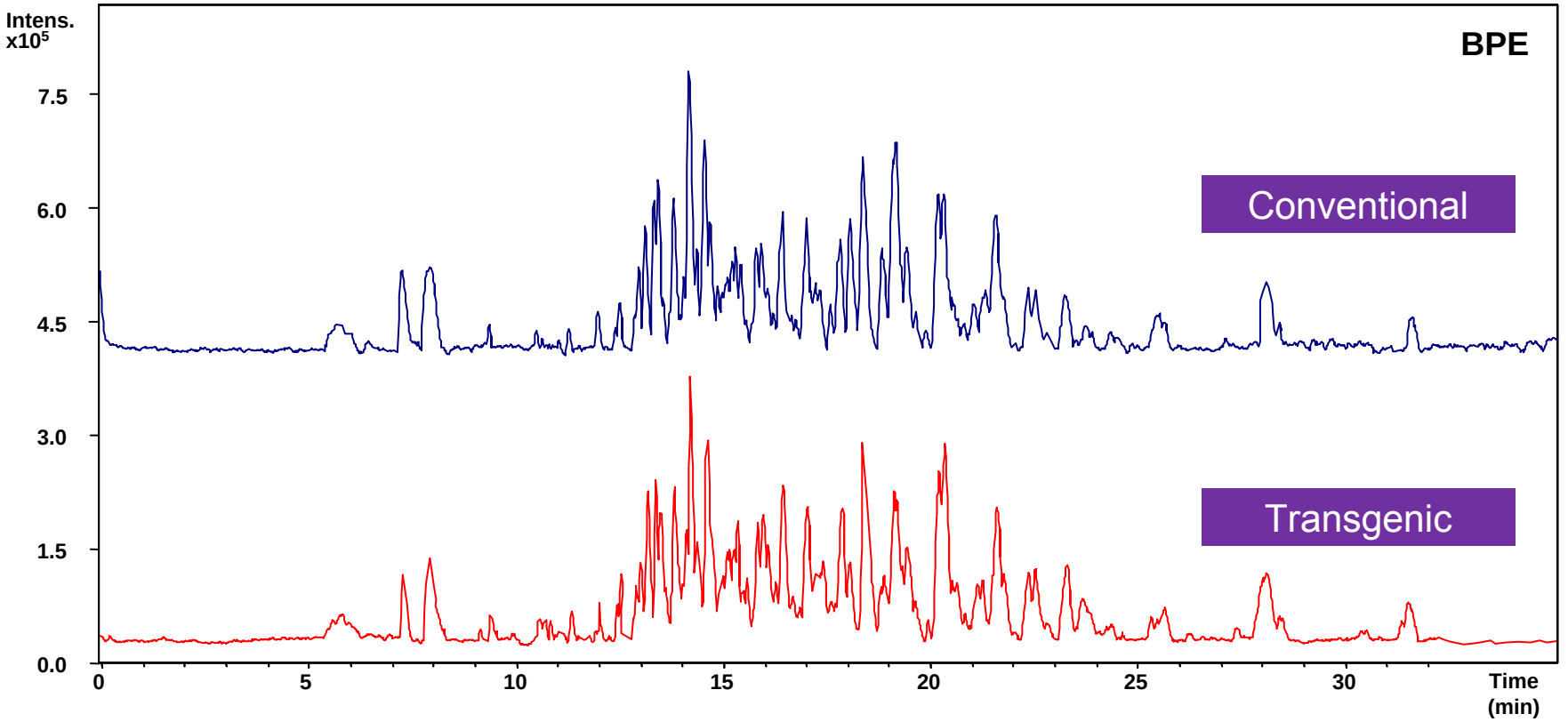
5 % Cutoff → The same peptides were not found in all the injections → ↑ cutoff in order to eliminate unstable signals

15 % Cutoff → The same peptides were found in all injections (simultaneous analysis of more than 150 peptides)



SHOTGUN PROTEOMICS by CE-TOF-MS:

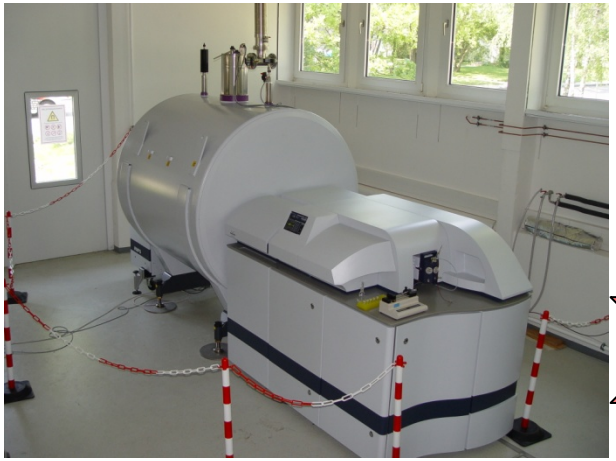
GM vs. wild soybean

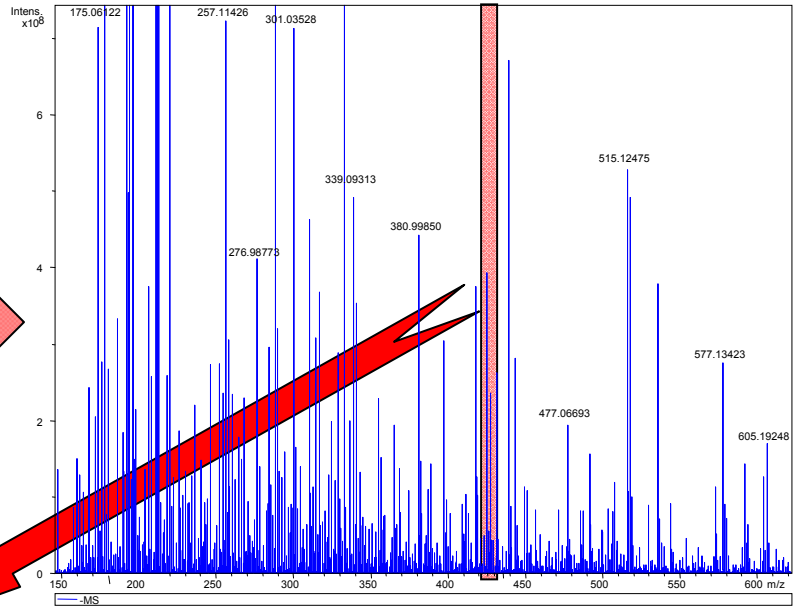


SIMILAR PEPTIDE PROFILE

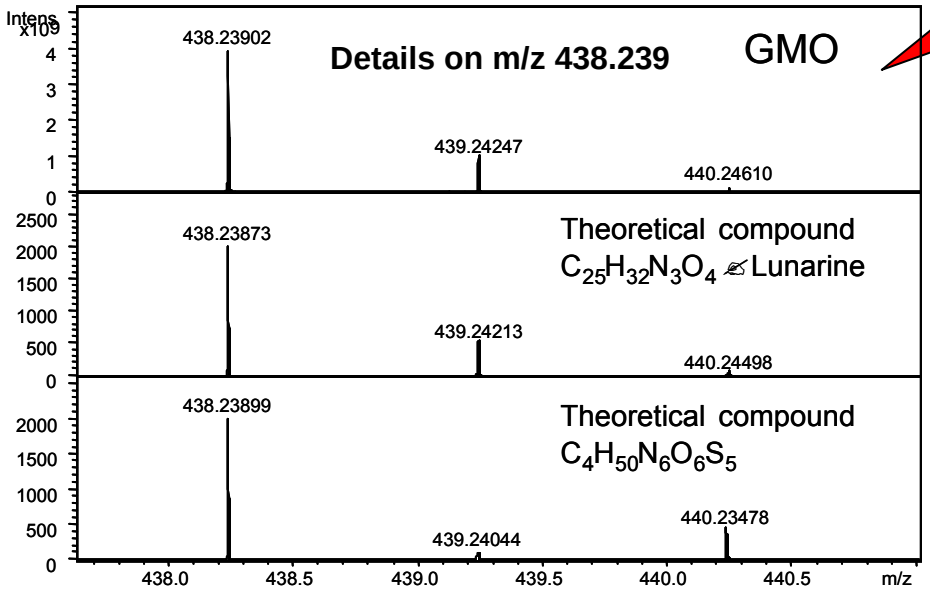
No differences were observed between the GM and wild soybean when a 15% abundance cutoff was used for the automatic deconvolution of the detected ions

METABOLOMICS by FT-ICR-MS, PLE and CE-TOF-MS: GM vs. wild corn



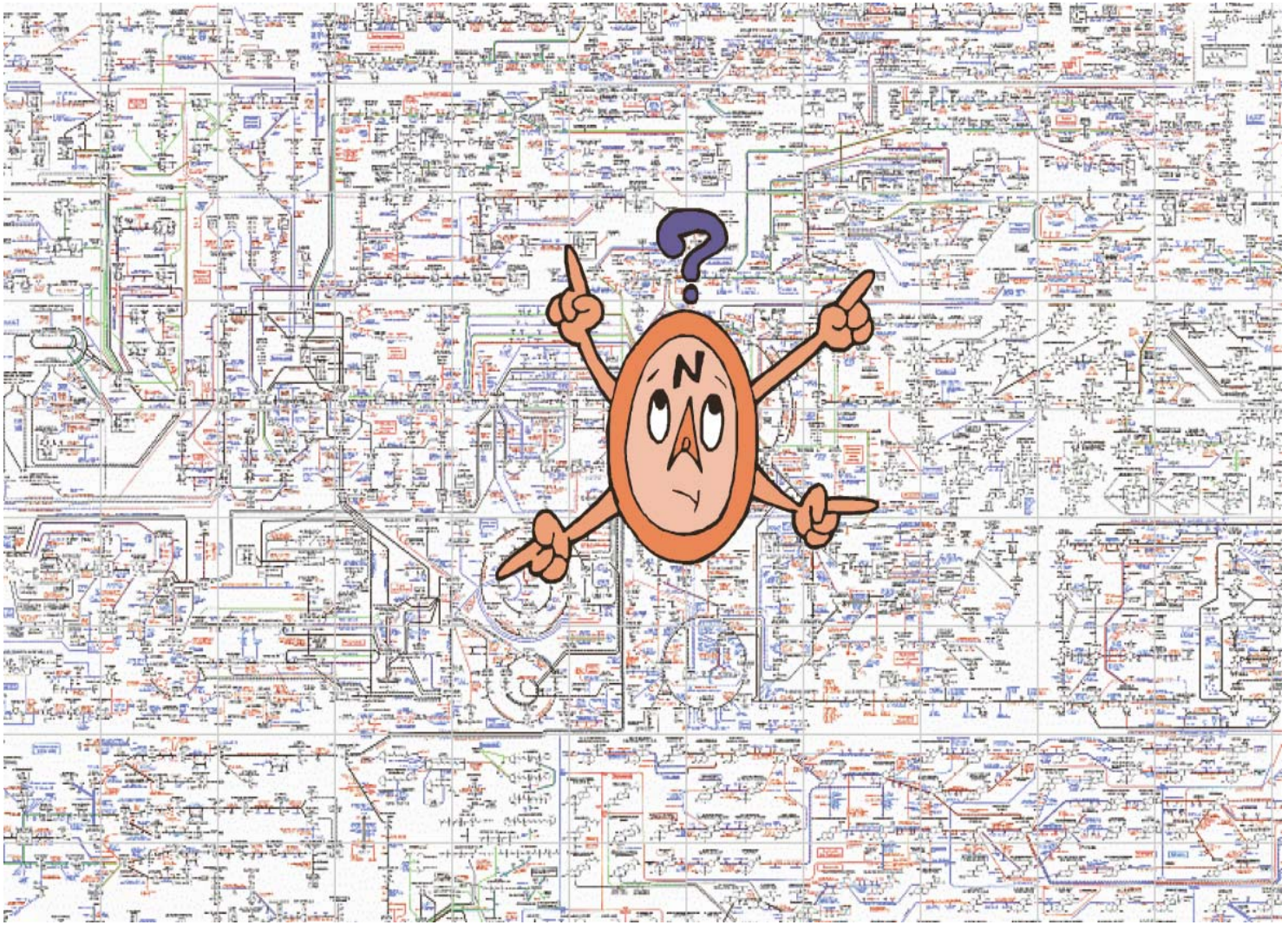


12 tesla FT-ICR-MS at GSF/Munich Germany
P. Schmitt Kopplin



Mass resolution: >600.000 in full scan
Mass accuracy: <0.1 ppm
>10.000 signals/mass spectra
>300 elementary composition assignements
(depending on the extraction conditions)

Although the high resolution and sensitivity provided by FT-MS allows the detection and identification of an impressive number of compounds, PLE and CE-TOF-MS can provide additional information useful to corroborate (or not) the metabolites identification.

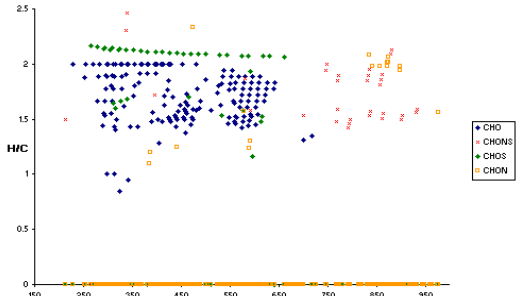


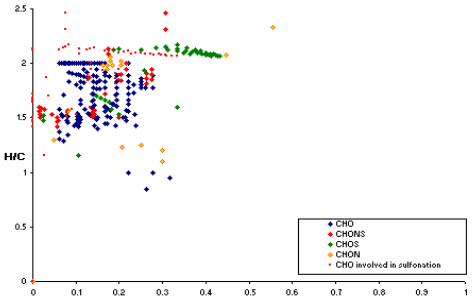
METABOLOMICS by FT-ICR-MS, PLE and CE-TOF-MS: GM vs. wild corn

FT-ICR-MS of wild maize

Mass resolution: >600.000 in full scan; Mass accuracy: <0.1 ppm; Signals/mass spectra: > 10.000
Elementary composition assignements: >300 (depending on the extraction conditions)

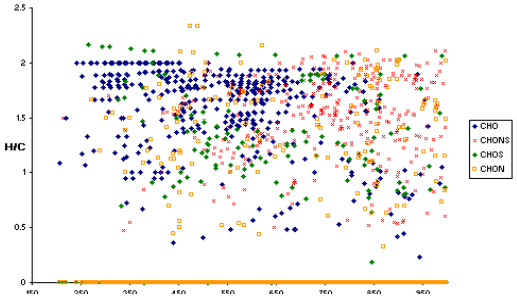
Extraction by PLE with:

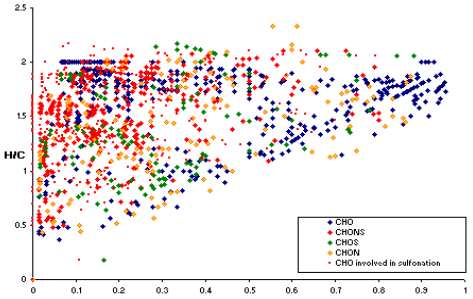




Tot	267
CHO	158
CHOS	60
CHON	17
CHONS	32

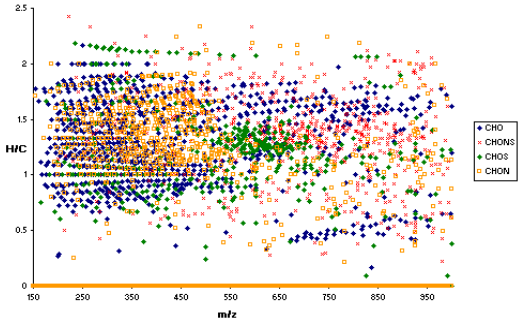
Hexane

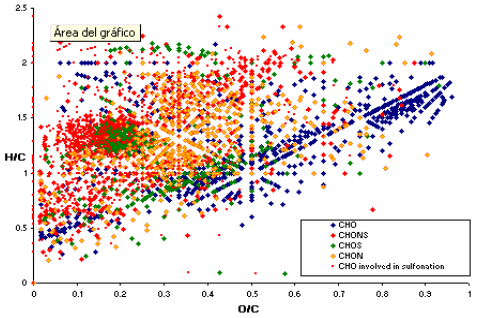




Tot	1222
CHO	393
CHOS	385
CHON	145
CHONS	299

Methanol

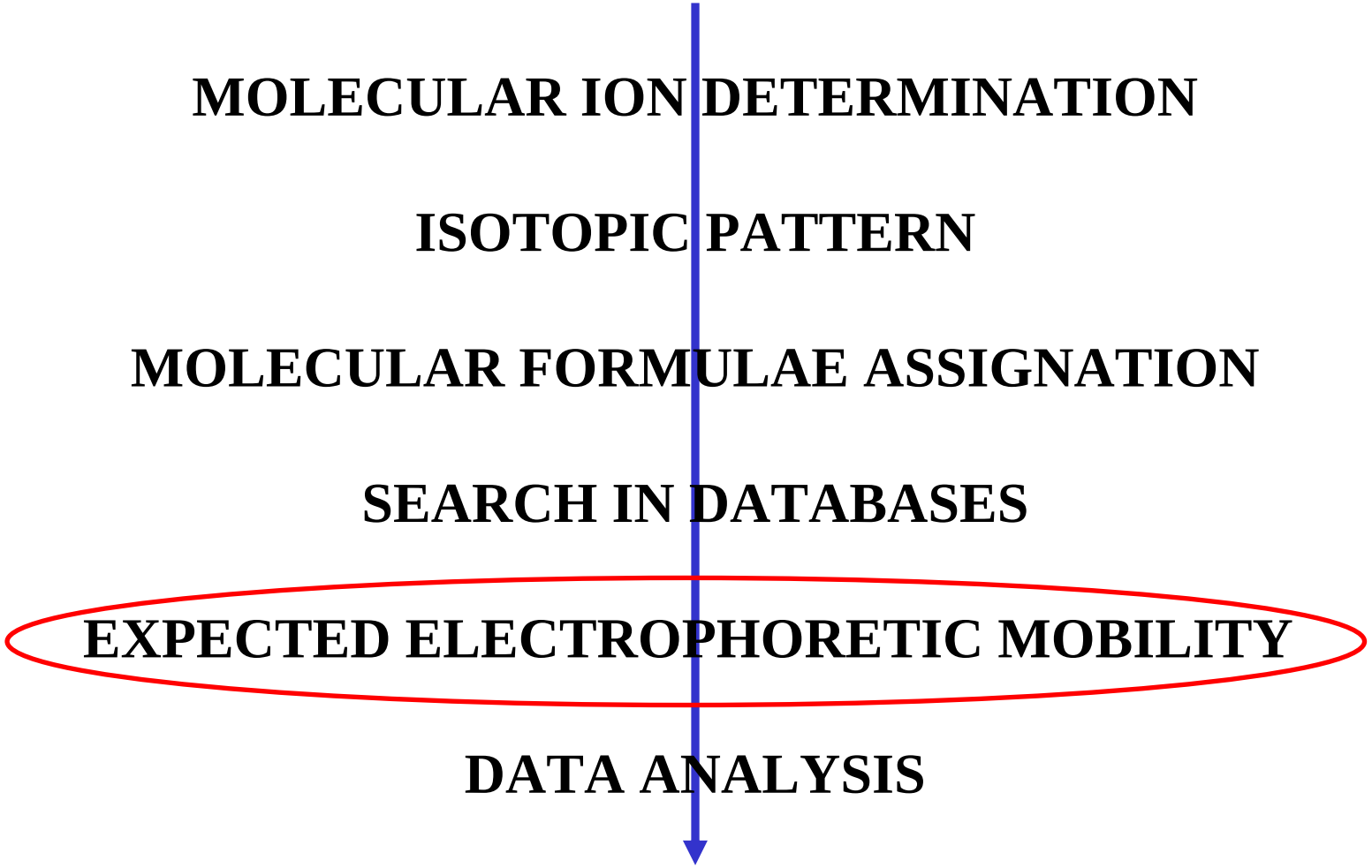




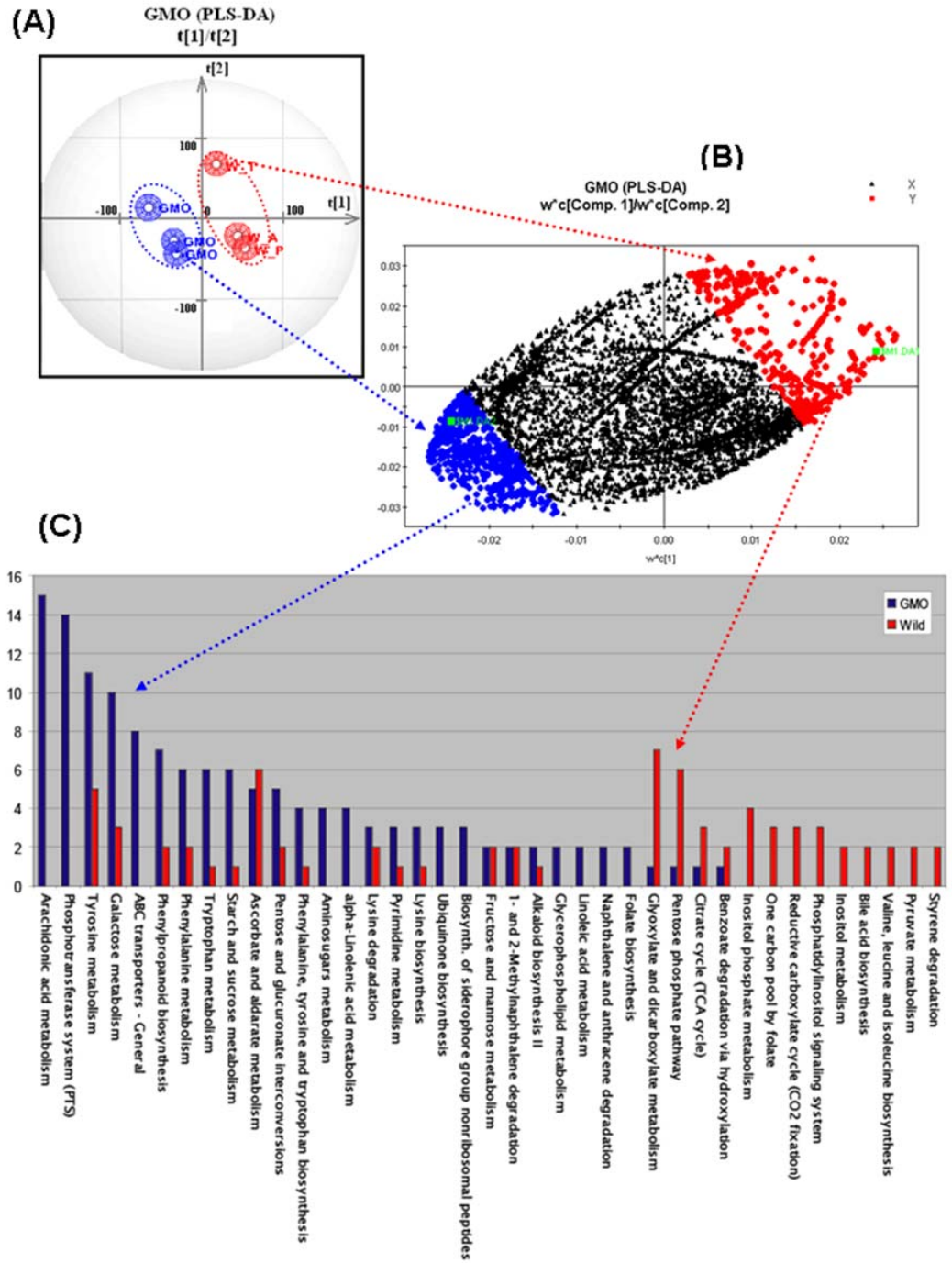
Tot	3111
CHO	907
CHOS	972
CHON	612
CHONS	620

Water

PROCEDURE FOR THE TENTATIVE CHARACTERIZATION OF METABOLITES BASED ON FT-MS and CE-TOF-MS DATA



SAMPLES CLASSIFICATION/BIOMARKERS DETECTION



Partial least squares–discriminant analysis (PLS-DA)(Q2(cum)=0.52 and R2(Y)=0.99) with six different maize varieties analyzed by FT-MS.

Maize samples: A) PR33P66; B) PR33P66 Bt; C) Tietar; D) Tietar Bt; E) Aristis; and F) Aristis Bt.

The score scatter plot underlines a different pattern for the transgenic (they are represenrepresented in blue color) and wild lines (red color). The different properties of the discriminative masses (represented in blue and red in the loading plot) are investigated with MassTRIX.
The model was built up with the data measured in negative mode.

Problem to be solved:
Number of available samples

Publicaciones de nuestro grupo sobre GMOs

-C. Simó, R. González, C. Barbas, A. Cifuentes
***Anal. Chem.* 77 (2005) 7709-7716 ---Proteomics**

-M. Herrero, E. Ibáñez, P.J. Martin-Alvarez, A. Cifuentes
***Anal. Chem.* 79 (2007) 5071-5077---Metabolomics**

-T. Levandi, C. Leon, M. Kaljurand, V. Garcia-Cañas, A. Cifuentes
***Anal. Chem.* 80 (2008) 6329-6335 ---Metabolomics**

- V. García-Cañas, M. Mondello, A. Cifuentes
***Electrophoresis* 31 (2010) 2249–2259 ---Genomics**

-C. Leon, I. Rodriguez, M. Lucio, V. Garcia-Cañas, P. Schmitt-Kopplin, A. Cifuentes
***J. Chromatogr. A* 1216 (2009) 7314-7323---Metabolomics**

-C. Simó, E. Domínguez-Vega, M.L. Marina, M.C. García, G. Dinelli, A. Cifuentes
***Electrophoresis* 31 (2010) 1175–1183---Proteomics**

-V. García-Cañas, C. Simó, C. León, E. Ibáñez, A. Cifuentes
***Mass Spectrom. Rev.* 30 (2011) 396– 416 –Proteomics + Metabolomics**

Los alimentos del futuro: Algunos retos actuales en Ciencia y Tecnología de Alimentos

-Aproximación global a la seguridad, calidad y trazabilidad de alimentos.

-Desarrollo, producción y monitorización de nuevos alimentos (p.ej., transgénicos).

-Producción de nuevos alimentos funcionales (con base científica) para mejorar la salud y/o prevenir enfermedades.

-Estudiar y comprender los efectos de la interacción alimentos-genes sobre la salud (Nutrigenómica).

-Entender las diferentes respuestas de los individuos a los alimentos: dietas personalizadas (Nutrigenética).

Running Foodomics projects at our lab on bioactivity of new functional ingredients on:

Alzheimer

Population study

Biological sample: Cebrospinal fluid (CSF)

In collaboration with **Karolinska Institute** (Stockholm, Sweden)

Diabetic children

Clinical trial

Biological samples: Urine and Plasma

In collaboration with **GSF** (Munich, Germany) **La Paz Hospital** (Madrid, Spain) **Univ. CEU-SP** (Madrid, Spain)

Colon cancer

Human cell lines

Biological samples: DNA, RNA, proteins and metabolites

Leukemia

Human cell lines

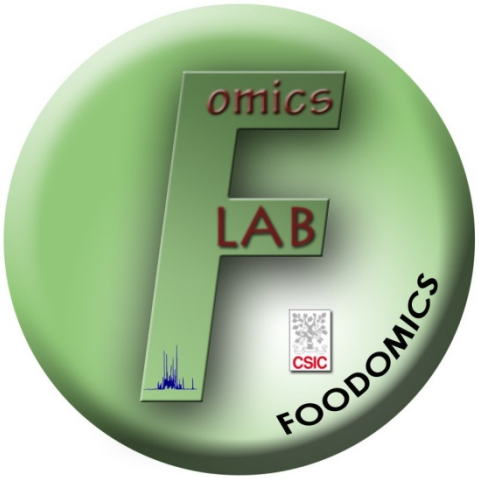
Biological samples: DNA, RNA, proteins and metabolites

In collaboration with **Univ. Miguel Hernandez**, Elche, Spain **University of Granda**, Granada, Spain

CONCLUSION GENERAL

La Foodómica (Foodomics) proporciona una visión global válida para afrontar y resolver los retos actuales en Ciencia y Tecnología de Alimentos y Nutrición.

Gracias!



Para más información:

http://www.cial.uam-csic.es/pagperso/foodomics/


20th International Symposium on Electro- and Liquid-Phase Separation Techniques
ITP2013
Puerto de la Cruz, Tenerife
Canary Islands
6-9 October, 2013
CHAIRMAN: Alejandro Cifuentes (National Research Council of Spain, CSIC, Spain)
CO-CHAIRMAN: Javier Hernández-Borges (University of La Laguna, Tenerife, Spain)