UNIVERSITY OF PARMA
FACULTY OF NATURAL SCIENCES

ACTIVITY REPORT

DEPARTMENT OF ORGANIC AND INDUSTRIAL CHEMISTRY
http://www.unipr.it/arpa/chimorg/

2008
Departmental Data

Staff
Full Professors: 7
Associate Professors: 11
Researchers: 10
Technical and Administrative Staff: 11

Research Activity

Edited by
Prof. Marta Catellani, Director of Department
Prof. Giovanni Sartori

Design and Layout
Dr. Andrea Secchi and Prof. Raimondo Maggi

Copyright 2008-2009 © Dipartimento di Chimica Organica e Industriale, Università di Parma
FOREWORD BY THE DIRECTOR OF THE DEPARTMENT

The major aim of this short booklet is to introduce the groups of the Department of Organic and Industrial Chemistry currently active in research and teaching, and to highlight the Department’s achievements after 40 years of activity.

The Department activity has always focussed on Scientific Research, having clear the concept that a good teaching at the University level, can be only based on high quality research. During the years, the professors and researchers of the Department, supported by the technical and administrative staff, have produced results of high scientific quality both in basic and applied research, which are widely recognised at national and international level.

The Department’s members have been carrying out a considerable teaching activity both theoretical and experimental. Particular attention is being devoted to the experimental Laurea and Doctorate theses, during which the students are followed very closely by their tutors, in order to improve their skill and achieve a solid preparation for their future jobs.

I am confident that the enthusiasm and dedication of all members of the Department will allow to overcome the financial difficulties currently experienced by Italian Universities and maintain for the future the excellence in Research and Teaching attained so far.

Prof. Marta Catellani

Director of the Department of Organic and Industrial Chemistry
CONTENTS

40 Years of Research and Teaching: Historical Notes........................................ 1

The Department of Organic and Industrial Chemistry............................ 3

The Department Research Profiles:

Catalytic Organic Syntheses............................................................... 4 – 7

Food Chemistry................................................................. 8 – 11

Molecular Recognition & Supramolecular Chemistry......................... 12 – 19

Facilities ......................................................................................... 20

Departmental Data (inside front cover)
The Department of Organic and Industrial Chemistry of the University of Parma was established in 1992 in continuation of the Institute of Organic Chemistry founded in 1968.

In 1967 Prof. Giuseppe Casnati was appointed to the chair of Organic Natural Products and in 1972 to that of Organic Chemistry at the Faculty of Sciences and, from 1968 to 1984, he was Director of the Institute of Organic Chemistry. The institute was hosted in the partially destroyed monastery and church of “Paolotti” located at Massimo D’Azeglio Street in the centre of Parma. Under Prof. Casnati's enlightened guide, the first group of academic and research staff began to operate in spite of remarkable logistic and structural difficulties, which were partially overcome by using two prefabricated buildings placed in the centre of an old church.

Starting from 1969, the scientific activity was gradually enriched through the contribution of new members coming from the area of Industrial Chemistry: Proff. Francesco Minisci, Gianfranco Albanesi and Giampaolo Chiusoli. Prof. Casnati soon realised that scientific research had to be performed in modern buildings constructed and equipped according to strict safety rules, possibly outside the city centre. The opportunity was offered by the acquisition by the University of Parma of an estate in via Langhirano, thanks to the efforts of the administrative director Dr. Gian Paolo Usberti. The chemistry building initiated in 1973, formed the nucleus of the new Campus, which nowadays hosts most of the scientific departments of Parma University, facilitating their collaboration and allowing to share complex instrumentations located in the Centro Interdipartimentale di Misure “Giuseppe Casnati”. However, the 1973 oil crisis followed by financial difficulties of the University, caused a delay in the construction of the chemistry building and only in 1985 the Institute of Organic and Industrial Chemistry could move into the new modern structure.
In October 1992, the same year of the establishment of the Department of Organic and Industrial Chemistry, Prof. Giuseppe Casnati, who had dedicated to Science almost 40 years of his passionate activity, prematurely passed away. His initial research line was centred on a biomimetic approach to chemical synthesis, based on taking advantage of non covalent interactions, quite common in biological systems, to obtain highly selective reactions. After his death his pupils Prof. Dossena, Gardini, Marchelli, Pochini, Sartori and Ungaro succeeded to him and pushed forward his ideas in original ways. Over the years the scientific interests of their organic chemistry groups thus evolved toward green chemistry, supramolecular chemistry, food chemistry, biotechnology and nanotechnology while the industrial chemistry group mainly investigated new metal-catalyzed processes, both in homogeneous and heterogeneous phase, and selectivity problems in industrial organic synthesis.

On the 40th anniversary of the teaching and scientific achievements of the groups operating in the Department of Organic and Industrial Chemistry, it seems appropriate to recall the work done which should be a legacy for the future activities. Beyond a rather cold and impersonal list of data, it is important to point out that the scientists of the Department, overcoming the many difficulties, always looked for excellence and creativity in Research and dedication to teaching. More than 500 young students were introduced into the professional world, after being trained to a rigorous scientific methodology during the research work required for their final thesis. The research performed in the Department was financed by public bodies at national and international level and have also attracted the interest of a remarkable number of private institutions and industries. Worth noting is also the skill and enthusiastic dedication of the technical and administrative staff of the Department, in spite of their restricted number with respect to the many duties required by a complex system such as an active academic department. Prof. Gian Piero Gardini succeeded Prof. Casnati in 1984 as Director of the Institute, then in 1992 as Director of the Department. The next Directors were in 1998 Prof. Giovanni Sartori, in 2006 Prof. Rocco Ungaro and, since October 2007, Prof. Marta Catellani.

THE DEPARTMENT OF ORGANIC AND INDUSTRIAL CHEMISTRY

The Department of Organic and Industrial Chemistry reflects a balance between pure and applied chemistry. The Department hosts 8 research laboratories whose facilities support the research in specialized areas, which include Catalytic Organic Syntheses, Food Chemistry, Molecular Recognition and Supramolecular Chemistry.

The current members of the Department are:

Full Professors:
Franca Bigi
Marta Catellani
Arnaldo Dossena
Rosangela Marchelli
Andrea Pochini
Giovanni Sartori
Rocco Ungaro

Associate Professors:
Arturo Arduini
Alessandro Casnati
Roberto Corradini
Mirco Costa
Enrico Dalcanale
Emanuele Dradi
Gianni Galaverna
Raimondo Maggi
Pietro Moggi
Gerardo Palla
Stefano Sforza

Researchers:
Laura Baldini
Augusta Caligiani
Mara Cornia
Chiara Dall'asta
Nicola Della Cà
Andrea Germini
Elena Motti
Francesco Sansone
Andrea Secchi
Tullia Tedeschi

Professor Emeritus:
Gian Paolo Chiusoli

Administrative Personnel:
Letizia Barantani
Donatella Lombardi
Paola Pedretti

Technical Personnel:
Luca Caggiani
Giuseppe Danese
Marco Dardari
Giuliano Ferri
Michela Ghillani
Andrea Giovanella
Costanza Guzzon
Massimo Levati

The background and research of the Department Members are described in the following pages.
Fundamentals of Catalytic Technologies

Main Research Topics
- Catalytic organic syntheses in homogeneous or heterogeneous phase
- C–H bond activation
- CO₂ and CO chemistry
- Aromatic and heterocyclic chemistry

History of the Group
The story of the group goes back to 1975 when Prof. Gian Paolo Chiusoli, formerly research director of the Donegani Institute, the main industrial research Institute in Italy, transferred his pioneering activity in the area of organometallic synthesis and catalysis to a small but enthusiastic group, which in a few years attained a high level of competence and international recognition. Fundamental aspects of catalytic technologies have been studied and significant advances in the synthesis of industrially interesting compounds have been achieved.

Professor Emeritus
Prof. Gian Paolo Chiusoli

Leader
Prof. Marta Catellani

Staff
Prof. Mirco Costa
Prof. Pietro Moggi
Dr. Elena Motti
Dr. Nicola Della Ca’

PhD: 1
Fellowship: 1
Fundings: MUR, University of Parma, contracts with private industries

Chemical structures and images related to catalytic reactions and compounds.
Catalytic Syntheses and Processes

The catalytic syntheses, studied by the group, involve the selective introduction of a variety of molecules from molecular pools into complex structures. These methodologies offer efficient tools for synthetic chemistry, both in terms of yield and selectivity and of environmental compatibility.

Special topics are the following:
- **Syntheses Based on C–H and C–C Bond Activation**
  The studies in progress mainly refer to the activation of usually inert C–H and C–C bonds through metallacycles able to promote the selective functionalization of organic systems. For example it is possible to adapt this new type of syntheses to the formation of the ubiquitous class of selectively substituted biphenyls. Through an appropriate modulation of the catalytic system it is possible to control the incorporation of a variety of molecules in ordered sequences to obtain complex molecules including the pharmaceutically interesting condensed heterocycles, selectively.

- **Carbon Dioxide and Carbon Monoxide Chemistry**
  Other synthetic procedures refer to the introduction of carbon dioxide or carbon monoxide or both into unsaturated molecules. In particular carbon dioxide is introduced directly into organic or organometallic substrates to obtain various classes of compounds spanning from carbonates to carbamates, ureas and heterocyclic compounds. The new technologies aimed at achieving the syntheses mentioned above under conditions favoring industrial application refer to the use of aqueous and non conventional solvents such as micellar systems in water or supercritical fluids such as carbon dioxide. The latter has been utilized for the synthesis of symmetrical and unsymmetrical ureas from amines and carbon monoxide.

The research on catalysis of sequential reactions takes also advantage of the use of metal nanostructures in both the areas described above.

**Catalysts for industrial processes**

The knowledge acquired through the study of catalytic syntheses can be utilized to develop industrially feasible catalytic processes. Current studies have succeeded in working out:

- **New Catalysts for Ambiently Friendly Polymer Transformation Processes**
  New catalysts able to promote a controlled cross-linkage of a polymeric matrix have been studied. They do not contain heavy metals and therefore are compatible with the new legislation.

- **Heterogeneous Catalysts for Dehydrogenation and Oxidation**
  Sol-gel methods have been used to prepare multicomponent mixed oxide catalysts, based on vanadium and niobium as key-elements, and Sb, Mo and Te as other components. Some of these catalysts appear promising for the atom-economic synthesis of basic feedstock such as olefins from parafins by oxidative dehydrogenation (ODH) and acrylic acid by selective oxidation of propane. XRD, FTIR, Raman spectroscopy, TGA, BET, XPS and SEM techniques have been used to investigate on the crystalline phases and other surface properties, and on their correlation with the catalytic activity.

**Selected Publications**

Clean Synthetic Methodologies Group (CSM group)

Main Research Topics
- Heterogeneous catalysis
- Zeolites, mixed oxides, clays
- Supported catalysts
- Nanoreactors
- Continuous flow technology
- Monolithic reactors

History of the Group
The group was founded in 1970 by Prof. Giuseppe Casnati and until 1990 faced the reactivity of ambidental systems developing methodologies to the regio- and stereoselective synthesis of a large series of phenolic fine chemicals, pharmaceuticals and natural products under homogeneous conditions. Since 1990 the exploitation of the heterogeneous catalysis for liquid phase production of fine chemicals represents the underlying theme of the group. The various aspects of the heterogeneous catalysis are deeply investigated taking into account the impact of the catalysis on the sustainable development.

Leader
Prof. Giovanni Sartori

Staff
Prof. Raimondo Maggi
Prof. Franca Bigi

PhDs: 3
PostDocs: 2
Fellowships: 3

Fundings: CIBA, Endura, Henkel, MAP, MUR

Tethering methodology on MCM-41 mesoporous silica
Eco-efficiency by combination of catalysis and nanoscience

The development of sustainable chemistry with the aim of pursuing pollution prevention together with a better industrial performance represents the general mission of the CSM group. In particular the heterogeneous catalysis is exploited to achieve economically efficacious and environmentally harmless production of fine chemicals.

The research mainly focuses on the following topics:

a) Use of commercially available heterogeneous catalysts: different clay materials are effective catalysts for a wide variety of organic reactions; both Brønsted and Lewis acidity play a role in the catalytic activity. Also zeolites, well known microcrystalline porous materials largely exploited in the petrochemical industry, are efficiently applied in the fine chemical production. These solid materials can be modified by doping with suitable cations (Cu, Ag, Fe, Sn) giving catalysts with specific activity.

b) Preparation of convenient mixed-oxides via co-precipitation or sol-gel methodology: these materials show adequate acid, basic or redox properties capable of promoting a large variety of reaction of practical interest.

c) Use of homogeneous catalysts supported on different inorganic and organic polymers: these materials are prepared by tethering a suitable catalyst to a porous rigid system or by hydrolysis and co-condensation of TEOS and a selected functionalized silyl alkoxide. Following the latter methodology it is possible to obtain organic-inorganic hybrid materials with controlled density of linked functions, and to recognize the parameters that affect their catalytic properties leading to the design of improved reaction conditions that are applied to the regio- and stereoselective preparation of fine chemicals.

The best catalytic activity of the supported catalyst is achieved by a synergistic cooperation of the active site with its microenvironment, whose nature can be tailored in a predetermined direction by a delicate modification of the physico-chemical parameters of the solid support. This approach now allows to efficiently combine catalysis and nanoscience and to design the best nanoreactor for each specific reaction.

An efficient technological application of the supported catalysts can be achieved by performing liquid-phase reactions under continuous flow conditions. To this end the preparation and use of monolithic reactors possessing regular channel distribution is under investigation. The group is actually involved in the preparation of new reactors consisting of one single piece of porous material containing the catalytic sites. The application of these new monolithic reactors allows improvement of the catalytic efficiency and saving energy.

Selected Publications
Main Research Topics
- Mycotoxins
- Natural Substances
- Antioxidants
- Cyclodextrin-based receptors
- Chiral and molecular recognition
- D-amino acids
- Proteolysis in food
- Xenobiotics

History of the Group
The research activity of the group developed from the chemistry of natural substances to the design of selectors to be used in HPLC and GC for molecular and chiral recognition in organic and bioorganic chemistry and in food chemistry. Recently, the recognition methods have been extended to the study of the presence, of the role and of the metabolic fate of native and masked mycotoxins and other natural substances (peptides, polyphenols, xenobiotics) in food also on account of the transformations occurring during food processing. One of our main recent research topic has become the study of the interactions between the main food components (proteins, carbohydrates, lipids) and mycotoxins and other natural substances.

Leader
Prof. Arnaldo Dossena

Staff
Prof. Gianni Galaverna
Dr. Chiara Dall’Asta

PhDs: 2
PostDoc: 1
Fellowships: 2

Fundings: EU-Projects, MUR, Regione Emilia-Romagna, Contracts with private industries.
Native and masked mycotoxins in food and feed

We developed several innovative analytical methods for detecting mycotoxins from Aspergillus, Penicillium and Fusarium in different commodities using chromatographic techniques coupled with tandem mass spectrometry or fluorescence detection. In particular, a new method based on alternate isotope-code derivatization assay (AIDA) has been developed. More recently, we became involved in the study of the occurrence of masked mycotoxins. Indeed, mycotoxins may undergo several transformations in the plant and during processing: thus, the final product may contain unknown toxic derivatives which can’t be detected by the common analytical methods. In particular, the metabolic transformation of mycotoxins to less toxic derivatives as well as their binding to macrocomponents such as proteins, starch or lipids, which may be carried out by the plant, is studied, in order to investigate the host-infestant interactions as well as the possible transformations induced by temperature or other processing parameters.

Cyclodextrins as mycotoxin receptors

Cyclodextrins are used as fluorescence enhancing receptors for mycotoxins. The study of the host:guest inclusion mechanism is performed by means of experimental techniques (NMR, Fluorescence, Circular dichroism) and molecular modelling in order to design optimum chemosensor devices. In particular, the use of fluorescence allows for highly sensitive and accurate detection of analytes, even at very low concentrations, minimizing the risk of false negative/positive results usually associated with other rapid tests (e.g. ELISA, lateral flow devices). Cyclodextrins are also studied as chromatographic modifiers both in HPLC and in capillary electrophoresis.

Proteolysis in food

Proteolysis in food is one of the main phenomena which characterizes the ageing process of meat and dairy products (ham, sausages, cheeses): it deeply influences the texture and the flavour of the final products as well as its nutritional properties. We investigated the proteolysis in connection with technological and biotechnological treatments and ageing of food with the aim of identifying markers of processing, ageing, tipicity (molecular DOP) and to correlate the enzymatic activities of the different microorganisms with the peptides and amino acids formed. In this way, the entire production of typical products (Parma ham, Parmigiano-Reggiano, Grana Padano, Felino salami) may be characterized.

Antioxidants in food

The presence and the role of natural antioxidants in food (polyphenols) in connection with agricultural practices (effect of UV light on tomatoes) or processing (effect of membrane processes in fruit juice production) are studied as well as their metabolic fate in humans (resveratrol in wine). Synthesis of different metabolites are performed to study their in vivo distribution and fate.

Selected Publications


Molecular markers for food quality

Main Research Topics
- Functional food, food supplements and nutraceuticals
- Characterization of lipids
- GC-MS of chiral compounds for food quality, processing and ageing
- Metabolomic analysis
- NMR spectroscopy for food typicality and healthfulness

History of the Group
The group has a long-run experience in researches concerning food, with studies aimed at the identification of molecules related to quality, typicality, nutritional values and healthy properties of food, and the evaluation of the changes occurring during processing, seasoning and storage. In particular, several new GC-MS methods were developed to detect molecules interesting as markers of quality. Recently, studies were oriented to the HR-NMR technique, with applications aimed at the determination of food typicality, in combination with multivariate statistical techniques. This experience was extended to lipidic matrices, in order to detect conjugated fatty acids and other functional components.

Leader
Prof. Gerardo Palla

Staff
Dr. Augusta Caligiani

PhDs: 1
Fellowships: 2

Fundings: Most of the research works are carried out with the financial support of local Food Producers and with ministerial funds
**Functional foods and food supplements**

Food for health and well-being is currently an attractive topic for food researchers, food industries and food supplements producers. Therefore we recently became interested in developing procedures for the characterization of functional compounds in food, for examples catechins, isoflavones, lycopene, conjugated fatty acids, polycosanol and in the metabolomic analysis by 1H NMR of food extracts that may present biological activity or are commercialized as food supplements, in order to validate simple and rapid protocols for the food supplements control.

**Characterization of functional lipids in food fraction**

Many analytical methods (GC-MS, Ag-TLC-GC-MS and HR-NMR) were developed for the characterization of unsaturated fatty acids, sterols, polycosanols in oils and fats. Researches are in progress on new varieties of oily seeds (e.g. pomegranate seed oil), on the determination of Conjugated Linoleic (CLA) and Linolenic (CLnA) Acids, which seems to exhibit antitumoral properties, and on sterol oxidation during meat product seasoning.

**GC-MS detection of chiral markers related to food quality, processing and ageing.**

Food constituents are natural substances and, in principle, are expected to be optically pure. Therefore, the detection of the presence of the other enantiomer may be significant for assessing the quality of a food product. Hence we developed simple and rapid GC-MS procedures for the chiral analysis of food components. For examples D-alanine was found to be a marker of microbial spoiling in milk and fruit juices and D-proline an ageing marker for wine and vinegar. D-amino acids were correlated to the roasting process in cocoa beans and hazelnut. Other chiral molecules were found to be markers of quality of wine and vinegar, for example R,S-acetoin and 2,3-butandiols (R,R-, S,S-, and meso-), that slowly change the isomeric ratio during ageing of traditional balsamic vinegar, or (-)epicatechin that epimerizes to (+)catechin during roasting of cocoa products.

**Characterization of typical foods by NMR spectroscopy**

In the past 15-20 years there has been a consistent and widespread growth in the use of NMR in food science, due to the simple sample preparation and the relatively short times of analysis, that allow to examine many samples, as required for food authenticity and quality control. We successfully applied 1H-NMR to food matrices (vinegars, cocoa, soybean etc.) to obtain simultaneous quantitative analysis of many food components (organic acid, amino acids, sugars, alcohols, polyphenols) and to classify food samples by means of multivariate components analysis (metabolomic analysis): in the case of vinegars, metabolomics lead to a correct classification of different samples of balsamic vinegars and traditional balsamic vinegars. Similarly, different lots of cocoa beans were discriminated as genetic variety and geographical origin. Moreover, a 2H-NMR simple method was developed to determine the 2H/1H ratio in vinegar samples, related to the sugar quality of the original must.

**Selected Publications**


Caligiani, A.; Cirilini, M.; Palla, G.; Ravaglia R.; Arlorio, M. *Chirality* 2007, 19, 329
Supramolecular Sensors and Materials Group

Main Research Topics
- Supramolecular sensors
- Self-assembly on surfaces
- Supramolecular polymers
- Artificial Olfactory Systems

History of the Group
Enrico Dalcanale’s team interests are focused on the design and preparation of functional materials, using the self-assembly approach. Over the years the major themes have been: macrocyclic liquid crystals, self-assembled monolayers and LB films, metal-directed self-assembly of coordination cages, supramolecular sensors and adaptive polymers. The group has been involved in studying metal-directed self-assembly of coordination cages, first in solution and then on gold and silicon surfaces. More recently the activity has been extended to the self-assembly of reversible polymeric structures and of multitopic receptors.

Leader
Prof. Enrico Dalcanale
PhDs: 6
PostDocs: 4
Fellowships: 0
Funding
EU (VI FP), MUR, DARPA, Companies
Supramolecular Sensors
Advances in supramolecular chemistry offer many opportunities to design and prepare molecules endowed with superior molecular recognition properties to be used in chemical sensors. Unfortunately, in most cases the complexation properties of synthetic receptors have been optimized in solution, while their use for gas sensing requires mastering molecular recognition at the gas-solid interface. Molecular recognition in the liquid phase cannot be automatically transferred to vapor and gas sensing, since in moving from the vapor to the condensed phase the analyte experiences a dramatic increase in non-specific dispersion interactions, which are negligible in solution. For all these reasons a precise receptor design is required, together with a detailed study of the complexation phenomena both in the gas and solid phase. Several steps are needed: first, compelling evidence of analyte complexation within the receptor layer must be obtained via adsorption isotherm measurements. The combined use of mass spectrometry and X-ray crystallography will respectively provide information about the gas phase and solid state interaction modes. If the dominant interactions in the two phases coincide, the knowledge assumes a predictive value for the receptor performances in sensors.

Self-assembly on surfaces
Self-assembly is the most promising approach to build organic nanostructures on surfaces, leading to hybrid organic-inorganic materials. The idea behind this approach is to exploit the thermodynamic control and reversibility of self-assembly for the error-free generation of 3D architectures, like coordination cages, directly on surfaces, which is one of the key requirements for the development of nanotechnology and molecular electronics. The extension of the self-assembly protocol to technologically interesting surfaces, like silicon, allows to build hybrid inorganic-organic structures featuring selective inclusion and other useful properties. The generation of such complex organic architectures on silicon will be pivotal in developing new integrated devices presenting peculiar optic, magnetic and sensing properties.

Supramolecular polymers
Design and preparation of supramolecular polymers is a topic at the forefront of contemporary chemistry, due to its potential fallout in scientific discoveries and technological applications. The essential feature of this class of polymers is the reversibility of the interactions holding together the constituent monomers. Such reversibility confers two important properties to supramolecular polymers: (i) responsiveness to external stimuli; (ii) self-healing properties. Both features are highly in demand in materials science. We devised and tested a bimodal self-assembly protocol for the generation of a dual-coded supramolecular polymer. Combination of two orthogonal and reversible interactions, namely solvophobic aggregation and metal-coordination, allows precise control at each step of the self-assembly cycle, leading to the formation of rod-like supramolecular architectures.

Selected Publications
Molecular and Chiral Recognition of Biomolecules - Biomedical and Food Applications

Main Research Topics
- DNA and RNA recognition
- Peptide Nucleic Acids
- Chiral Recognition
- Bioactive Peptides and Proteins in Food
- Food Allergens
- Cyclodextrin-based Fluorescent Sensors

History of the Group
The research activity of the group has developed from the chemistry of natural substances to the rational design of selectors able to perform chiral recognition of biomolecules of great interest, such as amino acids, in natural systems and in food. Peptides in food are being studied in relation to food quality and also in connection with the increasingly relevant problem of food allergies. Cyclodextrin-based selectors have been developed for the fluorescence sensing of biomolecules and metal ions. Lately the interest has been focused on the recognition of DNA and RNA by chiral peptide nucleic acids (PNAs). PNA probes have been developed to target DNA and RNA sequence of interest in biomedicine and in food. PNA probes are being used in connection with microarrays, HPLC, CE, MS, CD and fluorescence switch-on devices able to perform diagnostics as well as biomedical applications.

Leader
Prof. Rosangela Marchelli

Staff
Prof. Roberto Corradini
Prof. Stefano Sforza
Dr. Tullia Tedeschi
Dr. Andrea Germini

PhDs: 5
PostDoc: 0
Fellowships: 1

Fundings: EU, MUR, Emilia-Romagna Region, Contracts with Industries.
The Role of Chirality in DNA recognition: Synthesis of Chiral Peptide Nucleic Acids (PNAs) and Applications in Biomedicine

Peptide nucleic acids are polyamidic oligonucleotide analogs with high affinity for DNA and RNA and high sequence selectivity. They have been used in a large number of applications and are tested as candidates for antisense or anti-gene drugs. In this context, we evaluated the properties of modified PNAs carrying stereogenic centers at C2 and/or C5 carbon (figure).

![Diagram of PNAs and DNA interaction](image)

The best performance was offered by a modified PNA with a chiral insert of three lysine-based PNA monomers (“chiral box”) into an achiral chain, which was found to be highly sequence selective. The structure of the complex formed by this modified PNA with DNA in the solid state, represents a good model to explain helical preference and stereoselectivity at the molecular level. Using C2- or C5-substituted PNAs, the stereochemical preferences have been accurately investigated. These results allowed a better design of PNAs for applications in advanced biomedical diagnostics (detection of mutations linked to cystic fibrosis and Alzheimer disease). PNA with anti-gene antitumor activity are presently being developed.

DNA Detection in Food

Peptide nucleic acids (both achiral and chiral) were used for developing highly sequence selective tools for the identification of DNA from food samples. A range of detection techniques (from low- to high-tech) have been used. In particular, using the microarray technology multitracer assays were developed for genetically modified organisms (GMOs), food allergens (hazelnut, peanut) and for olive cultivar identification in extra-virgin olive oil samples.

New LC/MS methods for the detection of biomolecules

New LC/MS methods have been developed for lipopolysaccharides, oligonucleotides and peptides. The methods are currently being applied to the rapid analysis of the oligopeptide fraction (<10kDa) in food (cheeses, hams). Biological activities of small peptides in foods are also under investigation.

Cyclodextrin-based Enantioselective Fluorescent Sensors

Using the cyclodextrin scaffold, several fluorescent receptors were obtained, which were shown to perform fluorescence sensing of organic molecules and metal ions. A series of derivatives were shown to perform enantiomeric recognition of amino acids and derivatives. This effect was utilized in multiple fluorescence read-out systems performing very fast and simple enantiomeric analysis.

Selected Publications

From Supramolecular Chemistry to Nanoscience

Main Research Topics
- Molecular Machines and Devices (Rotaxanes and Pseudorotaxanes)
- Synthesis of Metal Nanoparticles
- Supramolecular Sensors for Anions
- Supramolecular Polymers

History of the Group
Our group has a recognized experience in the design, synthesis and structural characterization of calixarene compounds for their use in the field of Supramolecular Chemistry. The main research topics cover the synthesis of receptors for the selective binding of neutral and charged organic species, the preparation of rotaxane and pseudorotaxane compounds based on calix[6]arenes. More recently their activity has been oriented to the preparation of gold monolayer protected clusters (Au-MPCs) having calix[4] and calix[6]arene compounds in the protecting organic shell.

Leader
Prof. Andrea Pochini

Staff
Prof. Arturo Arduini
Dr. Andrea Secchi

PhDs: 2
PostDoc: 0
Fellowships: 2
Fundings: EEC, MUR
Calix[6]arene-based Rotaxanes and Pseudorotaxanes

*Pseudorotaxanes* and *rotaxanes* are very interesting and promising tools for the construction of working devices and molecular machines. In simple instances a *pseudorotaxane* can derive from the assembly of two distinct components: a large enough macrocycle which acts as a wheel and an acyclic component which, by threading the wheel, acts as an axle. The insertion of two bulky stoppers at the ends of the axle inserted into the wheel yields a *rotaxane*. Because of the large number of possibility to insert functional groups and binding sites onto both rims of the calixarene skeleton, the synthesis of *rotaxanes* or *pseudorotaxanes* having a calixarene as wheel could contribute to the development of new molecular devices having properties governed by a wider range of control elements. In the solid state such compounds are stabilized by a combination of several supramolecular interactions that involve all districts of the wheel. The particular structure of the triphenylureido calix[6]arene, in which different chemical information are inserted onto the two distinct rims, can be exploited as control element to guide the threading process of viologen-based axles. The particular structural features of this compound can be also exploited to allow the passage of larger species to yield channel-like structures.

Gold Monolayer Protected Clusters Based on Calixarenes

Over the past decade, so-called monolayer protected clusters (MPCs) of gold have been studied extensively owing to their extreme stability and the plethora of tunable properties that are controlled by the particle size and by the ligand chemistry. The stability is usually achieved by the use of thiolate ligands, which form a protective shell around the particles to which they are attached by the strong Au–S interaction. Recently, the introduction of recognition elements onto MPC surfaces enabled the manufacturing of nanoscale devices with potential applications as sensors, switches and new materials having tunable properties. In A very attractive topological property of MPCs is the possibility to anchor on their surface a discrete number of suitable receptors in a radial tri-dimensional arrangement. In this context thiolate calixarene derivatives have been used for the synthesis of Au MPCs which have shown interesting recognition abilities both in organic and water solvents.

Selected Publications


BioNanotechnology Group

Main Research Topics
- Self-Assembly
- Biologically active molecules based on molecular recognition
- Biosensors and Biomimetic catalysts
- Targeted diagnostics and therapeutics
- DNA non-viral vectors

History of the Group
The group has pioneered the chemistry of Calixarenes and their use in Supramolecular Chemistry. From the late seventies until the year 2000 the attention was mainly devoted to the development of calixarene-based selective ionophores, luminescent probes and molecular devices, whereas, more recently, the interest has been focused on biomolecular recognition, nanotechnology and supramolecular catalysis. Remarkable results are the design and synthesis of ligands for the removal of $^{137}\text{Cs}$ from radioactive waste, DNA delivery systems, lectin inhibitors and artificial nucleases.

Leader
Prof. Rocco Ungaro

Staff
Prof. Alessandro Casnati
Dr. Francesco Sansone
Dr. Laura Baldini
Dr. Mara Cornia

PhDs: 2
PostDoc: -
Fellowships: 2


Multivalent Calixarene Ligands in Bionanotechnology
Multivalent Peptido and Glycocalixarenes
Thanks to the presence of many reactive positions at the lower (OH groups) and at the upper rim (aromatic nuclei), calix[n]arenes are particularly attractive for the synthesis of ligands which exploit multivalency to obtain new supramolecular functions for biological and nanotechnological applications. We have synthesized calixarenes functionalized with carbohydrates (glycocalixarenes) and studied their interactions with specific lectins. Efficient inhibition of cholera toxin and galectins has been achieved using glycocalixarenes with exposed sugar units of different number and nature. In the case of cholera toxin the inhibition is remarkably high since the presence of a divalent calixarene ligand can increase up to 4000 times the affinity for the protein in comparison to a simpler monovalent ligand. On the other hand, calixarenes functionalized with amino acids (peptidocalixarenes) are able to form self-assembled nanotubes or chiral dimeric capsules, potentially useful for drug delivery and gas storage.

DNA condensation and cell transfection
Multivalent, water soluble guanidinium calixarenes are able to efficiently condense DNA and give cell transfection in a way which depends on the lipophilicity and conformational mobility of the macrocycle. The transfection efficiency can be predicted on the basis of Atomic Force Microscopy images (Figure 3). Calix[4]arenes blocked in the cone conformation condense a single plectoneme of pEGFP-C1 on mica giving small and compact aggregates (Fig. 3b) which can penetrate the cell membrane. On the other side, the mobile calix[8]arene derivatives interact with several plectonemes originating large gorgon-like structures (Fig. 3c) unable to cross the cell membrane.

Artificial nucleases
Copper (II) complexes of nitrogen containing ligands anchored at the upper rim of cone calix[4]arenes cleave RNA substrates with high efficiency (nearly 10^6 times faster than the background hydrolysis), showing a CpA selectivity which resembles that shown by natural RNases A.

Selected Publications
Instruments and Equipments

The department maintains an extensive range of modern instrumentation to facilitate sophisticated graduate and undergraduate research, in areas that include chemical synthesis, spectroscopy, materials and surface science, and chemical analysis.

Instrumentation includes NMR (multiple NMR spectrometers with field strengths up to 600 MHz), UV/Vis electronic absorption, FT-IR spectroscopy, fluorescence spectroscopy and several mass spectrometers.

- Varian Inova 600 MHz NMR spectrometer*
- Bruker AMX 400 MHz NMR spectrometer*
- Bruker Avance 300 MHz NMR spectrometer*
- Artificial noses based on MOS sensors
- DSC calorimeter
- Surface area analyzer
- UPLC/ESI-MS system
- HPLC/ESI-MS/MS system
- GC/MS equipments
- FT-IR spectrophotometer (ZnSe crystal)
- Microarray spotter

* Located at Centro Interdipartimentale di Misure “G. Casnati” of the University of Parma
La presente pubblicazione è stata effettuata per conto ed interesse della Facoltà di Scienze MM. FF. NN. dalla Prof.ssa Marta Catellani - docente della Facoltà.
Director of Department
Prof. Marta Catellani
+390521905415 marta.catellani@unipr.it

Secretary
Letizia Barantani
+390521905405 letizia.barantani@unipr.it

Fundamentals of Catalytic Technologies
Leader: Prof. Marta Catellani
+390521905415 marta.catellani@unipr.it

Clean Synthetic Methodologies Group
Leader: Prof. Giovanni Sartori
+390521905551 giovanni.sartori@unipr.it

Presence, Role and Metabolic Fate of Natural Substances and Xenobiotics in Foods
Leader: Prof. Arnaldo Dossena
+390521905413 arnaldo.dossena@unipr.it

Molecular Markers for Food Quality
Leader: Prof. Gerardo Palla
+390521905407 gerardo.palla@unipr.it

Supramolecular Sensors and Materials Group
Leader: Prof. Enrico Dalcanale
+390521905463 enrico.dalcanale@unipr.it

Molecular and Chiral Recognition of Biomolecules - Biomedical and Food Applications
Leader: Prof. Rosangela Marchelli
+390521905410 rosangela.marchelli@unipr.it

From Supramolecular Chemistry to Nanoscience
Leader: Prof. Andrea Pochini
+390521905408 andrea.pochini@unipr.it

BioNanotechnology Group
Leader: Prof. Rocco Ungaro
+390521905412 rocco.ungaro@unipr.it