Preface

Welcome to the Annual Report of the Department of Pharmacy at Uppsala University. Apart from the Chairman’s report, the report contains brief summaries of current research, as well as publication lists. More information about the department, our research, and other activities can be found at our web page, http://www.farmfak.uu.se/farm/.

I would like to express my sincere thanks to all personnel and students at the Department for their dedication and hard work during the year. I would also like to thank all the organizations and companies contributing to our research and teaching, either by participation in our research and teaching activities, or through provision of funding. I look forward to further fruitful collaboration during the coming year.

Uppsala 2014-03-31

Martin Malmsten
Chairman, Department of Pharmacy
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Chairman’s report
Research

The research performed at the department is centered around three different aspects of pharmaceuticals, i.e.,

1. Drug optimization
2. Drug delivery and pharmaceutical formulation
3. Rational drug usage

Within this overall frame, research is performed by our six research groups:

- **Biopharmaceutics** studies the interaction between drugs and biological processes, e.g., membrane transport and metabolism, and develops new concept formulations for drug delivery.
- **Drug Delivery** studies absorption, distribution, transport, and metabolism, as well as drug delivery, and develops new in vitro and computer models for predictions of ADMET properties of drugs.
- **Pharmacy Practice and Policy** focuses on societal aspects of pharmaceuticals and pharmacists, e.g., patient safety, the role of pharmacists, and communication issues related to the use of drugs.
- **Pharmaceutical Physical Chemistry** develops design principles for pharmaceutically relevant systems at a molecular and colloidal scale.
- **Pharmaceutics** studies pharmaceutical formulation and manufacturing.
- **Pharmacoepidemiology and Pharmacoeconomics** studies the causes and effects (clinical as well as social and economic) of the use of pharmaceuticals from a population perspective.

More information about our research follows in the reports of the groups below.

**PhD education**

With a continued demand for pharmaceutically oriented PhDs in academic, industrial, regulatory, and pharmacy sectors, the department maintains a high ambition regarding PhD education. The work of our PhD students contribute critically to both research and teaching at the department. The career paths for our PhDs remains both within and outside academia, e.g., within pharmaceutical industry, pharmacies, and agencies. This is an indication of the appreciation of our PhD training from society at large. Although the pharmaceutical sector in Sweden is under substantial changes, our PhDs have been able to find qualified positions after graduation.
Undergraduate education

The Pharmacy discipline is broad, with interfaces to science, technology, and social studies. Considering this, our teaching program is broad, and includes a number of subjects. To run the teaching program, our staff is organized in four teaching groups, each group supported by a director of studies. The groups are related to the main disciplines taught, i.e.,

1. Pharmaceutical physical chemistry
2. Pharmaceutics and biopharmaceutics
3. Social pharmacy
4. Pharmacoepidemiology

The department is currently involved in teaching at six education programs, i.e.,

1. Master in Pharmacy, Uppsala University
2. Bachelor in Pharmacy, Uppsala University
3. Master in Chemical Engineering, Uppsala University (with possibility to specialize in pharmaceutical sciences)
4. Master in Biomedicine, Uppsala University
5. Master in Drug Development, Uppsala University
6. Master in Drug Usage, Uppsala University

By tradition, the major parts of the undergraduate teaching at the department are within the two Pharmacy programmes, i.e., Master in Pharmacy and Bachelor in Pharmacy, at Uppsala University.

Within the programs, courses are given on basic and advanced levels. On the basic level, the courses are of broad content, covering the breadth of the discipline and with a course content that compares with international curriculum on this level. The advanced level consists of courses intended to give depth on certain selected subjects. The subjects dealt with are related to on-going research projects at the department and thus corresponds to the specific expertise of our staff. In all our disciplines we also offer Bachelor and Master theses courses as a means for the student specialization on a Pharmacy discipline.

It should be mentioned, finally, that the department has a long tradition of regularly giving courses intended for professionals in the form of commissioned teaching to agencies and industrial and other professional organizations.
In total, the department teaches around 40 different courses each year at different levels and with students of different backgrounds. The teaching program is thus both extensive and complex and requires a relatively large number of staff of broad knowledge.

During 2013, considerable activities have been devoted to developing new programmes for the Bachelor and Master programmes. The work has involved the entire Faculty of Pharmacy, as well as input from our Advisory Group and other stakeholders. While we are still only underway in this process, with major hurdles still to handle, it is rewarding to notice the enthusiasm and commitment the new programmes generate.

**Collaboration with society**

Many of our researchers and teachers are involved in collaboration with society in different ways. Besides the responsibility of scientists to communicate with the public through newspapers, radio, TV, etc., the collaboration with society today include a broad range of activities, including expert commissions to agencies and scientific societies, as well as innovation and commercialization activities. It is worth noting in this context that several pharmaceutical companies – about 10 companies over the years - have emerged from research conducted in our department. Relevant examples of such activities can be found in the list of commitments of staff later in this document.

**Personnel**

During 2013, personnel situation at the department has been stable from a personnel turnover perspective. The actions taken during 2012 to handle the practice period within our programmes were completed and have developed well. With our spread of teaching activities, finding good and efficient ways to replace personnel leaving is key. We are therefore happy to report that during the year, this has worked well.

**Administration and economy**

The regular university funding for research to the department has been relatively stable over the last few years. Combined with relatively strong external research funding, and balanced capital, the economic situation regarding research activities is stable, and has during 2013 allowed for continued strategic investments in research instrumentation. The varying funding for the undergraduate teaching does, however, remain a problem for the department, as well as for the Faculty of Pharmacy. Actions to address this have therefore been launched during the year.
Revenues to the Department of Pharmacy 2013 (kSEK)

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
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<tbody>
<tr>
<td>University funding - Undergraduate teaching</td>
<td>17,298</td>
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<td>Contract teaching</td>
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<td>University funding - Research and post-graduate teaching</td>
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<td>Research grants</td>
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<tr>
<td>Commissioned research</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>57,086</strong></td>
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</tbody>
</table>
Organization and personnel
Organization

Chairman

Martin Malmsten

Deputy chairman

Per Artursson

Department board

Martin Malmsten, chairman
Göran Alderborn, teacher representative
Per Hansson, teacher representative
Erik Björk, teacher representative, deputy
Christin Magnusson, teacher representative
Christel Bergström, teacher representative
Göran Frenning, teacher representative, deputy
Johan Gråsjö, representative for technical/administrative personnel, deputy
Richard Svensson, representative for technical/administrative personnel
Jonas Fagerberg, graduate student representative (Jan-June)
Elsa Lilienberg, graduate student representative (July-Dec)
Ronja Widenbring, graduate student representative
Anna Vildhede, graduate student representative, deputy
Marcus Wanselius, student representative (Jan-June)
Lukas Löfling, student representative (July-Dec)
Eva Nises Ahlgren, secretary

Director of administration

Eva Nises Ahlgren
Director of graduate studies

Per Artursson

Directors of undergraduate studies

Kerstin Bingefors
Anders Ericsson
Ida Bergström
Christin Magnusson

Computers and web

Göran Ocklind
Personnel

Senior staff

Bertil Abrahamsson, PhD, Adjunct professor
Göran Alderborn, PhD, Professor in Pharmaceutical Technology
Per Artursson, PhD, Professor in Dosage Form Design
Christel Bergström, PhD, Associate professor
Ida Bergström, MSc, Lecturer
Kerstin Bingefors, PhD, Senior lecturer
Erik Björk, PhD, Senior lecturer
Ragnar Ek, PhD, Associate professor
Anders Ericsson, PhD, Associate professor
Göran Frenning, PhD, Associate professor
Per Hansson, PhD, Professor in Physical Chemistry
Dag Isacson, PhD, Professor in Pharmacoepidemiology
Lars Knutson, PhD, Visiting professor
Sofia Kälvemark Sporrong, PhD, Senior lecturer
Hans Lennernäs, PhD, Professor in Biopharmaceutics
Christin Magnusson, BSc, Lecturer
Denny Mahlin, PhD, Assistant professor
Martin Malmsten, PhD, Professor in Pharmaceutical Physical Chemistry
Lena Ring, PhD, Associate professor, Adjunct senior lecturer
Erik Sjögren, PhD, Senior lecturer
Jannike Stenlund, MSc, Lecturer
Lena Strindelius, PhD, Senior lecturer
Helena Wennborg, MD PhD, Guest lecturer

PhD Students

<table>
<thead>
<tr>
<th>Emelie Ahnfelt</th>
<th>Hans Lennernäs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sara Andersson</td>
<td>Christel Bergström</td>
</tr>
<tr>
<td>David Dahlgren</td>
<td>Hans Lennernäs</td>
</tr>
<tr>
<td>Ilse Dubbelboer</td>
<td>Hans Lennernäs</td>
</tr>
<tr>
<td>Jonas Fagerberg</td>
<td>Christel Bergström</td>
</tr>
</tbody>
</table>
Jonas Gernandt    Per Hansson
Mina Heidarian Höckerfelt    Göran Alderborn
Joel Hellrup    Denny Mahlin
Claes Jidheden    Per Hansson
Henrik Jonsson    Göran Frenning
Elsa Lilienberg    Hans Lennernäs
André Mateus    Per Artursson
Lina Nyström    Martin Malmsten
Samaneh Pazesh    Göran Alderborn
Jenny Pedersen    Per Artursson
Ann-Sofie Persson    Göran Frenning
Linda Persson    Christel Bergström
Carl Roos    Hans Lennernäs
Shalini Singh    Martin Malmsten
Anna Vildhede    Per Artursson
Ronja Widenbring    Martin Malmsten
Kristin Wisell    Sofia Kälvemark Sporrong
Magnus Ölander    Per Artursson

**PhD Student, external**

Pia Frisk    Sofia Kälvemark Sporrong
Lena Thunander Sundbom    Kerstin Binge fors

**Research scientists**

Amjad Alhalaweh, PhD
Maria Backlund, PhD
Pawel Baranczewski, PhD
Fabienne Gaugaz, PhD
Michael Holmboe, PhD
Maria Karlgren, PhD
Lucia Lazorova, PhD
Patrik Lundquist, PhD
Malin Masterton, PhD
Pär Matsson, PhD
Josefina Nordström, PhD
Santiago Parpal, PhD
Christian Pedersen, PhD
Ann-Sofie Persson, PhD
Ivailo Simoff, PhD
Erik Sjögren, PhD
Richard Svensson, PhD
Carrie Tsoi, PhD

**Administrative and technical staff**

Johan Gråsjö, PhD
Pernilla Larsson
Eva Lide
Karin Johansson
Maria Mastej, BSc
Eva Nises Ahlgren, BSc
Göran Ocklind, PhD
Birgitta Rylén
Linda Strandenhed
Elin Svedberg, MPharm
Annette Svensson Lindgren
Lise-Britt Wahlberg
Ulla Wästberg Galik
Mini-biographies of permanent staff (January 1\textsuperscript{st} 2014)

Alderborn, G.

Research interests

Göran Alderborns research centers on particle science and formulation technology for pharmaceutical products. Current research projects focus on the characterization of mechanical properties of powders, the engineering of granular materials and process induced amophisation of particles.

Examples of current commitments

- Dean of the Faculty of Pharmacy, Uppsala University
- Member of the Editorial Board of Int J Pharm
- Member of the Editorial Advisory Board of Pharm Dev Technol
- Member of the Swedish Pharmacopoeia Commission, Medical Products Agency, Uppsala
- Member of the Powder Working Party of the European Directorate for the Quality of Medicines
- Member of the Board of the IF Foundation for Pharmaceutical Research, Stockholm

Artursson, P.

Research interests

Current research interests are directed towards predictive pharmacokinetics (ADMET) and biopharmaceutics in drug discovery and development. In particular, the role of drug transporting proteins for the cellular uptake, accumulation, metabolism and elimination of drugs and drug-like molecules is studied. During 2013, our collaborative platform for pharmaceutical profiling and drug optimization, UDOPP, became a facility within the Drug Discovery and Development platform at the Science for Life Laboratories.

Examples of current commitments

- Deputy Head of Department of Pharmacy, Uppsala University
- Deputy Head of the Committee for postgraduate studies at the Faculties of Pharmacy and Medicine
- Director for the ADMET facility within the Drug Discovery and Development Platform at the Science for Life Laboratories
- Node-director at the Chemical Biology Consortium Sweden
- Member of the Scientific Advisory Board of the Medical Products Agency
Baranczewski, P.

Research interests
Current research interests are directed towards development of in vitro ADME methodology, in vitro-in vivo extrapolation (IVIVE) and predictive pharmacokinetics (PBPK) in drug discovery and development. In particular, the use of proteomics approach for quantification of ADME proteins in cell systems and human tissues is under development. This knowledge will be used for improvement of IVIVE and PBPK models, and also for development of new model(s) for prediction of drug delivery and thus target efficacy.

Examples of current commitments
• Facility manager, UDOPP
• Member of Portfolio Management Committee at the European Gram Negative Antibacterial Engine (ENABLE) consortium within the New Drugs for Bad Bugs (ND4BB) Innovative Medicine Initiative (IMI) program.
• Member of Project Implementation Committee at the European Gram Negative Antibacterial Engine (ENABLE) consortium within the New Drugs for Bad Bugs (ND4BB) Innovative Medicine Initiative (IMI) program.

Bergström, C.

Research interests
Research is performed in the interface between medicinal chemistry, physical chemistry, pharmaceutics and biopharmaceutics. Experimental methodologies are combined with computational tools to interpret, understand and predict properties related to drug formulation, dissolution, solubility and absorption. Focus is set on the
development of rapid and accurate models, experimental as well as computational, to allow assessment of the potential for a drug candidate to be developed into a well functioning drug as early as possible in the drug discovery and development process.

**Appointments**

Adjunct Associate Professor, Monash University, Oct 2012-present.

**Examples of current commitments**

- Adjunct Associate Professor at Monash Institute of Pharmaceutical Sciences, Monash University
- Member of the Board of the Controlled Release Society Nordic Chapter
- Member of the PhysChem Forum committee
- Member of organizing committee for conferences and courses, exemplified by CRS Nordic Chapter summer school 2013.

**Bingefors, K.**

**Research interests**

Chris Bingefors works in the field of pharmacoepidemiology and pharmacoconomics. Main research areas are public health, quality of life and health services research with a special emphasis on the use of drugs. Her particular interests are psychiatric problems, pain and dermatology. Another area of expertise is the use of drugs from a gender perspective. Further, Chris Bingefors is active in pharmacy practice research.

**Examples of current commitments**

- Co-editor, Value in Health
- Member of the editorial board, International Journal of Pharmacy Practice
- Member of the core curriculum group: The Philosophy of Life and Modern Society. Centre for Environmental and Development Studies (CEMUS), Uppsala University
- Director of undergraduate studies in pharmacoepidemiology and pharmaco-economics

**Björk, E.**

**Research interests**

Erik Björk’s research focuses on mucosal transport of drugs, especially formulation aspects. Specific interest is nasal systemic transport, olfactory transport and transdermal administration of drugs.
Examples of current commitments

- Chairman of the Committee of Education at the Faculty of Pharmacy, Uppsala University
- Vice Dean at the Faculty of Pharmacy, Uppsala University
- Member of the board of Section for Pharmaceutics and Biopharmaceutics. The Swedish Academy of Pharmaceutical Sciences, Stockholm

Frenning, G.

Research interests

Göran Frenning’s research aims at enhancing the understanding of pharmaceutical processes through mechanistic modelling. His work is mainly directed towards particle-scale modelling of powder processes such as powder compression/compaction and powder flow, but also encompasses modelling of drug release, for example the release of catanionic mixtures from gels. Experimental work aiming at evaluating the developed models is an important part of these efforts.

Examples of current commitments

- Deputy member of the Board of the Department of Pharmacy, Uppsala University
- Member of the Gender Equality Committee at the Department of Pharmacy
- Reviewer for more than 20 international journals

Gaugaz, F.

Research interests

Fabienne Gaugaz is interested in the development of specific and selective treatments for cancer and in determining the efficacy of such drug candidates. Current research focuses on the targeted proteomic analysis of drug transporters, drug metabolizing enzymes and drug targets in healthy and cancerous tissue as components of a target efficacy model.

Hansson, P.

Research interests

Fundamental aspects of the interaction between charged polymers, in particular polymer networks, and oppositely charged macroions and surfactant self-assemblies in aqueous systems. Current focus is on the interaction between proteins/peptides and oppositely charged microgel networks and its implications on microgels as carriers of protein drugs and mechanisms of protein sorting. Of special interest is the interplay between
electrostatic, excluded-volume, and elastic interactions in relation to phase transitions and molecular transport.

**Examples of current commitments**

- Deputy member of the Committee of Education at the Faculty of Pharmacy, Uppsala University
- Member of the structure group for the development of new pharmacist programs at Uppsala University

**Isacson, D.**

**Research interests**

Dag Isacson works in the field of pharmacoepidemiology and pharmacoeconomics. Main research areas are reasons for and consequences of the use of drugs from a population perspective. In the research adverse drug reactions, drug-related problems as well as adherence are studied. Of special interest is the relationship between use of drugs and quality of life. In this research different methods to measure quality of life (Rating Scale, Time Trade Off, EQ-5D and Health Related Quality of Life) are compared. Another area is the application of pharmacoepidemiology and health economics in pharmacy practice.

**Examples of current commitments**

- Member of the editorial panel for The Annals of Pharmacotherapy
- Research Director, Pharmacoepidemiology and Pharmacoeconomics, Dept of Pharmacy

**Karlgren, M.**

**Research interests**

Maria Karlgren works in the area of ADME and predictive pharmacokinetics. More specifically, her research is focused on predictive cellular in vitro models for studying drug transport, drug-drug interactions, transporter pharmacogenomics and the interplay between drug transport and drug metabolism processes.

**Examples of current commitments**

- Member of the organizing committee of the Symposium on Pharmaceutical Profiling arranged by the Department of Pharmacy every second year
- Member of the UDOPP board and an UDOPP expert of in vitro drug transport
Kälvemark Sporrong, S.

Research interests
Sofia Kälvemark Sporrong’s research interests are professional ethics, pharmacy practice research, and pharmaceutical policy research. Current research deals with pharmacy policy, safety culture within pharmacy, the pharmacist professions, and patients’ view on research and researchers.

Examples of current commitments
- Member of the Steering Committee of the Special Interest Group in Social Pharmacy, Swedish Academy of Pharmaceutical Sciences
- Chair, Association of Women Researchers in Uppsala
- Member of the Board of Carl G and Lilly Lennhoff Foundation
- Member of the Board of Actavis Grant Committee
- Member of the Board of the Department of Pharmacy, Uppsala University
- Member of the election committee for the pharmaceutical faculty at Uppsala University

Lennernäs, H.

Research interests
His research aims to develop novel strategies of tissue drug targeting and delivery that aims to improve the clinical use and efficacy of drugs in various disease states, such as metabolic, endocrinological and cancer diseases. Especially the use of formulation technologies to construct novel medical treatments is a major focus. His research interest is also focused on clinical significance of mechanisms and function of membrane transport and metabolism of drugs/metabolites in the gastrointestinal tract, hepatobiliary system and cancer tissues. This work is performed in vivo with clinical models in humans and in various tissue and cell culture models. Hans Lennernäs has together with gastroenterologists developed and validated two new clinical intestinal perfusion techniques for investigations of intestinal transport and metabolism of drugs and nutrients. He is also one of the founders of the well-established Biopharmaceutics classification system. He has discovered and developed several pharmaceutical products based on drug delivery principles.

Examples of current commitments
- Member of the board Uppsala Clinical Reserach Center (UCR), Uppsala University
- Member of the Senate at Uppsala University
- Member of the editorial board of Molecular Pharmaceutics
- Member of the editorial board of Therapeutic Delivery
• Member of the editorial board of Eur J Pharm Sci
• Member of the editorial board of BMC Pharmacology
• Member of the board of the Oral Drug Delivery Foundation, USA (a non-profit organisation for promotion of education and research)
• Member of the board of LIDDS AB (www.liddspharma.com)
• Member of the board of Empros Pharma AB
• Member of the board of Recipharm Pharmaceutical and Manufacturing AB (www.recipharma.com)
• Member of the Executive Committee of OrBiTo (an IMI project) (www.liddspharma.com)
• Managing Entity for an IMI project (OrBiTo) (http://www.imi.europa.eu/content/orbito)
• Chairman for the World conference on Drug Absorption and Drug Delivery arranged by European Federation for Pharmaceutical Sciences in Uppsala, June 2013

Lundquist, P.

Research interests
Patrik Lundquist works in the field of ADME where he has studied the interplay of drug metabolizing enzymes and transporters in drug disposition. He also has a long standing interest in epithelial transport processes. He currently focuses on the role of the intestinal epithelium as a barrier to the absorption of drug molecules and the possibility to use nanoparticles to increase the bioavailability of peptide-based drugs.

Examples of current commitments
• Researcher on the collaborative EU-project Trans-Int which aims to develop new oral nanomedicines for the delivery of therapeutic macromolecules across the intestinal barrier.
• Member of the organizing committee of the Symposium on Pharmaceutical Profiling arranged every second year by the Department of Pharmacy

Mahlin, D.

Research interests
In his research, Denny Mahlin focuses on the solid state structure and particle properties of drugs and pharmaceutical excipients. Of special interest is to understand the relations between the molecular/nano-scale properties and the functional properties of materials, such as physical stability, dissolution, powder flow and compactability. In particular the use of the amorphous form of formulation components and the possibility to develop amorphous nano-composites are studied.
Examples of current commitments

- Scientific Advisor to the Editors of JPharmSci
- Member of the Board of Farmacins Alumnforening, Department of Pharmacy, Uppsala University

Malmsten, M.

Research interests

Martin Malmsten’s research focuses on the use of lipid and polymer systems as efficient discovery and delivery tools for bio-macromolecular drugs, notably antimicrobial and host-defense peptides. The research is focused on establishing an improved mechanistic understanding on the interaction between such drugs and lipid and polymer systems through novel developments in both conceptual understanding and analytical opportunities in self-assembly and responsiveness of such systems, and is based on extensive international research collaborations and state-of-the-art physicochemical methodologies.

Examples of current commitments

- Chairman of the Board of the Department of Pharmacy, Uppsala University
- Member of the Board of XImmune AB
- Editor for the Journal of Colloid and Interface Science
- Section editor for Current Opinion of Colloid and Interface Science
- Member of the Editorial Board of ISRN Biochemistry
- Member of the Editorial Board of Communications in Colloid and Interface Science
- Member of the Editorial Board of the Encyclopedia of Surface and Colloid Science
- Guest professor Charité, Berlin
- Member of the Royal Swedish Academy of Engineering Sciences (IVA)

Matsson, P.

Research interests

Pär Matsson’s research aims to determine the properties of small molecules that allow their development into successful therapeutics, with particular emphasis on how drug transport and metabolism pathways influence cellular drug exposure and effect. Current research involves a combination of experimental and computational techniques, including measurements of in vitro intracellular drug exposure, ligand and target based modeling of membrane transporters and drug-metabolizing enzymes, and chemical network modeling.
Examples of current commitments

- Scientific advisor in computational chemistry, Uppsala University Drug Optimization and Pharmaceutical Profiling Platform (UDOPP)

- Member of the organizing committee for the Symposium on Pharmaceutical Profiling arranged every second year at the Department of Pharmacy
Scientific reports
Biopharmaceutics

Professor Hans Lennernäs

The overall aim of this research program is to develop novel principles for an optimised and physiological based drug delivery and targeting. The long-term goal is to improve pharmacological effect and therapeutic outcome by reaching the active site and/or specific organ with high drug concentration at the right time and thereby avoiding unnecessary body exposure. In all cases the ongoing projects are driven by an obvious clinical need. Multi-disciplinary collaborations, using mainly clinical models, include research teams from pharmaceutical technology, material science, biopharmaceutics and pharmacokinetics, drug metabolism, toxicology, oncology, gastroenterology, endocrinology, urology and regulatory science. Projects are based on an in-depth understanding of the clinical significance and functional activity of carrier-mediated membrane transport and intracellular enzymatic processes. The disease-oriented projects have their targets in the hepatobiliary system, endocrinology, various tumour tissues and other target organs. Focal controlled release drug therapy is a particular strong focus in the oncology research project. Another strong research effort is to understand in the in vivo mechanisms determining drug absorption, liver first-pass effect and biliary excretion. These finding are the applied into discovery and development of novel oral drug delivery strategies.

The current research program has four projects:

- The ORBITO project aims to enhance the understanding of gastrointestinal absorption drugs from various pharmaceutical formulations, and apply this knowledge to create new experimental methods and theoretical models that will better predict the performance of these drugs in patients.
- Increase the understanding of novel oral formulations for poorly soluble compounds.
- Novel drug delivery approaches for drug targeting and focal controlled release of anti-cancer drugs based on pharmacokinetic, pharmacodynamic and clinical principles.
- Specific targeting to the hepatobiliary system based on ADME and clinical principles. Pharmaceutical development of novel treatements for liver cancer taking the role of local disposition in a diseased tissue into account. Buidling physiological based pharmacokinetic modelling with application to predicting and understanding the local dispistion of drugs in liver cancer tissue and as well gastrointestinal drug absorption.

We are using advanced clinical research models (both in vivo and in vitro), which are well established in our laboratory (such GI-intubation techniques and Ussing chamber) to examining the complex in vivo intestinal absorption and entero-hepatobiliary handling of drugs and metabolites in humans, with focus on transit, solubility-dissolution, membrane transport, metabolism and physiology. This research is a part of the ORBITO project. This research has also the potential to establish new in vivo valid
principles for delivery and targeting of drugs to this enterohepatic cycle and to develop novel formulation principles for poorly soluble drugs. In addition, this project has the objective to better understand hepatobiliary kinetics and exposure of drug and metabolites in relation to toxicity issues. The oral drug delivery principles are also adjusted to normal physiology to be able to apply to circadian rhythms such a hydrocortisone replacement therapy in adrenal insufficiency. In addition, the biopharmaceutic research group is developing novel anti-cancer treatment approaches at various stages of development, providing exciting perspectives for the future of controlled release focal cancer cure. One important factor for a successful outcome of such therapeutic approaches is ensuring local specific targeting of the therapeutic moiety at the tumour site. In collaboration with clinical groups an increased understanding of the limitations of current therapies for liver cancer is the major objective. Based on this knowledge novel approaches for a more efficient and safe local chemotherapy is developed.

Professor Lennernäs is the inventor of more than 15 patents and patent applications. He is one of the innovators and developers of a novel sublingual drug delivery system currently used for the treatment of various acute pain conditions. The product, Rapinyl®, has been approved in EU and USA. He has also together with co-inventors initiated two start-up companies that has developed a novel oral replacement therapy (www.duocort.com) for Addison disease and the development of focal drug treatment of localised prostate cancer (www.liddspharma.com). The oral modified release product, Plenadren®, was approved by EMA in July 2011.

Project members and collaboration partners

Projects 1 and 2: Biopharmaceutics and pharmacokinetics principles of oral drug delivery
Prof Hans Lennernäs, Prof Bertil Abrahamsson, Dr Erik Sjögren, David Dahlgren, Carl Roos and collaborators Uppsala University hospital, University of Mainz, University of Michigan and National Veterinary Institute. Internal collaborators are Prof Martin Malmsten and Prof Göran Alderborn

Projects 3 and 4: Novel drug delivery approaches for drug targeting and focal controlled release of anti-cancer drugs
Prof Hans Lennernäs, Elsa Lilienberg, Ilse Dubbelboer, Emelie Ahnfelt, Dr Erik Sjögren, Assoc Prof Niklas Axén and collaborators at Uppsala University hospital, Karolinska University hospital, Tamperer University hospital, Helsinki University hospital, and National Veterinary Institute
Figure 1. OrBiTo is a new European project within the IMI programme in the area of oral biopharmaceutics, involving nine universities, one regulatory agency, one non-profit research organization, three SMEs together with the twelve pharmaceutical companies (http://www.imi.europa.eu/content/orbito). The OrBiTo project will deliver novel methods and a framework for rational application of predictive biopharmaceutics tools for oral drug delivery. Biopharmaceutical parameters that are of main concern for a successful oral delivery include physical, chemical, and biological properties of the API, design and composition of the pharmaceutical formulation and the absorption conditions at different physiologically sites along the gastrointestinal (GI) tract. For instance, the transepithelial permeability changes to various extent along the small and large intestine for drugs transported by passive diffusion and/or carrier-mediated mechanisms. Regional differences in drug absorption is the main focus on two new PhD projects started at the department in April 2013 within the OrBiTo project.

Members of the group during 2013

Hans Lennernäs, Professor
Bertil Abrahamsson, Professor in industrial biopharmaceutics
Erik Sjögren, Research scientist
Emelie Ahnfelt, PhD Student
David Dahlgren, PhD Student
Ilse Dubbelboer, PhD Student
Elsa Lilienberg, PhD Student
Carl Roos, PhD Student

Publications, reviews and book chapters 2013

Hepatobiliary Disposition of a Novel Oral Thrombin Inhibitor. *Molecular Pharmaceutics*, 2013, 10 (11), 4252.


**Publications, reviews and book chapters 2012**


Publications, reviews and book chapters 2011


**Funding**

The group receives funding from the Swedish Research Council, Innovative Medicine Initiative and Pharmaceutical Industry.

**Presentations at symposia and congresses 2013**


8. Lennernäs, H. OrBiTo – an innovative biopharmaceutical tool. Pharmaceutical Faculty Day, Uppsala, September 2013


15. Sjögren, E. Poster presentation. Increased understanding of the systemic bioactivation of the double pro-drug ximelagatran in pigs through physiologically based pharmacokinetic modeling. 5th World Conference on Drug Absorption, Transport and Delivery, June 24-26, 2013, Uppsala, Sweden.


Patents and patents applications

15 patents and patents application in total.
Drug Delivery

Professor Per Artursson

The research in drug delivery is focused on predictive pharmacokinetics (ADMET) and biopharmaceutics (drug formulation, solubility and dissolution). Our research requires a multidisciplinary approach that combines computational chemistry and bioinformatics with cell- and molecular biology, biopharmaceutics, pharmaceutics and physical chemistry. New computational and experimental models are devised and used to study important mechanisms of drug disposition in the human body. In the ADMET area, the role of drug transporting proteins at cellular barriers is in focus. These integral membrane proteins determine the uptake, intracellular accumulation, metabolism and elimination of drugs. In the biopharmaceutical field, the effects of local tissue fluids on drug solubility and dissolution are in focus. The results of our research can rapidly be transferred to our collaborative platform for pharmaceutical profiling (UDOPP). The platform is an integrated node of the Swedish national infrastructure for chemical biology (CBCS). In 2013, it also became a facility within the newly funded Drug Discovery and Development platform at the Science for Life laboratories.

Intracellular unbound drug concentrations determine affinity to targets in the cell interior. However, due to difficulties in measuring them, they are often overlooked in pharmacology. In 2013, we devised a simple experimental technique for the determination of unbound intracellular drug concentrations in cultured cells that is based on parallel measurements of cellular drug binding and steady-state intracellular drug concentrations. Binding in an easily cultivated cell line was highly correlated with binding in liver-derived systems, whereas binding in plasma (previously used to approximate tissue binding) did not compare well with cellular binding. Surprisingly, we also found that our novel methodology could be used as an inexpensive, easily available alternative to brain tissues to determine the local exposure to unbound drug in the brain. To increase throughput, we combined drugs into cassettes for simultaneous measurement of multiple compounds. Our method estimated the unbound fraction in the brain with an average error of 1.9-fold, fig 1. Thereby, estimates of unbound drug exposure can now be implemented at a much earlier stage of the drug discovery process, when molecular property changes are easier to make.

Another highlight from 2013 is that we clarified and quantified the uptake mechanism in the liver (the target tissue) for the lipid-lowering drug atorvastatin. The impact of inhibition of atorvastatin uptake was also studied, using inhibitors with different transporter isoform specificity. Expression levels of the four transport proteins mediating atorvastatin uptake in human hepatocytes were quantified. These data, together with atorvastatin in vitro kinetics, were used to predict the maximal transport activity (MTA) and inter-individual differences in uptake contribution of each transporter in human subjects. Subsequently, impairment of hepatic uptake upon co-administration of five clinically interacting drugs was predicted using in vitro inhibitory potencies. The inter-individual differences in transporter expression and atorvastatin uptake resulted in marked differences in drug-drug interactions due to isoform-specific inhibition. We concluded that this variation should be considered in in vitro to in vivo extrapolations.
Fig 1. Optimization of drug efficacy in the brain requires understanding of the local exposure to unbound drug at the site of action. This relies on measurements of the unbound drug fraction ($f_{u,\text{brain}}$), which currently requires access to brain tissue. In 2013, we devised a novel methodology using homogenates of cultured cells for rapid estimation of $f_{u,\text{brain}}$. In the figure, literature data on the unbound drug fraction in the brain are compared with results obtained using our simple methodology.

During 2013 the research performed within the biopharmaceutical field focused on two areas; i) dissolution profiling of contemporary highly lipophilic drug molecules with the aim to establish new insights into molecular interactions between such compounds and lipid aggregates in intestinal fluids, and ii) formulate-ability of drug molecules with the purpose to develop predictive models forecasting successful formulation strategies. The primary goal is to develop in silico models that predict reasons for poor solubility of drugs and the successful formulation strategies to apply for such compounds. With regard to dissolution profiling we have developed methods to measure dissolution of extremely poorly soluble compounds ($<1 \ \mu\text{g/mL}$) with the µDISS and new in silico models for predictions of apparent solubility in fasted state simulated and human intestinal fluids were developed based on these data. We have also studied the effect of e.g. alcohol in the gastric and intestinal compartment on the dissolution of poorly soluble compounds. It was found that simultaneous intake of drug and ethanol can increase the fraction absorbed of such compounds as a result of the increased solubility in the stomach and duodenum when ethanol is present. Compounds being sensitive to the ethanol were found to be non-ionizable lipophilic drug structures. The increased absorption leads to a higher concentration in the blood and for compounds with narrow therapeutic window this may result in adverse drug reactions.
In the field of formulate-ability, solid-state transformations focusing on amorphous material have been analyzed in depth and structural features promoting glass-forming ability and dry stability of amorphous material have been identified and published during 2013. We also initiated a new project targeting pharmaceutical co-crystals as supersaturating systems. The first goal set for this project is to computationally predict which guest molecule to choose for poorly soluble drug molecule to produce a co-crystal. We also published the first paper in which computational predictions of drug loading capacity of excipients commonly used in lipid-based formulations were presented. These findings are now further investigated to reveal potential to predict the loading capacity of different lipid-based drug delivery systems.

At the pharmaceutical profiling platform (UDOPP), several collaborative investigations were performed together with medicinal chemists and drug discovery biologists. In collaboration with the Broad Institute, AstraZeneca and colleagues at Uppsala University, the impact of stereospecific intramolecular hydrogen-bonding on cell permeability and physicochemical properties was studied. Profiling of a series of stereoisomeric *T. cruzi* growth inhibitors revealed vastly different *in vitro* properties such as solubility, lipophilicity, pK<sub>a</sub> and cell permeability for two sets of four stereoisomers. Using computational chemistry and NMR spectroscopy, the formation of an intramolecular NH->NR<sub>3</sub> hydrogen bond was identified in the set of stereoisomers displaying lower solubility, higher lipophilicity and higher cell permeability. The intramolecular hydrogen bond resulted in a significant pK<sub>a</sub> difference that accounts for the other structure-property relationships. Application of this knowledge could be of particular value to maintain the delicate balance of size, solubility and lipophilicity required for cell penetration and oral administration for chemical probes or therapeutics with properties at, or beyond, Lipinski’s Rule of 5.

**Members of the group during 2013**

Per Artursson, Professor
Christel Bergström, Associate professor
Amjad Alhalaweh, Research scientist
Sara Andersson, PhD Student
Maria Backlund, Research scientist
Pawel Baranczewski, Research scientist
Jonas Fagerberg, PhD Student
Fabienne Gaugaz, Post doc
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Karin Johansson, BSc
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Santiago Parpal, Research scientist
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Linda Persson, PhD Student
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Richard Svensson, Research scientist
Carrie Tsoi, Research scientist
Anna Vildhede, PhD Student
Magnus Ölander, PhD Student

**Publications, reviews and book chapters 2013**


selected in vitro and in silico methods to predict acute oral toxicity in a regulatory context: Results from the European Project ACuteTox. *Toxicology in Vitro*, 2013, 27 (4), 1357.


**Publications, reviews and book chapters 2012**


**Publications, reviews and book chapters 2011**


6. Mahlin, D, Ponnambalam, S, Heidarian Höckerfeldt, M and Bergström, CAS. Toward In Silico Prediction of Glass-Forming Ability from Molecular Structure


**Funding**


**Doctoral dissertation**


**Awards**

Artursson, P. The 2013 Björn Ekwall memorial award from the Scandinavian Society for Cell Toxicology (SSCT)

Gaugaz, F. SNF Early Mobility Postdoc Fellowship, Swiss National Science Foundation

Pedersen, J. IF foundation Postdoc Award

**Arrangement of research seminars and courses 2013**


6. Departmental seminar: Dr Stefan Oswald, University Medicine of Greifswald. Expression of clinically relevant transporter proteins along the human intestine. Mar 22, 2013. Host: Per Artursson


9. Group seminar: Prof Helena Danielsson, Uppsala University. Exploiting the information rich output of SPR biosensor technology in drug discovery – from fragment to lead. Feb 8, 2013. Host: Per Artursson


Presentations at symposia and congresses 2013

Abstracts Posters


Abstracts Oral Presentation


Increasing expenditures for pharmaceuticals and limited health care resources have put focus on the use of medicines. Modern pharmaceuticals are well documented and sophisticated aids, but the final treatment outcome depends on how they are handled in society, by e.g. politicians, prescribers, pharmacists and patients. The overall aim for our research is to contribute to an improved understanding of the role of medicines for individuals and societies. This research is intended to lead to improved use of medicines, to the benefit of individuals and society at large.

We use theories and methodologies from social sciences and apply them on the field of pharmacy. Research questions are related to medicines and/or professions and organizations dealing with medicines. Nearly all projects are run by multidisciplinary research teams involving both internal and external researchers.

Our research deals with pharmacy policy, not least the recent deregulation of the pharmacy market, including sales of non-prescription medicines outside pharmacies. We also study health care professions, predominantly pharmacists. How are the pharmacy professions developing and how are they seen by society at large? Pharmacies and their services is another area for our research, for example we investigate safety and safety culture within pharmacy.
Pharmacy policy
Sofia Kälvemark Sporrong, Kristin Wisell

During the last years the pharmacy market in Sweden has been subject to significant changes, due to deregulation of e.g. pharmacy ownership, sale of non-prescription medicines outside pharmacies and the role of governmental authorities. We look into the ideological arguments behind these changes, as well as how different stakeholders have acted during this period of transformation.

Pharmacies and patient safety
Sofia Kälvemark Sporrong, Annika Nordén Hägg

We target the organizational level of pharmacy practice by investigating the influence of safety cultures on dispensing errors at pharmacies. This is done in order to understand the underlying mechanisms that trigger errors, the reporting of errors and, eventually, to initiate preventive measures. We also study safety issues regarding sales of non-prescription medicines outside pharmacies.

Pharmacy communication
Sofia Kälvemark Sporrong, Erika Olsson

The communication between pharmacy staff and patients with regard to prescription medicines is studied, especially when it comes to content of the dialogue, but also socio-demographic factors are taken into considerations.

Conducting research in pharmacies
Pia Frisk, Sofia Kälvemark Sporrong

When conducting research on experiences and attitudes of medicine users towards their specific treatments, pharmacies are practical for collecting data or including patients in studies. There are, however, methodological problems, e.g. with selection bias. Also, the dispensing process can be affected. In Sweden, short electronic questionnaires have been distributed through pharmacies for some years. Methodological and other aspects of this service are investigated.

Patients’ view of research and researchers
Sofia Kälvemark Sporrong, Malin Masterton

Patients are often taking part in research within the medical and pharmaceutical sciences. But how do they look upon their role as test subject, what are their conceptions of the usefulness of research and the underlying interests of researchers?
This is studied in order to make visible power relations and incentives in research on human subjects.

**Members of the group during 2013**

Sofia Kälvemark Sporrong, Senior lecturer  
Ida Bergström, Lecturer  
Pia Frisk, PhD Student  
Malin Masterton, Research scientist  
Jannike Stenlund, Lecturer  
Kristin Wisell, PhD Student  
Katarina Öjefors-Stark, Lecturer

**Publications, reviews and book chapters 2013**


**Publications, reviews and book chapters 2012**


4. Nordén-Hägg, A, Kälvemark Sporrong, S and Kettis Lindblad, Å. Exploring the relationship between safety culture and reported dispensing errors in a large sample


**Publications, reviews and book chapters 2011**


**Presentations at symposia and congresses 2013**


Pharmaceutical Physical Chemistry

Professor Martin Malmsten

Within the group for Pharmaceutical Physical Chemistry, research is performed on polymer and lipid systems as tools for discovery, optimization, and delivery of drugs, with particular focus of peptide and protein drugs, and antimicrobial and anti-inflammatory drugs in particular. The research is characterized by broad collaborations to span the range from basic biophysical and physicochemical investigations, to studies of antimicrobial and anti-inflammatory effects, as well as cell toxicity. The research is based on advanced experimental physicochemical methodology, often combined with theoretical modeling. Areas covered include i) host defense peptides, ii) interactions between microgels and peptides/proteins, iii) modeling of microgel interactions with proteins, peptides, and surfactants, iv) protein sorting in polyelectrolyte networks, and v) polymer-based nanoparticulate drug delivery systems.

Project area 1: Host defense peptides

Prof Martin Malmsten, Shalini Singh, Lise-Britt Wahlberg

As one of the main focus areas we investigate biological as well as biophysical properties of antimicrobial and anti-inflammatory peptides. Due to growing problems with multidrug resistance, there is an increasing need to find new types of antibiotics, which has prompted an increased interest in such peptides. Through structure-activity relationship studies, we have identified a number of peptides, e.g., from the complement and coagulation systems, which display potent antimicrobial and/or antiinflammatory effect, but simultaneously low toxicity. With these peptides, we investigate effects of single amino acid modifications to further improve efficiency and selectivity. The research involves parallel studies on antibacterial and antiinflammatory effects, cytotoxicity, and biophysical mechanistic phenomena on model lipid systems (vesicles, supported mono- and bilayers). Apart from results from our research being published in high profile journals, this has resulted in a number of patent applications, and in the development of some of these peptides towards therapeutic applications through two start-up companies. One of these peptides has successfully undergone two Phase I/IIa clinical trials, and is currently subject of further clinical trials. Exemplifying activities during 2013, lipid membrane and lipopolysaccharide (LPS) interactions were investigated for a series of amphiphilic and cationic peptides derived from human heparin cofactor II, using dual polarization interferometry, ellipsometry, circular dichroism (CD), cryoTEM, and z-potential measurements. Antimicrobial effects of these peptides were compared to their ability to disorder bacterial lipid membranes, while their capacity to block endotoxic effects of LPS was correlated to the binding of these peptides to LPS and its lipid A moiety, and to charge, secondary structure, and morphology of peptide/LPS complexes. In particular, fragmentation and densification of LPS aggregates correlate to the anti-endotoxic effect of these peptides, thus identifying peptide-induced packing transitions in LPS aggregates as key for anti-endotoxic functionality. PEGylation of these peptides reduces peptide binding to lipid membranes, an effect accentuated at increasing PEG length but less sensitive to conjugation site. The
reduced binding causes suppressed liposome leakage induction, as well as bacterial lysis. As a result of this, the antimicrobial effects of KYE28 is partially lost with increasing PEG length, but hemolysis also strongly suppressed and selectivity improved. Through this, conditions can be found, at which the PEGylated peptide displays simultaneously efficient antimicrobial affects and low hemolysis in blood. Importantly, PEGylation does not markedly affect the anti-inflammatory effects of these peptides. The combination of reduced toxicity, increased selectivity, and retained anti-inflammatory effect after PEGylation, as well as reduced scavenging by serum proteins, thus shows that PEG conjugation may offer opportunities in the development of effective and selective anti-inflammatory peptides.

![Graph showing the relationship between PEGylation and reduction in NF-κB activation]

**Project area 2: Interaction between microgels and proteins/peptides**

*Prof Martin Malmsten, Prof Per Hansson, Ronja Widenbring, Lina Nyström, Jonas Gernandt*

In this project area we investigate microgels as delivery systems for proteins and peptide drugs, including effects of peptide/protein-microgel interactions and of transport restrictions within the gel network, as well as effects on the loading/release and polypeptide distribution within the gel particles. In a series of studies, we have investigated effects of peptide composition (charge, hydrophobicity and their respective distributions), length, secondary structure, and cyclization. This research also addresses the role of excess electrolyte and pH on peptide loading/release, peptide distribution and transport kinetics within the gels, and degree of gel swelling/deswelling, and is based on a method combination of micromanipulator-assisted light microscopy, confocal microscopy, circular dichroism, and fluorescence spectroscopy. Exemplifying activities during 2013, we investigated proteolytic degradation and release of microgel-loaded peptides was investigated for trypsin, poly(acrylic acid-co-acrylamide) microgels, and oppositely charged polylysine, using a method combination of confocal microscopy and...
micromanipulator-assisted light microscopy. Results show that trypsin-induced release of polylysine increased with increasing trypsin concentration, decreasing microgel charge density, and decreasing peptide molecular weight. While the microgel offered good protection against enzymatic degradation at high microgel charge density, it was also observed that the cationic peptide enabled trypsin to bind throughout the peptide-loaded microgels, even when it did not bind to the peptide-void ones. With the exception of highly charged microgels, proteolytic degradation throughout the peptide-loaded microgel resulted in the generation of short and non-adsorbing peptide stretches, giving rise to the concentration and peptide length dependence observed. A simple random scission model was able to qualitatively capture these experimental findings. Collectively, the results demonstrate that microgel charge density, peptide molecular weight, and enzyme concentration greatly influence degradation/release of microgel-loaded peptides, and need to be considered in the use of microgels, e.g., as carriers for protein and peptide drugs.

Project area 3: Modelling of microgel interactions with proteins, peptides, and surfactants

Prof Per Hansson, Jonas Gernandt, Prof Martin Malmsten

Supporting our experimental activities on microgels as protein and peptide drug delivery systems, research in this area focuses on generic aspects of the interaction between macroions and polylions. The investigations are focused primarily on electrostatic and elastic effects in systems where proteins, peptides, and surfactant micelles form complexes with cross-linked polylion networks, but complexes in the absence of crosslinks are also investigated. A central problem addressed is the influence of electrostatic and elastic interactions on the distribution of macroions in microgels, in particular in relation to phase coexistence and discrete volume transitions. This is important for understanding binding/release mechanisms, protein sorting and encapsulation in microgels. Working mainly with analytical methods we have developed a molecular thermodynamic model which, in combination with an elastic field theory, allows for detailed modeling of the propagation of elastic forces in the inhomogeneous and anisotropic network states of core/shell gels. Recently we have successfully modeled temperature-sensitive poly(N-isopropyl acrylamide) core/poly(N-isopropyl methacrylamide). The results highlight the importance of the elastic coupling between phases coexisting in microgels. We have also successfully modeled the interaction between charged spherical polymer networks and oppositely charged...
proteins, peptides and surfactant micelles. The results explain the role of protein/peptide and polyion charge densities, protein/peptide size, cross-linking density and the concentration of added salt. In particular the results clarify the conditions required for the appearance of discrete gel volume transitions, induced by both core/shell separation and gel bulk instability.

**Project area 4: Protein sorting in polyelectrolyte networks**  
**Prof Per Hansson, Claes Jidheden**

In this recently started project we investigate how the interaction between two different water soluble proteins is affected by the presence of a polyelectrolyte of opposite charge, with special focus on segregation or proteins confined to the same polyelectrolyte network. By investigating the importance of the charge density of proteins and polyelectrolyte and other factors affecting the strength of electrostatic interactions the aim is to clarify to what extent electrostatic interactions mediated by polyelectrolytes is responsible for segregation of two different proteins. We have discovered that the cationic protein cytochrome c and a protein model (cationic/non-ionic mixed micelles) segregate in negatively charged polyelectrolyte networks to form different domains (core/shell). Two ‘sorting’ mechanisms have been observed and related to the relative strength of the polyelectrolyte-mediated between the proteins/protein models. Another objective is to clarify to what extent intrinsic (short range) attractions lead to segregation. The processes are investigated in small liquid compartments by means of microscopy techniques, assisted by micromanipulators. The problems addressed are relevant for encapsulation of two proteins in microgels for protein drug delivery, and for understanding protein sorting in the secretory machinery of living cells.

**Project area 5: Polymer-based nanoparticulate drug delivery systems**  
**Prof Martin Malmsten**

During 2013, we furthermore initiated a set of research activities within the area of polymer-based nanoparticulate drug delivery systems. An example of these activities was the establishment of a versatile platform methodology for improving dissolution kinetics, gastrointestinal absorption, and bioavailability of protein kinase inhibitors (PKIs). The approach is based on dissolving the PKI in an organic solvent together with a matrix-forming polymer, followed by nanoparticle precipitation by sub- or supercritical CO₂. Surfactants added after nanoparticle generation were found to be important for optimal PKI dissolution rate. Focusing on nilotinib, selected formulations were investigated by X-ray diffraction, modulated differential scanning calorimetry, vapor sorption measurements, and electron microscopy. The hybrid nanoparticles were demonstrated to consist of amorphous PKI embedded in a polymer matrix, displaying retained amorphicity also after 12 months of storage. Consequently, nilotinib release rate was dramatically increased in both simulated gastric fluid and simulated intestinal fluid. Similar results indicated flexibility of the approach regarding polymer identity, drug load, and choice of surfactant/copolymer. The translation of the increased dissolution rate found *in vitro* into improved GI absorption and bioavalilability *in vivo*
was demonstrated for male beagle dogs following oral administration of gelatin capsules containing the hybrid nanoparticles, where a 730% increase in the AUC\textsubscript{0-24hr} was observed compared to the benchmark formulation. Finally, the generality of the formulation approach taken was demonstrated for a range of PKIs.

**Members of the group during 2013**

Martin Malmsten, Professor
Per Hansson, Professor
Anders Ericsson, Associate professor
Günter Siegel, Visiting professor
Jonas Gernandt, PhD Student
Claes Jidheden, PhD Student
Lina Nyström, PhD Student
Shalini Singh, PhD Student
Lise-Britt Wahlberg, Technician
Ronja Widenbring, PhD Student

**Publications, reviews and book chapters 2013**


Publications, reviews and book chapters 2012


Publications, reviews and book chapters 2011


**Funding**

The group receives funding from the Swedish Research Council, EU, and Industry.
Doctoral dissertation


Presentations at symposia and congresses 2013

Pharmaceutics - Pharmaceutical formulation and manufacturing science

Professor Göran Alderborn

In the academic discipline Pharmaceutics, the administration, formulation and manufacturing of medicines are treated. The research group in Pharmaceutics at Uppsala University has the mission to deliver fundamental pharmaceutical research that can be translated into better and more cost-effective medicines that will improve health care to the benefit of individuals and society. Our ambition is to conduct pharmaceutical translational research, i.e. fundamental research that promptly can be translated into the development and manufacturing of effective and safe medicines.

The study of solid systems, their formulation and manufacturing dominates the research of the group with the overall aim to develop new and improved methods and strategies to predict and manipulate the properties of particles and particle systems. In addition, the group conduct research on new drug delivery solutions for controlled drug release.

The research programme of the group consists of a series of projects that are run by four project groups, each led by a principle investigator. In the Table below, an overview of the projects groups and the projects run are given and the projects are subsequently briefly described.

Overview of research programme and projects 2013

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Project area 1: Pharmaceutical materials science
Principle investigator: Denny Mahlin

The physical properties of materials are to a high extent influenced by its solid state. For instance, poorly soluble drugs may attain higher dissolution rate if made amorphous, i.e. transformed into a disordered, non-crystalline state. The mechanical properties, such as elasticity and hardness, of many excipients are also a function of the degree of molecular disorder. Characterization, prediction and control of the solid state of drugs and excipients are hence crucial components of pharmaceutical technology and drug formulation.

During 2013, the following projects have been running within the group:

(a) Properties of amorphous composites
Composites are formed by incorporation of nano-particles into spray-dried powders. The incorporated particles can give the solid advantageous properties, e.g. improved stability of an amorphous compound. We produce and utilize amorphous composites as model to find out how inclusion of various material components affects the properties of the amorphous state. Our focus is to incorporate micro- to nano-sized filler particles into spray-dried amorphous disaccharides and to find out how this affects the material properties and solid state tranformations of the formed composite in terms crystallization, particle agglomeration behaviour and mechanical properties.

(b) Prediction of disordering propensity of solids
Different materials have different propensity to become amorphous when exposed to manufacturing operations such as drying, mixing and compaction. By statistical modeling we are developing prediction tools which give us the opportunity to predict the disordering potential and amorphous stability of drug-like solids in the dry state and in aqueous dispersions. Since disordering leads to large changes in material properties,
predictions could help alerting problematic compounds that are intended to be included in a formulation. Also it can highlight the possibilities to utilize amorphization to improve material properties, such as poor solubility. The overall aim is to better understand the molecular properties that govern the ability of a solid material to become a stable amorphous solid, both during storage and dissolution.

Project area 2: Pharmaceutical physics
Principle investigator: Göran Frenning

Research in pharmaceutical physics focuses on the behaviour of powders and granular materials, especially under confined conditions, as during manufacturing of tablets. Our ambition is to develop mechanistic models and simulation tools that will enable knowledge at the particle level to be translated into a refined understanding of manufacturing processes ensuring a high quality of the final product. Current work ranges from the development of new test equipment for single particles and formulation of suitable models for particle interactions to full-scale distinct-particle simulations and experimental evaluations of their predictions.

During 2013, the following projects have been running within the group:

(a) Experimental studies of single particles under confined conditions
During manufacturing of tablets by confined compression, single particles generally undergo extensive deformation, being affected by multiple simultaneous contacts with other particles. To mimic these loading conditions, we are currently constructing a miniaturized triaxial apparatus that will be able to apply relatively high forces (up to a few hundred N) along all three spatial directions. This apparatus will enable a detailed study of the mechanical response of individual particles under confined conditions, an area where the current knowledge is limited.

(b) Mechanistic models for the interaction between particles under confined conditions
The vast majority of the currently used contact models are based on the assumptions of small deformations and independent contacts. These assumptions are not realistic during the later stages of tablet manufacturing by confined powder compression. We are currently developing models for the behaviour of plastically deforming spherical particles under confined conditions, utilising finite-element simulations for model validation. Procedures to enforce the constraint imposed by plastic incompressibility are investigated.

(c) Distinct-particle simulations of confined compression/compaction
The Discrete Element Method (DEM) is used to translate the understanding at the particle level, as formulated in the mentioned contact models for confined conditions, to the powder bed and tablet. The predictive ability of the models is tested against experimental data for mm-sized granules of various types.
Project area 3: Pharmaceutical technology

Principle investigator: Göran Alderborn

The technology of solid dosage forms technology has been an important research direction of the group for more than 20 years and a core topic within this project area is particle science. Based on our knowledge on the compression and compaction of powders, we will continue to investigate the use of powder compression as a means to derive measures of and predict particle properties. Moreover, we will continue our ambition to develop a theoretical framework for the properties of granular solids with a special reference to powder compaction. Our project on the properties of amorphous particles will also continue with a focus on the amorphisation of particles during powder flow.

During 2013, the following projects have been running within the group:

(a) **Formulation tools for characterizing particle mechanics and powder compactibility**

Powder compression is a common operation in the manufacturing of pharmaceuticals but also several other types of chemical products. Studies on powder compression and compaction have been conducted for several years within the group. We are now investigating the possibility to use traditional compression parameters as a means to classify powders into groups dependent on their compression behavior and particle mechanics. The overall ambition is to develop a protocol for the characterization of mechanical properties of particles based on powder compression analysis. In addition, we have also the ambition to derive an approach to predict the compactibility of powders based on powder compression analysis.

(b) **Multi-scale structure-property relationships for granular solids**

Fine particles are often transformed into larger particles, possessing improved physical and technical properties, by granulation. Granular solids are normally clusters of fine particles, characterized on the meso-scale by porosity or solid fraction and on the micro-scale by a complex structure. The granule structure will have a profound effect on the formulation and processing properties of the granules and the understanding of the relationship between granule formation process, granule physical structure and granule processing properties (process-structure-property relationships) for granular solids is an issue of emerging importance. The understanding of such relationships for granular solid needs to be developed in order to firstly, identify and establish strategies for the engineering of granules and, secondly, develop mechanistically based manufacturing control tools.

(c) **Mechanical amorphisation of particles**

It is today well established that a particulate solid may undergo a transformation from a crystalline to an amorphous state during mechanical processing involving breakage of particles, i.e. milling and compaction. However, it is also proposed that particle failure by deformation and friction due to particle sliding may cause such a disordering. Thus,
also powder handling involving stresses that will not break particles, such as powder flow, may amorphise the particles, causing alterations in the chemical and physical properties of the solid. We intend to investigate the amorphisation of particles during powder flow and the type of inter-particulate contact processes that may cause amorphisation. Furthermore, we wish to identify the mechanism on the molecular scale that is involved in the disordering of a solid during powder flow.

Project area 4: Drug administration

Principle investigator: Erik Björk

The release of the drug from a pharmaceutical formulation is often of great importance for the therapeutic effect. Understanding of the mechanisms controlling the release rate as well as knowledge on how to alter the release rate from different formulations are dominant aspects of the development of a dosage form.

During 2013, the following project has been running within the group:

(a) Formulations for mucosal and transdermal drug delivery

The objective of the project is to develop new formulation concepts for mucosal and skin administration of drugs, primarily by the nasal and transdermal route. Both low molecular drugs and peptides are in focus. The mechanistic understanding of the release of drugs from the formulation and its effect on the mucosal epithelium that may alter the absorption are parameters that are studied. Current examples are gel formulations with drugs included in vesicles with surfactants to alter the release. These systems can be used for application on different mucosa and also on the skin.

Members of the group during 2013

Göran Alderborn, Professor
Erik Björk, Senior lecturer
Ragnar Ek, Associate professor
Göran Frenning, Associate professor
Johan Gräsjö, Research engineer
Henrik Jonsson, PhD Student
Christin Magnusson, Lecturer
Denny Mahlin, Assistant professor
Lucia Lazorova, Research assistant
Josefina Nordström, Research scientist
Mina Heidarian, PhD Student
Joel Hellrup, PhD Student
Samaneh Pazesh, PhD Student
Ann-Sofie Persson, PhD Student
Lena Strindelius, Senior lecturer

Publications, reviews and book chapters 2013


Publications, reviews and book chapters 2012


**Publications, reviews and book chapters 2011**


**Funding**

The group receives funding from the Swedish Research Council and from Industry.

**Doctoral dissertation**


Gråsjö, J. Molecular arrangement, electronic structure and transport properties in surfactant gel- and related systems studied by soft X-ray and dielectric spectroscopy. Digital comprehensive summaries of Uppsala dissertations from the Faculty Science and Technology 1060, 2013.

**Presentations at symposia and congresses 2013**

1. Frenning, G. How pharmaceutical processes can be better understood by using mechanistic models. 6th International Symposium on Solid Oral Dosage Forms, Malmö, Sweden, April 21-23, 2013.


Abstracts Posters


Pharmacoepidemiology and Pharmacoeconomics

Professor Dag Isacson

For most drugs the effectiveness in clinical practice is lower than predicted from the results in clinical trials. Figure 1 shows the development of drugs from the initial idea to use in clinical practice. There are several reasons for the discrepancy. In controlled trials the drug is tested on homogeneous and well-diagnosed patient groups. Dosages, adherence and adverse drug reactions (ADRs) are monitored carefully and the effect of the treatment is continuously evaluated. When the drug is registered, marketed and subsequently used in clinical practice, circumstances are vastly different. Drug treatment is given to heterogeneous patient groups, in some cases with co-morbid diseases. There may be problems with treatment adherence, interactions and prescribed dosages. The effect of drugs used in real life clinical practice is named effectiveness in order to separate it from the efficacy recorded in clinical trials.

Factors that influence the use of drugs in clinical practice can be divided into environmental/societal factors and individual factors. Environmental/societal factors include the health care system, the drug distribution system, doctors, pharmacists and other health care professionals as well as family, friends, media and marketing. Individual factors are morbidity, adherence, attitudes, knowledge, expectations as well as gender, age, education, socioeconomic factors, life style, employment and household situation. Knowledge in this field is still scarce and research has increased considerably during the last decades.

The aim of the research in the group is to contribute to drug treatment with a higher quality and effectiveness – from clinical and economical perspectives – for both the patient and for society at large. Key issues are need, demand, use and outcome of drug treatment and pharmaceutical services.

The development of research methods is crucial. New statistical methods for analyzing longitudinal data, as well as various techniques for multivariate analyses are adapted for use in the study of outcomes of drug treatment. Another area is health economics where we focus on population based studies on use of drugs, health and quality of life. In our research we have also employed results from qualitative research to develop survey questions used in quantitative research.
In 1994/95 a large cross-sectional study on health, quality of life and use of drugs was carried out by the research group on a random sample of the population in the county of Uppland, Sweden. In 2004/05 a similar large cross-sectional survey was conducted this time on a random sample of Sweden as a whole. Many research articles and other information have been published based on these surveys. During the last couple of years much effort from the research group has been put into the planning, financing, as well as conducting a new cross-sectional survey named “Swedish Health 2012”. The survey which was administered by Statistics Sweden (SCB) was carried out during the autumn and winter 2012/13 on a random sample of 16000 individuals aged 18-84 years in Sweden. The respondents had the possibility to answer the questionnaire by using the net or the postal mail service. Information from the national prescription register as well as information from other national registers has been linked to the project. The data collection was anonymous and the project complies with the national research ethics legislation (Regional Ethical Review Board – Uppsala, Dnr 2012/073). The project enables further studies on health, quality of life and various aspects on the use of drugs in the Swedish general population.

Project areas 1: Psychiatric diseases, pain, use of drugs and quality of life

One area of interest is psychiatric diseases, pain, use of drugs and quality of life in the population. During the years several studies have focused on various types of pain, use of analgesics and quality of life, e.g. from a gender perspective. Depression and its impact on population health is another key area for the group. The close association between pain and depressive symptoms is studied on a population level.

Further, analyses are carried out on differences between men in women with respect to responsibilities for household work, employment, education, income and size of
community and how these factors are associated with health, use of medication and perceived quality of life. (In collaboration with the Centre for Gender Research)

**Project area 2: Dermatology and treatment of skin diseases in the population**

Over the years research has also been conducted in dermatology. In ongoing studies the focus is on the occurrence of dermatological problems in the population, treatment patterns and their impact on quality of life. (In collaboration with Professor Magnus Lindberg, Örebro University)

**Project area 3: Adverse drug reactions and drug related problems in the general population.**

Studies on adverse drug reactions in the general population have been carried out. Based on our Swedish cross-sectional survey on health, quality of life and the use of drugs in 2004/2005 a study of subjectively experienced adverse drug reactions and their association with self-perceived health status was concluded. With access now to data from our cross-sectional survey “Swedish Health 2012” (see above) further studies on adverse drug reactions as well as drug related problems are under way.

**Project area 4: Treatment adherence from a gender perspective with particular emphasis on depression and anxiety. (PhD-project Lena Thunander Sundbom).**

Two studies with focus on adherence to prescribed medication regimens have been carried out based on the cross-sectional survey performed in the Swedish population 2004/05. One study (published 2012) analysed gender differences in non-adherent behaviour patterns and reasons for non-adherence (NA) and the other study (published 2013) analysed the associations between symptoms of anxiety and/or depression and non-adherent behavior patterns and reasons for NA.

**Members of the group during 2013**

Dag Isacson, Professor
Kerstin Bingefors, Associate professor
Helena Wennborg, MD PhD
Lena Thunander Sundbom, PhD student
Publications, reviews and book chapters 2013


Publications, reviews and book chapters 2012


Publications, reviews and book chapters 2011

Other information
Dissertations


Awards and appointments 2013

Artursson, P. Björn Ekvall memorial award, Scandinavian Society for Cell Toxicology
Bergström, C. Adjunct Associate Professor, Monash University, Australia
Mahmoodi, F. Gabi Award, Swedish Academy of Pharmaceutical Sciences
Malmsten, M. Nordblad-Ekstrand Medal, Swedish Chemical Society
Fellowships

Alderborn, G: Member of the Royal Society of Sciences at Uppsala
Artursson, P: Fellow of the American Association of Pharmaceutical Scientists
Lennernäs, H: Fellow of the American Association of Pharmaceutical Scientists
Malmsten, M: Fellow of the Royal Society of Chemistry. Member of the Royal Swedish Academy of Engineering Sciences (IVA)
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