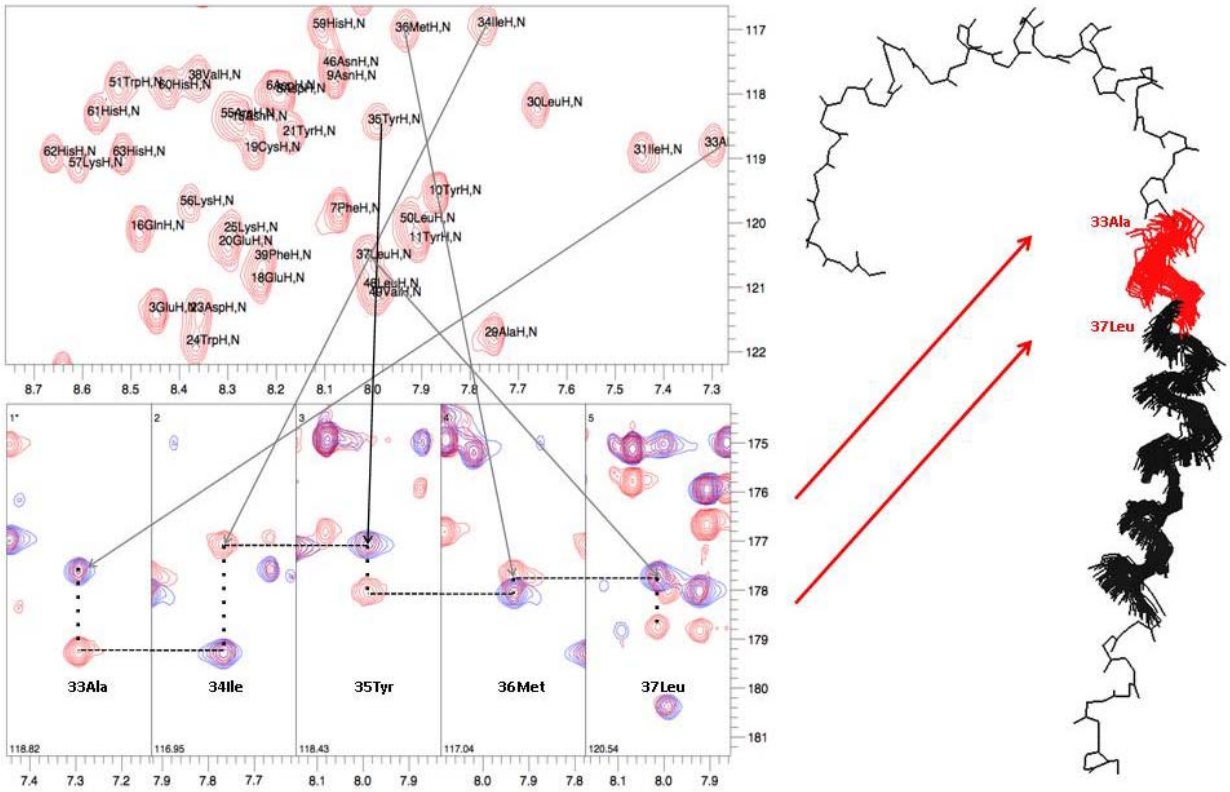
NUCLEAR MAGNETIC RESONANCE RESEARCH RESOURCE

2010-2011 Annual Report



http://nmr3.chemistry.dal.ca

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About the cover: the structure of the N-terminus and first transmembrane segment of the apelin receptor was determined in the facility by David Langelaan as part of his doctoral work with Dr. Jan Rainey. Both 2 dimensional and 3 dimensional NMR data were used to determine the structure shown on the right.

1. Introduction

1.1. Mission Statement

The Nuclear Magnetic Resonance Research Resource (NMR^3) is a research resource for nuclear magnetic resonance, with a client base distributed throughout the Atlantic region, primarily in the Maritime Provinces. The Centre was established as the Atlantic Region Magnetic Resonance Centre in 1982 through financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC) and Dalhousie University and has enjoyed continuous support from these and other sources throughout its history. The mission of the facility is to provide high-field nuclear magnetic resonance (NMR) spectral data and expertise to scientists in the Atlantic Region of Canada. The facility has enhanced numerous research programs and resulted in the training of numerous young scientists attending Universities in the Atlantic Region.

1.2. Executive Summary

The Nuclear Magnetic Resonance Research Resource supports users from the Atlantic region, primarily the Maritime Provinces, but also some international collaborators. The Centre provides NMR services to academic, industrial, and government (NRC) users, in forms ranging from training to data acquisition and interpretation to research collaboration. Housed in the Chemistry Building at Dalhousie University, the NMR^3 currently hosts 4 NMR spectrometers with a variety of capabilities, ranging from 250 MHz for liquids to 700 MHz for solids. It has a staff of two Ph.D. level chemists, who work with the users on data acquisition and interpretation, and facility maintenance. In addition, the NMR^3 partners with the NRC IMB lab in the operation of a 700 MHz spectrometer optimized for biological samples, and NMR^3 users are allocated up to 30% of the time on this instrument. Because of the high concentration of small- to medium-sized universities in the Atlantic Region, the NMR^3 plays a special role as a catalyst in enhancing research in the area, by providing both equipment and expertise in NMR that these universities cannot afford individually, and which would be highly redundant to provide at each.

Nuclear magnetic resonance (NMR) spectroscopy is the most important characterization technique available to chemists, biochemists and materials scientists, and is very important for many others including clinicians. Technological advances in the last decade have tremendously enhanced the value of NMR spectroscopic data and the variety of experiments now available. The Atlantic Region has a world-class reputation for research involving NMR spectroscopy and research that depends on NMR spectroscopy. In the previous year the Centre assisted over 40 research groups from a variety of locations throughout the Atlantic region, resulting in over 55 publications and over 100 highly qualified personnel trained.

1.3. Contact Info

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2. Highlights of the Year

2.1. Financial Update

As noted in last year's report, our NSERC operating grant was cut substantially due to changes in NSERC's support of research centres. Our grant was for a single year, which ended in April 2010. We spent that period working to increase funding from a variety of sources, including NSERC—an appeal was filed, and also a new proposal submitted, but with no success. Fortunately Dalhousie University and in particular the Dean of Science has been very supportive, awarding us both increased funding related to Dr. Lumsden's position, and, based on Dr. Zwanziger's CRC renewal (awarded in July 2010), funding to be used towards Dr. Werner-Zwanziger's position. We are very grateful for this support. While both are of limited duration, they give us time and flexibility to attract further outside funding.

2.2. MOOT XXIII Mini NMR Symposium

During the week-end of October 15th – 17th, 2011, the NMR^3 was proud host of the 23rd annual MOOT Mini NMR Symposium. Each year, this symposium provides an informal environment for students, post-docs, and faculty to present their research and network with other spectroscopists in the region. Traditionally, the meeting has been a gathering of spectroscopists from Quebec and Ontario and hosted at various locations throughout those 2 Provinces. MOOT XXIII was the first time this meeting was held outside the traditional region and is a testament to the stellar level of NMR-dependent research occurring in the Atlantic region. The meeting attracted a total of 68 participants with representation from McMaster University, Memorial University, University of Toronto, University of Ottawa, University of Guelph, York University, University of Windsor, St. Mary's University, and Dalhousie. Also represented were the NRC Institutes of Marine Biosciences and the Steacie Institute for Molecular Sciences, Agri-Food Canada, the Quebec/Eastern Canada High Field NMR Facility, Ocean Nutrition Canada, Bruker, Agilent Technologies, Cambridge Isotope Labs, and Isotec Stable Isotopes. The conference program consisted of a Friday evening Mixer, oral presentations Saturday and Sunday along with a poster session Saturday afternoon, and a Saturday evening banquet at the Halifax Citadel National Historic Site. A total of 16 talks and 18 posters were presented. We are extremely grateful to our MOOT XXIII sponsors: Bruker Ltd., Dalhousie University (President's Office, Faculties of Science and Medicine, and the Departments of Chemistry and Biochemistry), Agilent Technologies, Suraj Manrao Student Science Fund, Sigma-Aldrich, Wilmad LabGlass, CIL, the National Ultrahigh-Field NMR Facility for Solids, New Era Enterprises, and the Dalhousie Institute for Research in Materials.

3. Equipment

3.1. Overview of Current Resources

The following tables outline the current suite of spectrometers managed by the NMR^3.

Bruker/Tecmag AC – 250 MHz: Liquids Only		
Magnet	Oxford 250/54 mm	
Console	Bruker AC with a Tecmag upgrade to a DSPect-F12 Data Acquisition System	
Channel 1	Broadband Transmitter	
Channel 2	^{1}H and ^{19}F	
Probe 1	5mm QNP probe	Observe: ^{13}C, ^{31}P, ^{19}F/ dec.: ^{1}H, switchable under software control

Temperature Control	B-VT1000	Includes a 25L liquid nitrogen dewar and a nitrogen evaporator for generating cold N_2 gas.
Workstation	Dell Optiplex GX260 (Pentium 4) operating with Windows XP Pro SP2	
Spectrometer Software	NTNMR (Tecmag, Version 2.3.4 Build 30919)	

Bruker AVANCE – 300 MHz: Liquids Only		
Magnet	Bruker 300/54mm on a TMC Anti-Vibration Platform	
Console	Bruker Avance	
Channel 1	Broadband BLA2BB Amplifier (50 W ^{1}H & 135 W ^{13}C)	
Channel 2	Broadband BLA2BB Amplifier (50 W ^{1}H & 135 W ^{13}C)	
Probe 1	5 mm BBFO	Observe: ^{14}N - ^{31}P & ^{19}F / dec.: ^{1}H, z gradient coil and auto-tune / match accessory (ATMA)
Temperature Control	B-VT 3200	Includes a 25L liquid nitrogen dewar.
Workstation	HP xw4600 operating with Windows XP Pro	
Spectrometer Software	TopSpin 2.1 pl6	

Bruker AVANCE – 500 MHz: Liquids Only		
Magnet	Spectrospin 500/54mm UltraShield with anti-vibration posts	
Console	Bruker Avance	
Channel 1	Broadband (300 Watt BLAXH)	
Channel 2	^{1}H and ^{19}F (100 Watt BLAXH)	
Channel 3	Broadband (300 Watt BLAX)	
Probe 1	5 mm BBO	Observe: ^{14}N - ^{31}P / dec.: ^{1}H z gradient coil and auto-tune / match accessory (ATMA)
Probe 2	5 mm TXI	Observe: ^{1}H / dec.: ^{13}C and ^{15}N, z gradient coil.
Temperature Control	B-VT 3200	Air pre-cooled with a BCU-05 chiller, also includes a 25L liquid nitrogen dewar and a nitrogen exchange coil for generating cold N_2 gas.
Automation	60 sample B-ACS (Bruker Automation Control System)	
Workstation	HP xw4600 operating with Windows XP Pro	
Spectrometer Software	TopSpin 2.1 pl4	

Bruker AVANCE III – 700 MHz: Liquids Only**		
Magnet	Spectrospin 700/54mm UltraShield Plus with anti-vibration posts	
Console	Bruker Avance-III	
Channel 1	Broadband (500 Watt)	
Channel 2	^{1}H and ^{19}F (100 Watt)	
Channel 3	Broadband (500 Watt)	
Channel 4	Broadband (300 Watt)	
Probe 1	5 mm TCI Cryoprobe	Observe: ^{1}H / decouple: ^{13}C and ^{15}N, with z gradient coil and auto-tune / match accessory (ATMA). ^{1}H, ^{2}H (lock), and ^{13}C preamps cryogenically cooled.
Probe 2	1.7 mm TCI Cryoprobe	Observe: ^{1}H / decouple: ^{13}C and ^{15}N, with z gradient coil and auto-tune / match accessory (ATMA). ^{1}H, ^{2}H (lock), and ^{13}C preamps cryogenically cooled.
Probe 3	5 mm BBO	Observe: ^{15}N - ^{31}P / decouple: ^{1}H, z gradient coil and auto-tune / match accessory (ATMA).
Temperature Control	B-VT 3000	Air pre-cooled with a BCU-05 chiller. Also includes a 25L liquid nitrogen dewar and a nitrogen exchange coil for generating cold N_2 gas. All probes equipped with BTO2000 accessory
Automation	SampleJET - accommodates up to 5 x 96 tubes + 47 individual positions. Equipped with a cooling option to cool samples down to 4°C.	
Workstation	HP xw4600 operating with Red Hat Enterprise Linux (Release 4)	
Spectrometer Software	TopSpin 2.1 pl4	

***Instrument sited at the NRC Institute for Marine Biodiagnostics NMR lab located adjacent to Dalhousie. The spectrometer is jointly owned and operated with this NMR lab.*

DSX 400 MHz: Solids Only		
Magnet	Buker 400/89 UltraShield	
Console	Bruker Avance DSX	
Channels 1-3	Broadband Transmitter	
Probe 1	2.5mm MAS	^{69}Ga-^{31}P / ^{19}F-^{1}H

Probe 2	4mm HXY MAS	in dual mode: 45MHz - ^{31}P / ^{1}H Insert Pairs for X/Y (triple) mode: ^{31}P/^{11}B, ^{31}P/^{27}Al, ^{11}B/^{13}C, ^{13}C/^{195}Pt, ^{23}Na/ ^{29}Si, ^{6}Li/^{29}Si
Probe 3	4mm MAS	^{13}C-^{31}P/ ^{19}F-^{1}H
Probe 4	7mm	^{15}N-^{31}P/ ^{19}F-^{1}H
Probe 5	HP wideline probe	^{109}Ag – ^{31}P , high temperature design
Workstation	Silicon Graphics O^{2} operating with IRIX 6.3	
Spectrometer Software	XWIN-NMR 3.6 pl6	

AVANCE 700 MHz: Solids Only		
Magnet	Buker 700/54 UltraShield	
Console	Bruker Avance	
Channels 1-3	Broadband Transmitter	
Probe 1	2.5mm MAS	^{13}C-^{31}P / ^{19}F-^{1}H
Probe 2	4mm MAS	^{15}N-^{13}C/ ^{19}F-^{1}H, ^{43}Ca
TriGamma™ Probe	3.2mm MAS	^{15}N-^{29}Si/^{11}B-^{31}P/^{1}H
Triple Resonance Probe	4mm MAS	^{29}Si/^{11}B/^{1}H
Low Gamma Probe	5mm MAS	Special inserts for ^{43}Ca, ^{39}K, ^{91}Zr, ^{107}Ag, ^{67}Zn, ^{25}Mg, ^{135}Ba, ^{33}S, ^{14}N, ^{47,49}Ti, ^{89}Y, ^{87}Sr /^{19}F-^{1}H,
EFREE Probe (contact Jan Rainey, if you are interested in using this probe).	5mm static solenoid	HCN/P
Workstation	Dell (Pentium) operating with RedHat Linux	
Spectrometer Software	XWIN-NMR 3.6 pl6	

3.2. Major Changes/Events over Past Year

1. Acquisition of Low-Frequency Probehead for AVANCE-700: Thanks to the successful Research Tools and Instruments – Category 1 grant (NSERC) "Acquisition of an NMR Probe for Low-Frequency Nuclei" led by Professor Josef Zwanziger and co-applicants Professors Daniel Boyd, Mark Filiaggi, Jan Rainey, Mary Anne White, and Ulrike Werner-Zwanziger a probe head for our 700MHz solid state NMR spectrometer for the detection of nuclei such as ^{43}Ca, ^{39}K, ^{91}Zr, ^{107}Ag, ^{67}Zn, ^{25}Mg and others was purchased. The probe head was delivered in November 2010 and has become a major research tool. It has been already extensively used for the NMR studies of ^{43}Ca, ^{39}K, and ^{67}Zn in glasses and ceramics.

2. Installation of a Bruker AVANCE 300 Spectrometer: In October, 2010, a Bruker AVANCE 300 NMR spectrometer was installed in Room 431 of NMR^{3}. Purchased with monies obtained via the Dalhousie Teaching Equipment Fund and the NMR^{3}, the spectrometer provides a very nice complement to the pre-existing suite of NMR^{3} high-resolution NMR spectrometers. The spectrometer is equipped with a used, but completely refurbished, 7 Tesla magnet and a 2-channel AVANCE console. As outlined in section 3.1, the instrument is equipped with a Z-gradient BBFO probe that includes the Bruker auto-tune and match feature, making it an extremely easy spectrometer to use. High scheduling priority is given to

Dalhousie Undergraduate labs and other teaching related purposes, with the remaining time available for research projects. A training course was devised shortly after the installation and, at the time of this writing, a total of 64 researchers had completed the training.

3. *Routine use of EFREE Static Solids Probe* – thanks to a generous infrastructure donation from Bruker BioSpin to Dr. Jan Rainey, we have a state-of-the-art triple-resonance static solids probe. The default probe configuration is a 5 mm solenoidal coil, allowing for study of samples in round tubes with outer diameter 5 mm. Typically, this style of probe is used for solution samples of phospholipid bicelles prepared in such a way as to impart anisotropy in magnetic susceptibility. Bicelles of this size scale tumble too slowly for solution-state NMR and align relative to the B_0 field of the spectrometer, providing relatively sharp lines in comparison to powder pattern spectra. The probe has an inner solenoid coil capable of exciting/observing ^{13}C alongside either ^{15}N or ^{31}P and an outer ^{1}H "cage coil" optimized for decoupling with minimal heating due to electric field ("EFREE"). Beyond bicelle samples, other uses for the probe may certainly be envisioned and are encouraged!

3.3. Major Plans for Near Term Changes

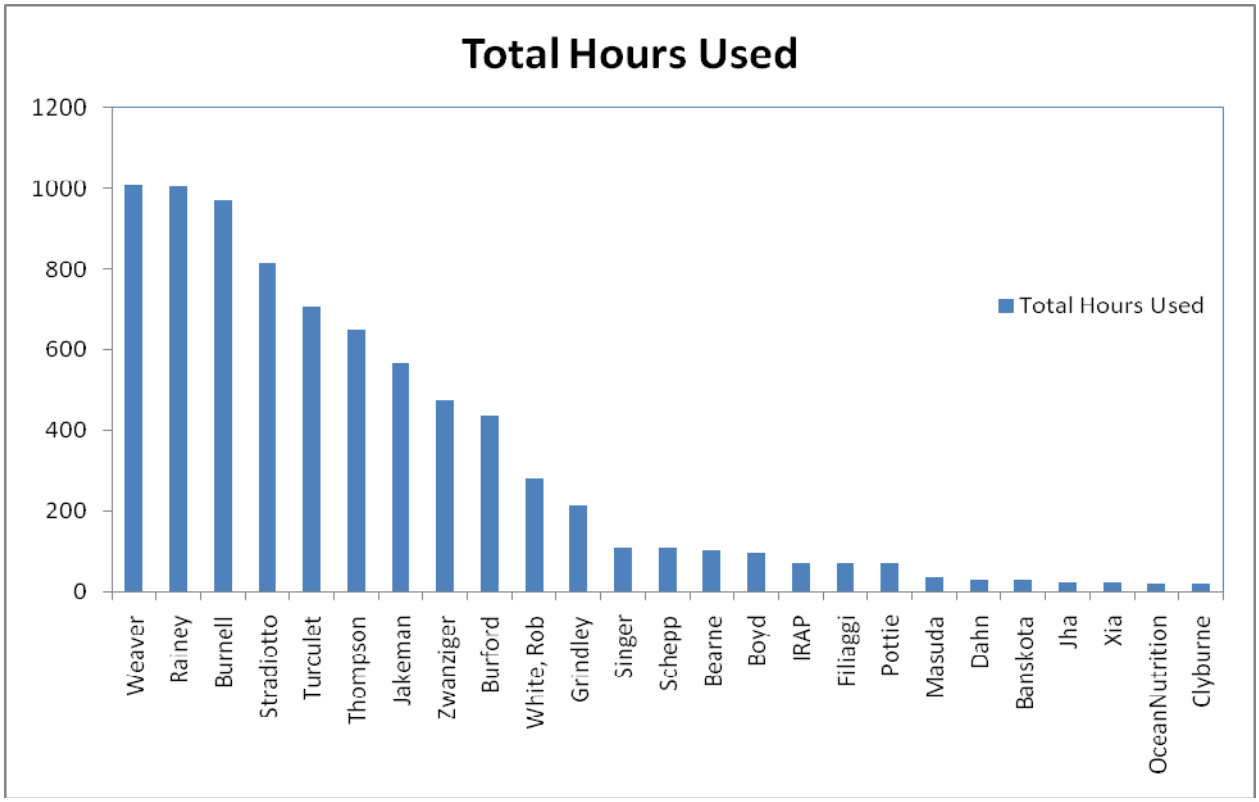
1. NSERC RTI Application for 500 MHz Bruker SmartProbe: An NSERC application is being submitted to the Research Tools and Instruments grant competition this year for a Bruker 5mm BBFO 500 MHz SmartProbe. This probe is a recent and innovative addition to the Bruker family of probes and offers marked increases in sensitivity, water suppression, and flexibility compared to the older BBO probe technology. Of particular interest is the ease of obtaining double resonance NMR data involving ^{19}F and ^{1}H nuclei. For example, both $^{19}F\{^{1}H\}$ experiments as well as $^{1}H\{^{19}F\}$ experiments can be performed trivially (no recabling required) with this probehead.

2. *User fees:* The shift in funding for NMR-3 away from NSERC funding and towards increased subsidization by Dalhousie University means that we will need to reconsider the user fee model. Currently, all academic users pay one rate, regardless of home institution. Unfortunately for non-Dalhousie users, we will likely have to change this model so that Dalhousie users benefit from the internal subsidization of costs while external users do not. Beyond academic users, NMR-3 currently does not have a separate rate for users based at government laboratories, with these users paying academic rates. Other Canadian NMR facilities typically charge a rate more reflective of cost-recovery for government users, and we will likely be proposing a similar modification to our fee structure. Any and all changes to user fees will be presented to the User Group for discussion and ratification prior to implementation.

4. Usage

4.1. Usage Summary

Over the last year, NMR^3 users logged over 8,000 hours of data acquisition time on the various instruments. This usage was divided among 41 separate research groups, distributed amongst Dalhousie, (19), Other Academic (15, including 3 international collaborations), and Industrial/Government labs (7). The usage profile for the heaviest user groups is shown below in the bar graph. This usage generated 57 publications. As the graph and publication list clearly show, NMR^3 continues to have a significant impact both in terms of usage and deliverables.



4.2. Publications Arising From NMR³ Data

PUBLICATIONS 2010-2011 (since the last Annual Report)

1. **[Ir(COD)Cl](2) as a Catalyst Precursor for the Intramolecular Hydroamination of Unactivated Alkenes with Primary Amines and Secondary Alkyl- or Arylamines: A Combined Catalytic, Mechanistic, and Computational Investigation,** KD Hesp, S Tobisch, and M Stradiotto, Journal Of The American Chemical Society 132, 413-426 (2010).

2. **2-Propynyl 2,3,4,6-tetra-O-acetyl-alpha-D-mannopyranoside**, H Al-Mughaid, KN Robertson, U Werner-Zwanziger, MD Lumsden, TS Cameron, and TB Grindley, Acta Crystallographica Section C-Crystal Structure Communications 67, O60-O63 (2011).

3. **A Highly Versatile Catalyst System for the Cross-Coupling of Aryl Chlorides and Amines**, RJ Lundgren, A Sappong-Kumankumah, and M Stradiotto, Chemistry-A European Journal 16, 1983-1991 (2010).

4. **A P,N-Ligand for Palladium-Catalyzed Ammonia Arylation: Coupling of Deactivated Aryl Chlorides, Chemoselective Arylations, and Room Temperature Reactions,** RJ Lundgren, BD Peters, PG Alsabeh, and M Stradiotto, Angewandte Chemie-International Edition 49, 4071-4074 (2010).

5. **β-Alanine as a small molecule neurotransmitter**, KE Tiedje, K Stevens, S Barnes, and DF Weaver,

Neurochemistry International 57, 177-188 (2010).

6. **Biophysical characterization of G-protein coupled receptor-peptide ligand binding,** DN Langelaan, P Ngweniform, and JK Rainey, Biochemistry And Cell Biology-Biochimie Et Biologie Cellulaire 89, 98-105 (2011).

7. **Bismuthenium-pnictonium dications [R ' BiPnR(3)](2+) (Pn = As, Sb) containing carbenoid bismuth centers and rare Bi-Sb bonds**, E Conrad, N Burford, R Mcdonald, and MJ Ferguson, Chemical Communications 46, 4598-4600 (2010).

8. **Chemoenzymatic Synthesis, Inhibition Studies, and X-ray Crystallographic Analysis of the Phosphono Analog of UDP-Galp as an Inhibitor and Mechanistic Probe for UDP-Galactopyranose Mutase**, SK Partha, A Sadeghi-Khomami, K Slowski, T Kotake, NR Thomas, DL Jakeman, and DAR Sanders, Journal Of Molecular Biology 403, 578-590 (2010).

9. **Comprehensive Chemical Characterization of Complexes Involving Lead-Amino Acid Interactions**, CDL Saunders, LE Longobardi, N Burford, MD Lumsden, U Werner-Zwanziger, BH Chen, and R Mcdonad, Inorganic Chemistry 50, 2799-2810 (2011).

10. **Configurations and conformations of glycosyl sulfoxides**, H Liang, M Mackay, TB Grindley, KN Robertson, and TS Cameron, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 88, 1154-1174 (2010).

11. **Conversion of 4,4-Difluoro-4-bora-3a,4a-diaza-s-indacenes (F-BODIPYs) to Dipyrrins with a Microwave-Promoted Deprotection Strategy**, SM Crawford, and A Thompson, Organic Letters 12, 1424-1427 (2010).

12. **Copper-mediated nuclease activity of jadomycin B**, SMA Monro, KM Cottreau, C Spencer, JR Wentzell, CL Graham, CN Borissow, DL Jakeman, and SA Mcfarland, Bioorganic & Medicinal Chemistry 19, 3357-3360 (2011).

13. **Correlation of network structure with devitrification mechanism in lithium and sodium diborate glasses**, B Chen, U Werner-Zwanziger, JW Zwanziger, MLF Nascimento, L Ghussn, and ED Zanotto, Journal Of Non-Crystalline Solids 356, 2641-2644 (2010).

14. **Design and applications of an in situ electrochemical NMR cell**, XC Zhang, and JW Zwanziger, Journal Of Magnetic Resonance 208, 136-147 (2011).

15. **Diverse DNA-Cleaving Capacities of the Jadomycins through Precursor-Directed Biosynthesis**, KM Cottreau, C Spencer, JR Wentzell, CL Graham, CN Borissow, DL Jakeman, and SA Mcfarland, Organic Letters 12, 1172-1175 (2010).

16. **Effects of solvent dielectric on H-1 and C-13 NMR random coil chemical shifts**, ML Tremblay, AW Banks, and JK Rainey, Biochemistry And Cell Biology-Biochimie Et Biologie Cellulaire 88, 414-414 (2010).

17. **Efficient and Controllably Selective Preparation of Esters Using Uronium-Based Coupling Agents**, JDK Twibanire, and TB Grindley, Organic Letters 13, 2988-2991 (2011).

18. **ESI-MS Differential Fragmentation of Positional Isomers of Sulfated Oligosaccharides Derived from Carrageenans and Agarans**, AG Goncalves, DRB Ducatti, TB Grindley, MER Duarte, and

MD Noseda, Journal Of The American Society For Mass Spectrometry 21, 1404-1416 (2010).

19. **E/Z Product distribution in the metathesis of allyl alcohol derivatives with a first generation Ruthenium-based catalyst,** JR Moulins and DJ Burnell, Tetrahedron Letters 52, 3992-3994 (2011).

20. **Geminal acylation of alpha-heterosubstituted cyclohexanones and their ketals**, IR Pottie, SN Crane, AL Gosse, DO Miller, and DJ Burnell, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 88, 1118-1124 (2010).

21. **Hydrolyzable Tannins (Chebulagic Acid and Punicalagin) Target Viral Glycoprotein-Glycosaminoglycan Interactions To Inhibit Herpes Simplex Virus 1 Entry and Cell-to-Cell Spread**, LT Lin, TY Chen, CY Chung, RS Noyce, TB Grindley, C Mccormick, TC Lin, GH Wang, CC Lin, and CD Richardson, Journal Of Virology 85, 4386-4398 (2011).

22. **Identification of reaction products from reactions of free chlorine with the lipid-regulator gemfibrozil**, WH Krkosek, SA Koziar, RL White, and GA Gagnon, Water Research 45, 1414-1422 (2011).

23. **Improved Synthetic Route to C-Ring Ester-Functionalized Prodigiosenes**, MI Uddin, S Thirumalairajan, SM Crawford, TS Cameron, and A Thompson, Synlett 13, 2561-2564 (2010).

24. **Interrogation of the active site of OMP decarboxylase from Escherichia coli with a substrate analogue bearing an anionic group at C6**, S Thirumalairajan, B Mahaney, and SL Bearne, Chemical Communications 46, 3158-3160 (2010).

25. **Intramolecular hydroamination of unactivated alkenes with secondary alkylamines catalyzed by iridium phosphino-phenolate complexes**, KD Hesp, R Mcdonald, and M Stradiotto, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 88, 700-708 (2010).

26. **Investigations into the Nucleophilic meso-Substitution of F-BODIPYs and Improvements to the Synthesis of 4,4-Difluoro-4-Bora-3a,4a-Diaza-s-Indacene,** SM Crawford, and A Thompson, Heterocycles 83, 311-322 (2011).

27. **Isolation of phosphorylated polysaccharides from algae: the immunostimulatory principle of Chlorella pyrenoidosa**, ER Suarez, JA Kralovec, and TB Grindley, Carbohydrate Research 345, 1190-1204 (2010).

28. **Kinetics and Thermodynamics of the Monomer-Dimer Equilibria of Dialkoxydibutylstannanes**, SR Whittleton, AJ Rolle, RJ Boyd, and TB Grindley, Organometallics 29, 6384-6392 (2010).

29. **Lithiated 1,4,5,8-Naphthalenetetraol Formaldehyde Polymer, An Organic Cathode Material**, A Kassam, DJ Burnell, and JR Dahn, Electrochemical And Solid State Letters 14, A22-A23 (2011).

30. **Membrane catalysis of peptide-receptor binding,** DN Langelaan, and JK Rainey, Biochemistry And Cell Biology-Biochimie Et Biologie Cellulaire 88, 203-210 (2010).

31. **Metabolic footprinting of the anaerobic bacterium Fusobacterium varium using H-1 NMR spectroscopy**, KL Resmer, and RL White, Molecular Biosystems 7, 2220-2227 (2011).

32. **Nazarov Cyclizations of an Allenyl Vinyl Ketone with Interception of the Oxyallyl Cation Intermediate for the Formation of Carbon-Carbon Bonds**, VM Marx, and DJ Burnell, Journal Of

The American Chemical Society 132, 1685-1689 (2010).

33. **New insights concerning the mechanism of reversible thermochromic mixtures,** H Tang, DC Maclaren, and MA White, Canadian Journal of Chemistry-Revue Canadienne De Chimie 88, 1063-1070 (2010).

34. **Non-resonant two-photon photochemistry of a Barton ester, N-phenylacetyloxy-2 pyridinethione**, NP Schepp, CJM Green, and FL Cozens, Photochemical & Photobiological Sciences 9, 110-113 (2010).

35. **P-31 NMR Studies Demonstrating the Assembly of catena-Phosphorus Frameworks from Chlorophosphinochlorophosphonium Cations**, YY Carpenter, N Burford, DL Michael, and R Mcdonald, Inorganic Chemistry 50, 3342-3353 (2011).

36. **Palladium-Catalyzed Cross-Coupling of Aryl Chlorides and Tosylates with Hydrazine**, RJ Lundgren, and M Stradiotto, Angewandte Chemie-International Edition 49, 8686-8690 (2010).

37. **Palladium-Catalyzed Mono-alpha-arylation of Acetone with Aryl Halides and Tosylates**, KD Hesp, RJ Lundgren, and M Stradiotto, Journal Of The American Chemical Society 133, 5194-5197 (2011).

38. **Palladium-catalyzed synthesis of indoles via ammonia cross-coupling-alkyne cyclization**, PG Alsabeh, RJ Lundgren, LE Longobardi, and M Stradiotto, Chemical Communications 47, 6936-6938 (2011).

39. **Phosphinopnictinophosphonium frameworks**, E Conrad, N Burford, U Werner-Zwanziger, R Mcdonald, and MJ Ferguson, Chemical Communications 46, 2465-2467 (2010).

40. **Platinum-Catalyzed Alkene Cyclohydroamination: Evaluating the Utility of Bidentate P,N/P,P Ligation and Phosphine-Free Catalyst Systems**, CB Lavery, MJ Ferguson, and M Stradiotto, Organometallics 29, 6125-6128 (2010).

41. **Probing Mesitylborane and Mesitylborate Ligation Within the Coordination Sphere of Cp*Ru((PPr3)-Pr-i)(+): A Combined Synthetic, X-ray Crystallographic, and Computational Study**, KD Hesp, FO Kannemann, MA Rankin, R Mcdonald, MJ Ferguson, and M Stradiotto, Inorganic Chemistry 50, 2431-2444 (2011).

42. **Prototypical arsine-triel adducts (R3AsEX3 for E = B, Al, and Ga)**, E Conrad, J Pickup, N Burford, R Mcdonald, and MJ Ferguson, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 88, 797-803 (2010).

43. **Relationship between thermal conductivity and structure of nacre from Haliotis fulgens,** LP Tremblay, MB Johnson, U Werner-Zwanziger, and MA White, Journal of Materials Research 26, 1216-1224 (2011).

44. **Rhodium- and Iridium-Catalyzed Hydroamination of Alkenes**, KD Hesp, and M Stradiotto, Chemcatchem 2, 1192-1207 (2010).

45. **Rhodium phosphino-enolate complexes as chemo- and regioselective catalysts for the hydroformylation of styrenes**, YS Uh, A Boyd, VR Little, PG Jessop, KD Hesp, J Cipot-Wechsler, M Stradiotto, and R Mcdonald, Journal Of Organometallic Chemistry 695, 1869-1872 (2010).

46. **Substituent controlled reactivity in the Nazarov cyclizations of allenyl vinyl ketones,** VM Marx, RL Stoddart, GS Heverly-Coulson, and DJ Burnell, Chemistry – A European Journal 17, 8098-8105 (2011).

47. **Stereo- and Regioselective Gold-Catalyzed Hydroamination of Internal Alkynes with Dialkylamines**, KD Hesp, and M Stradiotto, Journal Of The American Chemical Society 132, 18026-18029 (2010).

48. **Structural aspects of the photoelastic response in lead borate glasses**, V Martin, B Wood, U Werner-Zwanziger, and JW Zwanziger, Journal Of Non-Crystalline Solids 357, 2120-2125 (2011).

49. **Synthesis of new cores and their use in the preparation of polyester dendrimers**, JDK Twibanire, H Al-Mughaid, and TB Grindley, Tetrahedron 66, 9602-9609 (2010).

50. **The Development of New Therapeutics for Alzheimer's Disease**, MD Carter, GA Simms, and DF Weaver, Clinical Pharmacology & Therapeutics 88, 475-486 (2010).

51. **The first series of alkali dipyrrinato complexes**, AA Ali, J Cipot-Wechsler, SM Crawford, O Selim, RL Stoddard, TS Cameron, and A Thompson, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 88, 725-735 (2010).

52. **The predictive accuracy of secondary chemical shifts is more affected by protein secondary structure than solvent environment**, ML Tremblay, AW Banks, and JK Rainey, Journal Of Biomolecular Nmr 46, 257-270 (2010).

53. **The reactivity of diarylmethyl carbocations within non-protic zeolites**, GL Hallett-Tapley, NP Schepp, and FL Cozens, Canadian Journal Of Chemistry-Revue Canadienne De Chimie 89, 347-358 (2011).

54. **Transition-Metal-Catalyzed Trifluoromethylation of Aryl Halides**, RJ Lundgren, and M Stradiotto, Angewandte Chemie-International Edition 49, 9322-9324 (2010).

55. **Trapping the Oxyallyl Cation Intermediate Derived from the Nazarov Cyclization of Allenyl Vinyl Ketones with Nitrogen Heterocycles**, VM Marx, FM Lefort, and DJ Burnell, Advanced Synthesis & Catalysis 353, 64-68 (2011).

56. **Vinylogous anionic processes in the formation and interconversion of tetracyclic ring systems**, PD Thornton, TS Cameron, and DJ Burnell, Organic & Biomolecular Chemistry 9, 3447-3456 (2011).

57. **Zwitterionic Relatives of Cationic Platinum Group Metal Complexes: Applications in Stoichiometric and Catalytic sigma-Bond Activation**, M Stradiotto, KD Hesp, and RJ Lundgren, Angewandte Chemie-International Edition 49, 494-512 (2010).

THESES 2010-2011 (since the last Annual Report)

1. **Characterization and Isolation of Newly Discovered Metabolic Products of *Fusobacterium varium***, N.T. Moussa, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

2. **Complexes Involving Pnictogen-Pnictogen Bonds**, Stuart Lucas, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

3. **Design and Application of P, N-Ligands for Platinum-Group Metal Catalyzed Reactions**, Rylan J. Lundgren, Ph.D. Thesis, Chemistry, Dalhousie University.

4. **Effect of Chain Length in Anionic Fragmentation Using Electrospray Ionization and Collision Induced Dissociation**, M. Ruzic-Gauthier, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

5. **Evaluation and Synthesis of Sugar 1-Phosphate Substrates for Nucleotidylyltransferases,** Steve Beaton, M.Sc. Thesis, Pharmacy, Dalhousie University.

6. **Feasibility of the GB1 Fusion Protein for Overexpression and NMR Analysis of Membrane Proteins,** Lesley Seto, B.Sc. Honours Thesis, Biochemistry & Molecular Biology, Dalhousie University.

7. **Interpnictogen Cations**, Brendan Peters, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

8. **Investigations into the Reactivity and Structure of Phosphinophosphonium Cations and Related Species**, Yuen-Ying Carpenter, Ph.D. Thesis, Chemistry, Dalhousie University.

9. **Late Transition Metal Complexes for E-H Bond Activation and Additions to Multiple Bonds,** Kevin D. Hesp, Ph.D. Thesis, Chemistry, Dalhousie University.

10. **New catena-Phosphorus Cations,** James Sharpe, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

11. **Phosphorus Insertion into P-P Bonds,** Dane Knackstedt, M.Sc. Thesis, Chemistry, Dalhousie University.

12. **Precursor-Directed Biosynthesis of Novel Jadomycins and Expansion of the Jadomycin Library**, Stephanie Dupuis, M.Sc. Thesis, Pharmacy, Dalhousie University.

13. **Thermodynamic Characterization of the Membrane Catalysis Mechanism of the G Protein-Coupled Receptor Ligand, Apelin,** Christopher A. Doyle, Honours Thesis, Chemistry, Dalhousie University.

14. **Towards the Asymmetric Oxidation of Diaryl Sulfides and Towards the Synthesis and Diastereoselective Complexation of Chiral Dipyrrinato and Bis(dipyrrinato) Ligands**, Heather A. Cosh., M.Sc. Thesis, Chemistry, Dalhousie University.

15. **Towards the Synthesis of Asymmetric 2-(arylsulfinyl)pyrroles and the Synthesis of Pyrrole-bound Ruthenium Complexes,** Carla LM Jackson, M.Sc. Thesis, Chemistry, Dalhousie University.

16. **Towards the Synthesis of New P-N and N-heterocyclic Carbene Ligands for Application in Buchwald-Hartwig Amination,** Lauren Longobardi, B.Sc. Honours Thesis, Chemistry, Dalhousie University.

4.3. Summaries of Research Programs

S. Bearne (Biochemistry and Molecular Biology, Dalhousie) The prime objective of my research program is to understand the nature of the protein-ligand interactions which enzymes utilize to effect rate enhancements. I am studying catalysis by CTP synthase (CTPS) and variety of racemases. My efforts are focused on [1] using transition state analogue inhibitors to probe the role of protein-ligand interactions in transition state stabilization, [2] determining the intrinsic stability of reactive intermediates formed during catalysis and how specific protein-ligand interactions stabilize these intermediates, and [3] developing inhibitors of enzymes that are of therapeutic interest. Part of my work involves synthesis of small molecules as inhibitors or alternative substrates for these enzymes, and requires routine access to an NMR spectrometer (^{1}H, ^{13}C, ^{31}P, and ^{15}N on either the 250 or 500 MHz instruments). In addition, we use NMR as a method to conduct kinetic experiments and to probe the interaction between enzymes and small molecules.

N. Burford (Chemistry, Dalhousie) We are investigating synthetic routes to new, structurally simple molecules containing P, As, Sb or Bi (pnictogens), in which the pnictogen center exhibits unusual structure and/or is engaged in a new 'bonding environment'. Our research program is establishing new directions in the chemistry of the pnictogens that are changing the way in which the chemistry of the non-metal elements is considered in general. Assessment and interpretation of structure and bonding relies on a wide variety of techniques, including infrared and Raman spectroscopies and mass spectrometry. X-ray crystallography is a very powerful technique for providing structural information, but it requires that the sample be obtained as a high quality single crystal, and this is often impractical. NMR spectroscopy on solutions and solids is our most important characterisation tool. We make use of all NMR active nuclei, so that essentially every experiment that involves studying a reaction or characterising a material requires the use of NMR spectroscopy at some stage. The ability to perform correlations between the nuclei of a variety of elements will greatly aid these efforts. All of the graduate students and most of the undergraduate students in the research group are hands-on users of NMR-3 facilities. Our recent discoveries of phosphines that behave as unusual Lewis acids (acceptors) are most illustrative of the importance of NMR spectroscopy to this program. The significance of the scientific discovery lies in the contrasts with the traditional Lewis base (donor or ligand) label for phosphines. A variety of complexes have been prepared and are NMR novel in terms of their chemical shift and coupling features. The potential for synthetic utility of these complexes is demonstrated by the observation of ligand exchange at the phosphine Lewis acid, which was recognised by NMR spectroscopy in solution and then exploited by monitoring reactions by NMR.

J. Burnell (Chemistry, Dalhousie) has been a fairly heavy user of the 500 MHz NMR spectrometer. Their needs have been, and will continue to be, in simple 1D ^{1}H and ^{13}C NMR spectroscopy, supplemented by numerous 2D spectra (COSY, HMQC, HMBC, NOESY). Their interests are in the areas of synthesis and methodology for the construction of new carbon-carbon bonds. The work on total synthesis involves routes to very complex natural products, fredericamycin A (a hexacyclic antibiotic), kempane diterpenes (tetracyclic compounds with approximately ten stereogenic centers), vinigrol (a platelet-aggregation inhibitor) and aquariolide (a complex marine metabolite).

J. Clyburne (Chemistry, Saint Mary's University) The Clyburn research group examines small molecule chemistry and coordination chemistry with application to Green chemistry. We examine the chemistry of new materials in non-volatile solvents and their application to catalysis and separations. In this light, we extensively use a variety of chemical characterization techniques to assess both the nature and purity of the molecules that we prepare. The ARMRC provides routine access to standard NMR techniques, as well as non-routine analysis. During the past year we have NMR data on over 150 samples.

F. Cozens (Chemistry, Dalhousie) The Cozens lab has established a highly innovative research program to investigate the mechanisms of fast reactions using pico- and nano-second flash photolysis. The Cozens group uses NMR spectroscopic facilities to characterize synthetic substrates and products.

A. Culf (Atlantic Cancer Research Institute & Mount Allison University) Dr. Culf's research interests can be placed into five related themes: 1) synthesis of bioactive molecules, 2) creation of photo-stable flourophores for reliable utilization in a range of biological applications, 3) metabolomic profiling of cells, tissues and organs, 4) study of protein-protein interactions with synthetic peptides and peptoids, and 5) microarray slide fabrication. The ARMRC staff has collaborated with Dr. Culf on the characterization of spirobicyclic molecules using the liquid and solid state NMR capabilities of the ARMRC. These spirobicyclic molecules are emerging as new "previleged" pharmacophoric structures with application to a diverse range of human disease states. With his collaborators Dr. Culf is exploring spirocycles synthesized via intramolecular Janovsky σ-complexes with post-synthetic catalytic functional group manipulations uncovering unique proton transfer behavior for a series of spirohydantoins. More recently, NMR structural analysis has been undertaken for a series of elctronically deactivated bifunctional amide-esters for a pending publication in collaboration with the NMR3 staff.

J. Dahn (Physics, Dalhousie) ^{1}H and ^{19}F NMR are being used to study the impact of water and HF scavengers on $LiPF_6$ containing electrolytes for Li-ion batteries. Once scavengers are shown to have the desired response in the electrolyte, scavenger-containing electrolytes are incorporated in Li-ion batteries for testing. Also, ^{13}C and ^{1}H NMR is being used to learn about polymer electrode materials, synthesized in-house.

M. Filiaggi (Applied Oral Sciences & the School of Biomedical Engineering, Dalhousie) The Filiaggi lab focuses chiefly on the development of novel degradable calcium phosphate materials for use in bone tissue regeneration and drug delivery applications. Of particular interest is a family of condensed calcium phosphates or calcium polyphosphates (CPP) distinguished by their multiple (and complex) phosphate chain structures. Through the NMR-3 facilities, ^{31}P NMR spectroscopy has become an essential tool for our group to track precessing and degradation effects on the phosphate chain structure, including semi-quantitative phosphate chain length determinations. In addition, ^{13}C solid state NMR of antibiotic-loaded CPP has enabled further evaluation of drug-matrix interactions. While our focus thus far has been on P-O bonding in these materials, systematic processing studies of these ceramics in aqueous environments suggest that Ca ions serving an ill-defined cross-linking function within these chain structures are likely key to the evolving structural changes observed. We anticipate as well that these Ca ions will play a significant role in any potential matrix-drug interactions expected to impact matrix processing and drug release profiles. To this end, studies utilizing the newly acquired dedicated low-frequency solid-state probe to track changes in Ca bonding within this structure are anticipated. Collectively, these NMR studies together with other analytical tools are expected to direct processing optimization of these matrices to suit the drug delivery application of interest, including the treatment of chronic bone infections for which localized long-term therapeutic release is required.

K. Ghandi (Chemistry & Biochemistry, Mount Allison University) My research program and the use of NMR in that is as follows: (1) Spectroscopic measurement of intermolecular interactions in ionic liquids and mixtures of molecular and ionic liquids. For these investigations, we study the variation of NMR spectra as a function of temperature and mole fraction and compare our experimental and computational data to reveal information on intermolecular interaction and structure of binding complexes in these systems. (2) Spectroscopic measurement of precursors of free radicals in different solvents. In these studies, NMR is used to make sure the free radical precursors are stable under thermodynamic conditions of our studies. (3) Studies of phase transition in ionic liquid crystals. In these studies, the line shape is used along with DSC and microscopic measurements to investigate phase transitions in ionic liquid

crystals. The phase transition information is essential for our investigation of radiation chemistry in ionic liquid crystals. (4) Investigation of products of free radical polymerizations in green solvents.

T. B. Grindley (Chemistry, Dalhousie) is interested in a variety of topics through which NMR spectroscopy is a constant thread. Study of the stannylene reaction has been a long term project in the lab and variable temperature ^{119}Sn and ^{19}F NMR spectroscopy as well as ^{1}H and ^{13}C NMR spectra currently play important roles in this work. The synthesis of glycodendrimers, potential vaccines, is facilitated by ^{1}H and ^{13}C NMR studies of structure as well as by measurements of diffusion by DOSY NMR. A study of glycosyl sulfoxides made use of 1D gradient nOe measurements to determine that solution conformations were very different than X-ray or *in silico* conformations. COSY, HSQC, TOCSY, and HMBC experiments were used to determine the structures of immunostimulating polysaccharides from edible green microalgae in collaboration with Ocean Nutrition and structural studies of polysaccharides in collaboration with others continue.

D. Jakeman's (Pharmacy and Chemistry, Dalhousie) research in biological chemistry uses NMR spectroscopy to determine the structure and dynamics of a wide variety of novel bio-molecules. Jakeman has developed a bacterial culture that ferments various amino acids into complex natural products (MW 500 - 800) with anticancer and antibacterial activity. 1D and 2D NMR spectroscopy is required to elucidate the structure of these molecules (MW 500 - 800). A second research project, involving a NSERC PGSA funded student, involves the synthesis of sugar nucleotide diphosphates as substrates for various glycosyltransferases and the subsequent enzymology. NMR spectroscopy is of fundamental importance to determine the structure of the substrates and any products from the enzymatic reactions. A third project involves the synthesis of sugar nucleotide diphosphate analogues as inhibitors of nucleotidylyltransferases. Extensive use of ^{31}P NMR spectroscopy is required to monitor the synthesis of the various phosphonate and fluorophosphonate inhibitors. A fourth project involves determining the structure of a novel series of membrane proteins responsible for cell-to-cell fusion. The structure of theecto-domain of these proteins has been determined by solution state NMR spectroscopy and stable isotope labeling studies are underway to produce ^{15}N labeled protein for structure and dynamic studies. Extensive 2D and 3D protein structure determination experiments (TROSY, NOSEY, TOCSY) will be required to solve the structure of the protein in various micelle or lipid environments. Publications are in preparation.

D. G. Marangoni's (Chemistry, St. Francis Xavier) research programme in colloid chemistry involves investigations of the physico-chemical behaviour of self-organizing molecular systems in solution. The molecular systems under investigation are: a) ionic and non-ionic surfactants; b) polymer/surfactant complexes; and c) invert emulsions and reverse micelles.

(a) The thermodynamic and micellar properties of self-assembled aggregates of both ionic and non-ionic surfactants in aqueous mixtures containing organic polar compounds will be determined in order to better understand the subtle balance of forces responsible for surfactant aggregation. Knowledge of thermodynamic properties is essential for the application of surfactant technology to process such as tertiary oil recovery, micellar catalysis, lubricants, cleaners, and in the cleanup of contaminated soils.

(b) The preparation and characterization of novel surfactants. This research programme deals with both aqueous and non-aqueous systems and will focus on the preparation and investigation of their structural properties of new surfactant systems, and the mixed micelles and aggregates that are formed by these systems in solution.

(c) The research on polymer/surfactant system deals with the understanding the nature and strength of the interactions of various surfactants with both charged and neutral polymers. Currently the interaction between novel zwitterionic surfactants with non-ionic polymers and ionic surfactants is in progress. These systems will be valuable in cosmetic preparations.

J. Masuda (Chemistry, Saint Mary's University) Research in the Masuda research group involves reactivity of main group-based molecules, in particular that of phosphorus-based radicals and cations. We are investigating the reactivity of these systems with small molecules such as hydrogen, carbon dioxide and carbon monoxide. Not only are new methods to existing molecular systems envisioned, but also new functional groups are targeted, resulting in an understanding of the bonding and reactivity of these molecular architectures. Access to the facilities and the expertise of the coordinators at the NMR-3 Center is essential to the success of my NSERC Discovery funded research program.

R.S. McDonald and E. Martin (Mt. St. Vincent) collaborate with **S. Darvesh** (Neurology Depart. Dal) on the design, synthesis, purification and characterization of several classes of 10-substituted phenothiazines which are then assayed for their ability to inhibit human cholinesterases. High field NMR (proton and carbon-13) has proven to be the most effective tool for the characterization of all our new compounds. The scientists at the Regional Magnetic Resonance Centre have been most professional and helpful in the rapid through-put of samples and in the interpretation of rather complex 2-D spectra, which we have utilized for some compounds. In addition, we have found that proton NMR is the most effective method for detecting the presence of small amounts of contaminants in the samples, be they traces of recrystallization solvents or residual starting materials.

I. Pottie (Mt. St. Vincent) We are investigating new methodologies that can be used within the Henry reaction. Traditionally, it is a reaction between a lithium nitronate and an aldehyde or ketone to produce a 1,2-nitroalcohol. Presently, two new methodologies are being developed: 1) the Mukaiyama-Henry reaction, which use silyl nitornates within the reaction conditions and 2) the use of boron nitronates within the reaction conditions. Both methodologies will lead to an general approach for an intramolecular Henry reaction. The research group is also interested in taking the chemical products from the above mentioned projects and developing these products into chemical structures that can be used in the diagnosis and possible treatment of Alzheimer's disease. All of these projects rely heavily on the ARMRC for product analysis and characterization. Mount Saint Vincent University does not have an NMR instrument suitable for generating data acceptable for peer review publications, so we rely solely on the ARMRC to conduct NMR experiments. Without it, this NSERC/CIHR funded research could not move forward.

J. Rainey (Biochemistry & Molecular Biology and Chemistry, Dalhousie) Our structural biology oriented research program makes extensive use of NMR spectroscopy. The overall goal is to understand the sub-molecular mechanisms that underlie interactions between proteins and molecules ranging from small drug molecules to other proteins. In particular, intermolecular interactions are studied with cell surface membrane-bound proteins and with proteins from the extracellular matrix. Peptides and proteins isolated from these settings are characterized in the solution-state, primarily in aqueous conditions, using standard multidimensional homo- and heteronuclear high-resolution NMR spectroscopy. Because both the cell membrane and the extracellular matrix are supramolecular assembly environments, the real environment for each class of proteins we study is best studied using solid-state NMR methods. In particular, static solid-state NMR methods (as opposed to magic angle spinning methods) are being developed and used by our group. We are particularly fortunate, courtesy of Bruker Biospin, to have recently received a state-of-the-art 700 MHz E-free triple-resonance static probe. Static solid-state NMR allows determination of the structure, position and orientation of the protein of interest relative to the remainder of the supramolecular assembly, rather than just the structure of the protein in isolation. This provides unique detail about protein structure and function in complex supramolecular environments.

N. Schepp (Chemistry, Dalhousie) The research being carried out in the Schepp group relies extensively on the use of the NMR facilities provided by ARMRC. This research is directed towards using laser flash photolysis techniques to examine the behaviour of reactive species that are generated as short-lived intermediates in enzyme-catalyzed reactions. Fundamental properties of the reactive intermediates are

obtained to more fully understand the role of key intermediates in the catalytic activity of enzymes. The research is partitioned into several distinct areas, but each area relies on the preparation of organic substrates for use in the laser and enzyme studies, and also in the identification of products generated photochemically and/or enzymatically. These substrates and products must be characterized in detail, and in each case, the primary tools for characterization are the NMR facilities provided by ARMRC.

R. Singer (Chemistry, Saint Mary's) is exploiting the unique properties and advantages of ionic liquids as reaction media in organic or organometallic reactions. This research relies heavily on multinuclear NMR spectroscopy and includes a variety of elements, including P, F, and B. The study of the critical solvent–reactant and solvent–product interactions requires the use of high field NMR spectroscopy. The development of new organometallic reagents (e.g. silyl metal and stannyl metal reagents) to be used in organic synthesis requires multinuclear (F-19, P-31, Se-77 and Si-29) NMR spectroscopy. The isolation, characterization, and synthesis of biologically active molecules from natural sources such as plant volatiles and insects, and the synthesis of insect pheromones are all of commercial importance for use in integrated pest management studies.

M. Stradiotto's (Chemistry, Dalhousie) group focuses on developing new classes of ancillary ligands/transition metal complexes that exhibit interesting and unusual reactivity patterns, with the goal of incorporating such reactivity into synthetically useful substrate transformations. Our current research program is focused on the development of: highly effective ancillary ligands for use in challenging Buchwald-Hartwig aminations, including reactions involving ammonia; new late metal catalyst complexes for the hydroamination of unsaturated substrates; and zwitterionic relatives of more traditional cationic late metal complexes, in anticipation that these may prove useful in a range of catalytic substrate transformations. Key themes that link these programs include: the establishment of innovative ligation strategies for use in constructing suitably reactive transition metal complexes; the evaluation of structure-activity relationships including mechanistic studies to guide the development of increasingly reactive complexes; and the development of new and synthetically useful substrate transformations.

A. Thompson (Chemistry, Dalhousie). Our research focuses on the development of new methodology for the synthesis and application of functionalized or homochiral pyrrolic molecules. Dipyrrins are excellent ligands and form interesting structures upon complexation with metal ions. Suitable bis(dipyrrins) form helical dinuclear metal dimers upon complexation. Our approach towards novel homochiral helical dipyrrin complexes is two-pronged, involving both chiral templates and chiral auxiliaries to effect diastereoselective. We are also working to synthesize and assess the anti-cancer properties of analogues of the tripyrrolic natural product prodigiosin.

L. Turculet (Chemistry, Dalhousie). Research in the Turculet group is focused on the design, synthesis, and study of reactive, well-defined transition metal complexes of unique construction. Key to this endeavor is the development of new types of structurally simple auxiliary ligands that enforce unusual bonding environments for both early and late transition metals, in anticipation that this will lead to new and/or improved metal-mediated reactivity. We are especially interested in designing ligands that incorporate unusual donor fragments, as well as bifunctional ligands that can help to orient substrate molecules within the coordination sphere of a transition metal. Specific metal-mediated reactivity being addressed includes polymerization chemistry, atom/group transfer chemistry, and the activation of robust sigma bonds, e.g. C-H, Si-H, C-O, C-N. These studies seek to advance our understanding of how metal-ligand interactions influence metal-centered reactivity. Such insights, when coupled with data obtained from mechanistic investigations, will provide the basis for the development of fundamentally new and synthetically useful stoichiometric or catalytic reactions.

K. Vaughan (Chemistry, Saint Mary's) Vaughan's research involves the synthesis of a variety of new triazenes and bis-triazenes in order to explore their potential properties as antitumour agents. The

methodology is based on the diazonium coupling reaction with a primary or secondary amine, sometimes in the presence of formaldehyde. New compounds are characterized by various analytical methods, including high field NMR spectroscopy.

D. Weaver (Tier I CRC, Neurology/Chemistry, Dalhousie) is involved in the design and synthesis of drugs for neurological diseases, especially epilepsy and Alzheimer's disease. Last year, his research group generated 147 novel molecules as drug candidates (121 in the epilepsy project and 26 in the Alzheimer's project). Each of these was the product of a several-step synthesis requiring high field NMR spectroscopic characterization. The research group also designs synthetic oligopeptides (4-8 residues) as putative therapeutics and as model receptor sites, such as octapeptides containing the HHQK tetrapeptide as model receptors for Alzheimer's drugs.

Mary Anne White (Chemistry, Dalhousie) We make use of ARMRC in two ways: characterization of materials by solution NMR, and solid-state studies to understand the relationships between structure and properties of materials. The latter is of importance to us in studies of materials ranging from modified zeolites to be used for catalysts, to organic solids for use in thermochromic mixtures. Many different techniques can provide structure-property probes, but for these materials ^{13}C and ^{29}Si NMR studies are especially insightful.

R. White (Chemistry, Dalhousie) R.L. White's research program in biomolecular chemistry focuses on novel aspects of bacterial metabolism and fragmentation reaction mechanisms of biologically relevant gas-phase anions. Both endeavours rely on the use of isotopically labelled compounds, synthetic chemistry, and multinuclear NMR spectroscopy. A quantitative 1H NMR method was developed to follow changes in the exometabolome of an intestinal bacterium and to determine major nutritional factors influencing the production of short-chain fatty acids. These beneficial metabolites exert positive effects on colonic health. Ongoing gas-phase investigations of structurally related amino acid derivatives synthesized in our laboratory have revealed new mechanistic insights into decarboxylation and other fundamental reactions of carboxylate anions.

E. Zodrow (Palaeobiology Laboratory at the University College of Cape Breton) Professor Zodrow has devoted his career to the taxonomy and biostratigraphy of plant fossils, specifically those of the Late Carboniferous Period. He specialises in palaeophytochemotaxonomy, the emerging science of classifying plant fossils by their biochemical nature. Using cutting edge mathematics, Prof. Zodrow also studies fractal geometry in the structure and architecture of plant fossil, i.e., fractal taxonomy. He is at the forefront of this exciting new branch of palaeobotany and his work has taking him all over the world, collaborating with scientists from different continents. Recently, Professor Zodrow and Dr. Werner-Zwanziger are applying ^{13}C solid state NMR to analyze the distribution of chemical functional groups of fossil cuticles, other fossil-plant parts and the associated coals. In the long term, they hope to determine differences between species, learn about the pathways of organic-matter transformation, and deduce information about the fossilization processes due to the influence of surrounding rocks, or diagenesis.

Josef W. Zwanziger (Tier 1 Canada Research Chair in NMR Studies of Materials, Chemistry, Dalhousie) Our research program includes NMR at many different levels. We are broadly interested in materials science, particularly structure property relationships in composite and disordered materials. We use solid-state NMR to study the structure of glassy materials, and have most recently used NMR spectroscopy in this context to relate structure to the optical response of so-called zero stress optic glasses. This work is funded by our NSERC Discovery grant and multiple grants supporting technology transfer, as this work has led to multiple patent filings. In another NSERC-funded project we are collaborating with scientists in Brazil and Argentina to study the relationship between structure and the devitrification mechanism of glass. For this work we use extensive multidimensional and multiresonant solid-state NMR experiments to correlate the intermediate range structure of the glass with that of crystals of identical composition, in

order to deduce what rearrangements are necessary upon crystal formation. In another project, we are developing an NMR probe capable of simultaneous electrochemical experiments such as CV and high-resolution liquid NMR spectroscopy. The idea here is to have the ability to take NMR spectra as a function of applied potential, so that we can study processes in battery electrolytes and more generally to study organic reaction mechanisms. Finally, we are performing computation NMR studies, and have recently implemented the calculation of NMR parameters from first principles into an open-source planewave-pseudopotential DFT code.

5. Education and Training Activities

5.1. Training of Highly Qualified Personnel

Training of HQP is a key component of NMR^3 activities. As the following sections describe in more detail, training on the instruments is provided for on-site use, and in addition our staff assist with NMR training and support at our regional partner universities. On-site at NMR^3, HQP training includes undergraduates, graduate students, and post-doctoral fellows from around the region.

5.2. Training Overview

Anyone wishing to become a hands-on user of a high-resolution NMR spectrometer at the NMR^3 is required to first attend a 1.5 h lecture on a variety of basics, including safety in an NMR laboratory, proper sample preparation, locking, shimming, etc. Attendance at the lecture and passing the concluding multiple-choice quiz is a prerequisite for getting hands-on training. Next, researchers are introduced to the AC/Tecmag-250 spectrometer in 2 x 1 h sessions in small groups. After demonstrating proficiency and competency on the AC/Tecmag-250, users can take a 1 h training course on the AVANCE 300 and/or the AVANCE 500 using the sample changer. Both of these training courses also finish with a short quiz and a practical exam. Further advanced training is provided for students requiring more specialized NMR experiments. In particular, advanced training is available for the hands-on use of the 500 spectrometer without the sample changer, and for performing variable temperature NMR experiments. In addition to spectrometer training, classroom tutorial sessions are held on the basics of processing 1D and 2D NMR data with Bruker's software package called TopSpin.

Hands-on access to the 700 MHz spectrometer located at NRC is currently provided to the majority of researchers via Dr. Mike Lumsden. The exception to this statement is the NMR savvy research group of Professor Jan Rainey from the Department of Biochemistry and Molecular Biology at Dalhousie. Individuals from this group have been trained to use the spectrometer themselves. Additionally, training courses were provided this year for researchers requesting walk-up access to the 700 MHz spectrometer using ICON-NMR and the SampleJET. Students and postdoctoral fellows from the research groups of Professors David Jakeman, Alison Thompson, Bruce Grindley, and Jan Rainey have completed this training.

Access to the Bruker Avance 400 and 700 MHz NMR spectrometers for solids is handled differently, because solid state NMR is barely routine in our facility and because of the different user profiles. Users basically fall into one of three groups:

1. Those who require solid state NMR spectroscopy only once, or rarely during their graduate careers and are not from Dalhousie University. This category also includes remote industry and government users.
2. Those who require solid state NMR occasionally, but do not use it as a main tool of their research. These users are typically from Dalhousie University.
3. Those, whose research centers around solid state NMR.

For the first group, solid state NMR spectra are provided by Dr. Ulrike Werner-Zwanziger, often without the presence of the researcher. The results are typically given in report form whose detail concerning the interpretation depends on the solid state NMR expertise of the user. For the second group, solid state NMR spectroscopy is typically performed by Dr. Ulrike Werner-Zwanziger in collaboration with and in the presence of the user. Training, more in the form of teaching is done during the acquisition of the experiments. This form of collaboration allows for more tailored research and interpretation. The final group of users typically stem from the research group of Professors Josef Zwanziger and Jan Rainey. Their students and Postdoctoral Fellows become proficient enough to conduct their experiments independently. Due to the non-routine form of their research, training here is done more in the form of collaboratively developing the experiments and determining their experimental parameters, which the users can then apply to their research materials. Some users become so independent, that they can develop experiments on their own.

5.3. Educational Activities

Over the past several years (including this reporting period), NMR^3 has provided an introduction to NMR to Junior high school, high school and undergraduate students participating in the chemistry components of Shad Valley, the High School Science and Engineering Week, and the Super Nova summer camps. On the liquid state NMR spectrometers, students are briefly introduced to the concepts of NMR, basic NMR safety and sample preparation. They then help to prepare a sample and run a ^{13}C spectrum, process the data, and interpret the results in the context of a CSI-type crime scene investigation. When time permits, students are introduced to the concepts of superconductivity as well as parallels between detecting an NMR signal and FM radio. The solid state NMR demonstrations introduce the mission of the NMR-3, the build of the solid state NMR magnets and probes and samples, the principles of solid state NMR (explained on research results for the identification of recycling products or other materials related to the interest of the visitors depending on their background knowledge).

In terms of integration with the Dalhousie Chemistry undergraduate curriculum, for the fourth consecutive year, a high-resolution NMR experiment on the Tecmag/AC-250 was included in the second year Physical Chemistry course at Dalhousie University (CHEM 2304 / ~80 students). Students were first given basic training on the AC-250 and subsequently they obtained ^{1}H NMR spectra for samples of 3 unknown aromatic compounds. The students were taught how to process the data using NT-NMR and were required to interpret and identify the aromatic compounds. As well, approximately 35 students taking the 3rd year organic chemistry course CHEM 3401 relied on the AV-500 for NMR analysis of reaction product mixtures. Finally, and new to the curriculum, a lab involving the study of reaction kinetics was conducted that made use of all 3 high resolution NMR spectrometers in NMR^3 (CHEM 3404 / ~ 30 students).

Additionally, chemistry students from Saint Mary's University taking an undergraduate chemistry course in Advanced Spectroscopy visited NMR^3 again this past year to complete a high-resolution NMR experiment on methods in carbon-13 NMR.

The staff also has been active in general science outreach by giving three lectures with demonstrations to grades three and four of primary schools including presentations about magnets and about rocks.

6. Financial Report

Financial support came from two sources, Dalhousie University and User Fees. Indirect salary expenses paid by Dalhousie University include portions of the salaries of the electronics technologist, glassblower, machinist, computer specialist, and the bookkeeper. This past year, the University paid the Coordinator's full salary and benefits whereas the Solid-State NMR Coordinator's salary was paid through CRC

funding. Direct costs of the facility this past FY included magnet cryogens, lab supplies, travel and all service and maintenance costs. As well, the facility partially funded the capital purchase of the AV-300 NMR spectrometer.

During the FY, academic hands-on use of the AC-250 and AV-300 was billed at $4.50 per hour and the AV-500 at $5.50 per hour. No distinction was made between peak and off-peak usage in terms of billing. Solid-state NMR spectrometer time was charged at $6.50 per hour. Liquids service spectra for academics (spectra run by an NMR^3 staff member) were charged at twice the academic rate. The NMR^3 contingency tax was not collected during the FY as the fund reached its target amount in 2004-2005. Service for industrial clients was billed at $65 on the AC-250 and AV-300, $130 per hour on the AV-500 and $100 per hour for solid-state service. The industrial spectral processing fee was $50 per hour.

Routine processing of NMR data by a staff member was billed at $5 per spectrum for the first 20 processed spectra within any given research group. All additional processed spectra cost $20 per spectrum. For advanced processing requests such as line shape fits or simulations, an additional $5 per spectrum was charged. Structural assignments and other forms of spectral interpretation requested of NMR^3 staff were billed at $25 per hour (minimum 1 hour charge). A charge of $5 per sample was levied to prepare routine samples for NMR analysis (liquids and solids) whereas $25 per sample was charged when air-sensitive samples required packing in a glove box for solid-state NMR analysis.