Narrative of Research and Teaching Activities of the Ontario Chair in Green Chemistry and Engineering Activities at Trent University: 2010 - 2011

This narrative examines the activities of the Ontario Research Chair in Green Chemistry and Engineering at Trent University, Professor Suresh Narine, under three headings - teaching, outreach and research activities.

1.0 Teaching Related Activities:

The Ontario Research Chair in Green Chemistry and Engineering at Trent University was slated to have the following teaching related activities from 2011 (text in *italics* are cut and pasted from the original application to COU):

The proposed Chair will have the following teaching responsibilities:

Undergraduate

- *Department of Physics, first year course, 2010: "Physics for the Life Sciences".*
- *Departments of Physics and Chemistry, fourth year course, 2011: "Physics and Chemistry of Colloidal Biomaterials"*
- *Department of Chemistry, fourth year course, 2012: "Techniques in Green Chemistry: Organic Synthesis Reactions Suitable for the Conversion of Lipid Molecules into Toxin-Free Polymers."*
- *Development in 2013 of a Trent Centre for Community Based Education community-based course: "Biomaterials- Chemistry, Ethics, and Economics".*
- *Supervision of senior undergraduate students (up to 10 per year) in project-based courses.*

Graduate

- *Materials Science and Environmental and Life Sciences Graduate Programs, 2010, "Biomaterials"*

Professor Narine was successful in securing two major research Chairs in 2011 - the Ontario Research Chair in Green Chemistry and Engineering and the Senior NSERC/GFO/ERS Industrial Research Chair in Lipid Derived Biomaterials. Due to the unusual amount of research activity and research administration that Professor Narine is engaged in as a result of holding two major research chair positions, his teaching load at Trent University has been reduced to zero.

1.1 Courses Offerred

Despite this teaching reduction, the course "Physics and Chemistry of Colloidal Biomaterials" was offered as a graduate course in 2010 - 2011, as planned. In 2012, this course has been modified by Dr. Narine and the materials incorporated into a course which is being offered in the winter term of 2012, entitled - **Topics in Biomaterials: Lipid Based Materials - Green Chemistry and Materials Physics**. This course is being offered to graduate students in the Materials Science graduate program at Trent University and University of Ontario Institute of Technology (UOIT), graduate students in the Environmental and Life Sciences graduate program at Trent University and graduate students in the Sustainable Studies graduate program, and to senior undergraduates from Trent University. This course is being taught by Professor Narine, and a course outline is attached in Appendix I.

Also as per the original plan, Professor Narine plans to offer the course **"Techniques in Green Chemistry: Organic Synthesis Reactions Suitable for the Conversion of Lipid Molecules into Toxin-Free Polymers"** in the fall of 2012.

The development a Trent Centre for Community Based Education community-based course: "**Biomaterials- Chemistry, Ethics, and Economics"** is continuing apace, with plans still intact for this course to be offered in 2013.

1.2 Undergraduate Students Supervised

Nine high school/undergraduate students were supervised in 2010 - 2011 (the original plan called for a total of 10 students - this, on contemplation, was an unrealistic number, but nevertheless, the number of undergraduate students supervised continues to be quite high):

1. Florence Bohnes, Physics, Universite Louis-Pasteur, France
2. Mark Baker, Physics, University of West Ontario, Ontario
3. Bruce Darling, Physics, Trent University, Peterborough, Ontario
4. Mike Floros, Chemistry, Trent University, Peterborough, Ontario
5. Christopher Anzenberger, Chemistry, Trent University
6. Devon Merkely, Chemistry, Trent University, Peterborough, Ontario
7. Dave Evans, Nanomaterials, University of Waterloo
8. Naiomi Burns, Peterborough High School Student
9. Stephanie Singh, Toronto High School Student

1.3 Graduate Supervision

There are ten (10) graduate students in the research program, either solely supervised or co-supervised by Professor Narine. Their projects are all related to Biomaterials, but range widely in terms of focus:

1. **Jiaqing Zuo,** MSc. Graduated, April 2011. Jiaqing worked on lipid based thermoplastic polyesteramides, successfully defended her thesis, and co-authored one publication in the high impact factor journal Polymer.

2. **Arun Gopinath** is new MSc student in Materials Science, a Physicist, from MG University in Kerala, who will be seeking to transfer into the Ph.D. program. Arun will be working on lipid crystallization.

3. **Prasanth Kumar** is an MSc student in Materials Science, also seeking to transfer into the Ph.D. program, also from MG University in Kerala - a Chemist, he is working on lipid based polymers and polymer composites.

4. **Latchmi** Singh is an MSc. student, also seeking to transfer into the Ph.D. program, she is a Chemist from the University of Trinidad and Tobago and from the University of the West Indies. She is working on the synthesis of green lubricants.

5. **Shegufa** Merchant is an MSc. student in Materials Science who will be seeking to transfer into the Ph.D. program, also. She is a chemist, who will be working on the synthesis of hybrid polymers - silica and lipid based hybrid materials, and this represents a collaboration between Professor Vreugdenhil's group and Professor Narine's group. Shegufa is from Toronto, India and the Persian Gulf.

6. **Michael Floros** is an MSc. student in Materials Science who will also be seeking to transfer into the Ph.D. program. He is a chemist and is working on anti-microbial polymer films. Mike is from Toronto.

7. **Ghazaleh Pourfallah** is doing an MSc. in the Materials Sciences Program. She is a chemist who is working on omega hydroxy polyesters derived from lipids. Ghazaleh is from Iran.

8. **Lila Ajumni** is a Ph.D. student in the ENLS program, working on life cycle analysis and fate analysis of green materials. He is co-supervised by Professor Chris Metcalfe and Professor Narine. Lila is from Cameroon.

9. **Nguyen Quoc Thien** is from Viet Nam and is working with Professors Neil Emery and Suresh Narine on modification of soybeans so as to influence the fatty acid profiles to be more industrially beneficial to producign green chemicals.

10. **Emily Morrison** is an MSc student in the Masters in Sustainability program beginning in January 2012, working with Professors Narine and Zohar on a critical analysis of the policy environment governing biomaterials, and its impact on the commercialization of such materials.

2.0 Outreach Activities:

The Ontario Research Chair in Green Chemistry and Engineering at Trent University was slated to have the following outreach activities from 2011 (text in *italics* are cut and pasted from the original application to COU):

In addition to the plans for technology transfer and commercialization with our commercial partners outlined above, the Chair will also commit to establishing a multi-stakeholder network with representatives from the Ontario Ministry of Agriculture, Food and Rural Affairs, the Ontario Ministry of the Environment, the Ontario Ministry of Natural Resources, Environment Canada, Primary Producers, Processors, Academics and other stakeholders, who will be engaged annually and semi-annually through an annual workshop and 2-3 seminars per year. The intent would be to allow the research advisory committee for the Chair to be guided by interactions with this stakeholder community and to allow the stakeholder community to be informed of new products, processes and understanding developed by the Chair's program.

Outreach activities did not take the form of a workshop organized at Trent University, as there were multiple opportunities to interact with all but one of the stakeholder groups identified above, at multiple workshops, seminars and individual meetings, laboratory tours and conference call updates during 2010 and 2011. This time has been spent defining contact points with the specific stakeholder groups, and in 2012, the first update workshop to the program will be held at Trent. Specifically, the following stakeholder groups were engaged during 2010 - 2011:

2.1 Industry

The following companies toured the facilities at Trent and held discussions with our team:

1. Dupont (toured facilities, held discussions on collaboration)
2. Archer Daniel Midland (multiple meetings, toured facilities, held discussions on collaboration, project defined and now active)
3. Pepsico (multiple meetings, toured facilities, held discussions on collaboration,project defined and just completed)
4. HP Polymers (toured facilities, held discussions on collaboration)
5. General Motors (toured facilities, held discussions on collaboration)

6. Elevance Renewable Sciences ((multiple meetings, toured facilities, held discussions on collaboration, this is our main industrial partner, with multiple projects underway).

2.2 Government Ministries

Staff from the following government ministries toured our facilities and held feedback discussions with our staff:

1. Ontario Ministry of Agriculture, Food and Rural Affairs (we had multiple visits with representatives from this ministry, and participated in two Bioeconomy workshops put on by this ministry at their headquarters in Guelph, Ontario. In particular, we have had constant feedback with this ministry and have a close working relationship with its staffers).

2. Ontario Ministry of the Environment (we have had one visit by Director Dale Henry and members of his team to tour our facilities and discuss our program, and then an update teleconference with this team to update them on our progress.).

3. Agriculture and Agri-Food Canada (we had a visit and tour by Director Ted Pidgeon and regular telephone updates to this organization). We also participated in two workshops held by Agriculture and Agri-Food Canada to discuss the Bioeconomy and strategies to address impediments to growth of this sector in Canada.

2.3 Enabling Organizations

The following organizations have also toured our facilities and engaged with our staff:

1. Grain Farmers of Ontario - this organization represents some 23, 000 farmers in Ontario whose markets are affected by our research activities (one of our main funders, we have had multiple visits by the GFO's representatives and their board members, including attendance at three Research Advisory Committee Meetings).

2. Soy 20/20 (we have had three visits by Soy 20/20 staff, including their CEO, Mr. Jeff Schmalz, and have held discussions with them on collaboration, communication and feedback programs).

3. Ontario Centres of Excellence (we have had three visits and numerous meetings with Director John Fielding and his staff member Balinder Rai. We have partnered with the OCE in one project with Pepsico and plan to partner with them on an internship project in 2012, also).

4. Ontario Agri-Food Technologies - OAFT (we have had two visits and tours by their President, Dr. Gord Surgeoner, and have worked closely with them to develop the "Ontario Bioproducts A team").

5. Ontario Bioproducts A team - A specialized business-savvy biomaterials team providing solutions for industry, this organization was put together by a number of university professors working in the biomaterials area, under the leadership of the OAFT. We have been an integral part of this team, and have had numerous meetings with our counterparts across the country.

6. Sustainable Chemistry Alliance (we have had regular updates and conversations with Dr. Murray Mclaughlin of the alliance, and participated in an ideation session with Dr. Mclaughlin in Ottawa at the NRC).

2.4 Universities

In addition to the above stakeholders, including the list of Universities represented in the Ontario Bioproducts A team, we have also developed close collaborative and communication relationships with the following universities:

1. Professor Mohini Sain, University of Toronto (we have had numerous visits from Professor Sain and his group and have visited his facilities at University of Toronto numerous times).

2. Professors Misra and Mohanty, University of Guelph (similarly, we have had numerous meetings with these stakeholders, from the University of Guelph, and have participated in their workshops).

3. Professor Leonardo Simon, University of Waterloo (Professor Simon visited our laboratory and interacted with our team, and Professor Narine also visited Professor Simon's laboratory at the University of Waterloo - the two groups committed to working on collaborative projects).

2.5 Seminars and Presentations

In addition to the above outreach efforts, Professor Narine and the rest of the staff have been very active in terms of presenting our work at national and international conferences:

Presentations in 2011

1. **Suresh S. Narine,** *Chemical Modification of Vegetable Oils to Produce Novel Alcohols, Isocyanates and Polyurethanes*, January 7 - 9, 2011, International Conference on Composites and nanocomposites (ICNC 2011), Mahatma Ghandi University, Kerala, India. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 120 people in audience).

2. **Suresh S. Narine,** *Seeds of Change: The Economic Potential of Oilseed Crops Unlocked Through the Biorefinery Concept*, January 10 - 25, 2011, Talk Delivered as Erudite Visiting

Professor, Mahatma Ghandi University, Kerala, India. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 200 people in audience).

3. **Suresh S. Narine,** *The Biological Revolution: Sustainable Growth from Photosynthetic Materials*, January 10 - 25, 2011, Talk Delivered as Erudite Visiting Professor, Mahatma Ghandi University, Kerala, India. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 200 people in audience).

4. **Suresh S. Narine,** *The Transition to Health: How Culturally Important Foods Like Vanaspati are Changing in the Health Conscious Marketplace*, January 10 - 25, 2011, Talk Delivered as Erudite Visiting Professor, Mahatma Ghandi University, Kerala, India. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 200 people in audience).

5. **Suresh S. Narine,** *Tommorrow's Materials from Today's Oilseed Crops: Better Living Through Chemistry?*, January 10 - 25, 2011, Talk Delivered as Erudite Visiting Professor, Mahatma Ghandi University, Kerala, India. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 200 people in audience).

6. **Suresh S. Narine,** *Remaking the World: How Green Chemistry and Biomaterials are Creating a Sustainable Future*, 22 March, 2011, Invited University-Wide Talk, Cave Hill Campus, University of the West Indies, Barbadoes. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 80 people in audience).

7. **Suresh S. Narine,** *The Physics of Chocolate*, 27 March, 2011, Invited Presentation, Chocolatada, Alumni House, Peterborough, Trent University, **Invited Talk.** *Talk Delivered by Suresh Narine* (Approximately 80 people in audience).

8. **Suresh S. Narine,** *Remaking the World: How Green Chemistry and Biomaterials are Creating a Sustainable Future*, 21st April, 2011, Invited University-Wide Talk, University of Trinidad and Tobago (UTT), Trinidad. **Invited Talk, Keynote Talk.** *Talk Delivered by Suresh Narine* (Approximately 30 people in audience).

9. **Suresh S. Narine**, Laziz Bouzidi and Nissim Garti, *TAG Isomers of Stearic and Oleic Acid: Symmetry-Induced Differences in Crystallization Behaviour*, 102nd Annual AOCS Meeting, May 1 – 4, 2011, Cincinnati, Ohio, U.S.A. **Invited Talk.** *Talk Delivered by Laziz Bouzidi*

10. Laziz Bouzidi, **Suresh S. Narine** and Nissim Garti, *The Propensity of Individual TAG Species to Bind Oil: Influence of Symmetry and Chain Length Mismatch.* 102nd Annual AOCS Meeting, May 1 – 4, 2011, Cincinnati, Ohio, U.S.A. *Talk Delivered by Laziz Bouzidi*

11. Jiaqing Zuo, Shaojun Li and **Suresh S. Narine,** *Synthesis and Physical Properties of Polyester Amides Derived from Lipid Based Components.* 102nd Annual AOCS Meeting, May 1 – 4, 2011, Cincinnati, Ohio, U.S.A. *Poster, Delivered by Jiaqing Zuo.*

12. Leila Hojabri and **Suresh S. Narine**, *Totally Biobased Diisocyanates, Polyols, and Polyurethanes*, 102nd Annual AOCS Meeting, May 1 – 4, 2011, Cincinnati, Ohio, U.S.A. *Poster, Delivered by Leila Hojabri.*

13. Latifeh Ahmadi and **Suresh S. Narine**, *A Comprehensive Toolbox to Evaluate the Functional Properties of Waxes*, 102nd Annual AOCS Meeting, May 1 – 4, 2011, Cincinnati, Ohio, U.S.A. *Poster, Delivered by Latifeh Ahmadi.*

14. **Suresh S. Narine,** *Lipid-Derived Polymer*s: A Biorefinery Approach, Third International Conference on Biodegradavble and Biobased Polymers - Biopol 2011, 29 - 31 August, 2011, University of Strasbourg, France. **Invited Talk.** *Talk Delivered by Suresh Narine* (Approximately 320 people in audience).

Presentations in 2010

15. **Suresh S. Narine,** *The evolution of technology in Agriculture: Moving from Commodities to Added-Value products*, January 13, 2010, Our Fields, Our Future – Agricultural Symposium, Norwood Community Centre, Norwood, Ontario. An event hosted by the Greater Peterborough and Area Economic Development Corporation (Approximately 120 people in audience). **Invited Talk, Keynote Talk.**

16. **Suresh S. Narine,** *Innovation and Its Role in Our Development*, March 27, 2010, Peterborough, Symposium on the Creative and Competitive Economy: A part of Canada at 150: Rising to the Local Challenge. Trent University, Peterborough, Ontario **Invited Talk** (Approximately 80 people in the audience).

17. **Suresh S. Narine,** *Totally Green Polymers produced entirely from oilseeds: Chemistry and Materials Science*, March 31 – April 1, 2010, Bioplastics and Green Composites 2010 Workshop, Delta Hotel and Conference Centre, Guelph, Ontario. (Approximately 100 people in audience). **Invited Talk.**

18. **Suresh S. Narine,** *Phase behavior of Assymetric/Symmetric Triacylglycerols and their Binary Mixtures*, 18 April 2010, Invited Talk to the Casali Institute of Applied Chemistry, Hebrew University of Jerusalem, Jerusalem, Israel (Approximately 85 people in audience). **Invited Talk.**

19. **Suresh S. Narine,** *Biomaterials at Trent: A Lipid-Based Approach*, Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Bioeconomy Research Highlights Day, 13 April, Guelph, Ontario, Canada. ***Invited Contribution.***

20. **Suresh S. Narine,** *Moderator: Science and technology* , 13th May 2010, University of Guyana 40th Republic Anniversary Public Symposia Series, National Library Auditorium, Georgetown, Guyana (Approximately 50 people in audience) **Invited Participation.**

21. Laziz Bouzidi, Tolibjon Omonov, and **Suresh S. Narine,** *Quantifying Oil Binding Capacity of Crystallized Fat Networks*, 16 – 19 May, 2010, 101st Annual American Oil Chemists'

Meeting in Phoenix, Arizona, U.S.A. *Talk Delivered by Laziz Bouzidi (Approx. 60 people in audience).*

22. Laziz Bouzidi, Tolibjon Omonov, and **Suresh S. Narine,** *Mechanisms of Oil Binding in Crystallized Networks of TAGs: Concept of Effective Critical Concentration,* 16 – 19 May, 2010, 101st Annual American Oil Chemists' Meeting in Phoenix, Arizona, U.S.A. **Invited *Talk*** *Delivered by Suresh Narine (Approx. 60 people in audience).*

23. **Suresh S. Narine**, *Lipid-Based Polymers: Polyols, Di-Isocyanates, Polylactones and Polyurethanes,* 7 – 10 September, 7th International Symposium on Natural Polymers and Composites, Gramado, Brazil. **Invited *Talk*** *Delivered by Suresh Narine (Approximately 150 people in audience).*

24. **Suresh S. Narine**, *Lipid-Based Polymers: Climate Change, Environmental Footprint, Economic Development and the Enabling Paradigm,* 7 – 10 September, 7th International Symposium on Natural Polymers and Composites, Gramado, Brazil. **Invited *Talk*** *Delivered by Suresh Narine (Approximately 150 people in audience).*

25. **Suresh S. Narine**, *The Biological Revolution: Is it imminent?,* 12 September, Universidade Estadual Paulista, Butukatu, Brazil. **Invited *Talk*** *Delivered by Suresh Narine (Approximately 120 people in audience)*

26. **Suresh S. Narine**, *Seeds of Opportunity: Functional Polymers from Oilseeds,* Polymers and the Environment: Emerging Green Technologies & Science, BioEnvironmental Polymer Society Annual Conference, October 13-15, Sheraton Centre Toronto Hotel, Toronto, Ontario, Canada. **Invited Talk.** *Delivered by Suresh Narine* (Approx. 50 people in audience).

27. Jiaqing Zuo **and Suresh S. Narine**, *Synthesis, Physical Properties and Biodegradability of Polyester Amides derived from lipid based components,* Polymers and the Environment: Emerging Green Technologies & Science, BioEnvironmental Polymer Society Annual Conference, October 13-15, Sheraton Centre Toronto Hotel, Toronto, Ontario, Canada. **Invited Talk.** *Delivered by Suresh Narine* (Approx. 50 people in audience).

28. **Suresh S. Narine**, *Chemical Modification of Vegetable Oils to Produce Novel Alcohols, Isocyanates and Polyurerthanes,* December 15 – 20, 2010, Pacifichem, Honolulu, Hawaii, U.S.A. **Invited Talk.** *Delivered by Suresh Narine* (Approx. 80 people in audience).

2.6 International Collaborations

An impressive array of international collaborations have been set up as part of the Chair's program:

1. Mahatma Ghandi University, Kerala, India (a number of student and faculty exchanges have occurred, and this is set to continue as we embark on collaborative projects with this university).

2. Universidade Estadual de Paulista (UNESP), Botucatu, Brazil (in addition to student and faculty exchanges, Trent University through the Chair's program, the University of Toronto, and UNESP has been successful in securing funding from the Canada-Brazil Research Partnerships Program, and this is resulting in increased collaboration among these universities).

3. Hebrew University, Jerusalem, Israel (we have had faculty visits from this university and Professor Narine has also visited the Hebrew University. A number of crystallization-based projects have been established).

3.0 Research Activities:

The Ontario Research Chair in Green Chemistry and Engineering at Trent University was slated to have the following research related focus over the course of the program (text in *italics* are cut and pasted from the original application to COU):

1) *A fundamental understanding of the crystallization of lipid and modified lipid networks to direct the modification of natural molecular ensembles and processing conditions in order to design crystal network structures with specific physical properties in a stable thermodynamic state.*
2) *Development of chemical modification techniques that can alter the chemical functionality of lipids, so as to produce high value chemicals, functional monomers and functional supra-molecular assemblies, including nano-scale delivery systems.*
3) *A fundamental understanding of the inter-relationships between the chemical functionality of monomers, processing conditions, derived structural hierarchies, and the resultant physical functionality of the polymer networks created from lipid-derived monomers.*

The above three objectives are referred to as fundamental objective 1, 2, and 3, respectively in the text that follow. Significant progress has been made in all three of the above objectives, and are reflected in the published work cited below. Of particular importance, however, is the patent filed in 2011 (ref. 18 below), which describes the synthesis of an entirely new class of compounds - complex esters - which are derived from vegetable oils entirely, and represent new technology for a line of green, biodegradable lubricants derived entirely from a renewable resource. In addition to the patent, the work addresses fundamental objectives 1 and 2, in that a set of new compounds have been synthesized, and they represent an ensemble of molecules which remain fluid to extremely low temperatures, maintain a desirable viscosity profile over a

very wide temperature range, are oxidatively and thermally stable, and resist hydrolysis in basic and acidic environments. Because of these properties, they represent a quantum leap in terms of the performance of a typical lubricant, and is expected to out-perform the lubricants available on the market today - both synthetic and petroleum-based. Should this technology result in commercialization, the impact on the environmental footprints of lubricants would be game-changing. Furthermore, the impact on the environment via the abatement of climate change due to the switching of petroleum as a feedstock to renewable lipids would be significant. Even if the technology does not get adopted in full, but only replaces a percentage of lubricants, the impact is significant, and the learning that the work provides to practitioners in the area is significant - the simple architecture of the molecules that were synthesized, and their structure and function relationships will impact other diverse fields such as cosmetics, pharmaceuticals, emulsifiers, food, drilling fluids, metal working fluids and aircraft de-icing fluids. In each case, the potential for toxics reduction and switching to a renewable feedstock is significant. Reference 3 in the list below is the first of some six (6) publications that will be published from this body of work (held back due to the need to patent the work), and together, these publications will represent seminal research in the area of structure and function of complex estrers derivable from renewable lipid sources.

In the area of fundamental objective 3, work was published related to the use of lipids entirely to produce polyesteramides (ref. 5 below). This work described the relationship of structure to function of a homologous series of lipid-derived monomers. In particular, the polyesteramides produced demonstrated superior properties in many cases, and comparable properties in all cases, to previous polyesteramides produced. The difference is, of course, that these were produced entirely from vegetable lipids. The advantage of polyesteramides is that they have the biodegradability of a polyester and the thermal and mechanical properties of a polyamide. This work, in addition, suggests how monomers need to be adjusted structurally in order to target certain ranges of physical properties, and as such represents significant contribution to the field of renewable, biodegradable polymers.

Refs. 1 and 2 in the list below represent the development of a fundamental understanding of the crystallization and oil binding behavior of pure triacylglycerides - very fundamentally important understanding if we are to be able to effectively harness these materials as environmentally friendly waxes, lubricants, food materials and polymers.

The remainder of the publications listed below have titles that are self-explanatory in terms of their potential impact on the environment.

<u>Manuscripts published in 2011</u>

1. Laziz Bouzidi and **Suresh S. Narine** (In Press, 2011), *Relationships between molecular structure and kinetic and thermodynamic controls in lipid systems. Part II: Phase behavior and Transformation path of SSS, PSS and PPS Saturated Triacylglycerols – Effect of Chain Length Mismatch,* Chemistry and Physics of Lipids.

2. Laziz Bouzidi and **Suresh S. Narine** (In Press, 2011), *Relationships between molecular structure and kinetic and thermodynamic controls in lipid systems Part III: Crystallization and phase behavior of 1– palmitoyl 2-, 3 –stearoyl-sn-glycerol (PSS) and tristearoyl-sn-glycerol (SSS) binary system,* Chemistry and Physics of Lipids.

3. Laziz Bouzidi, Shaojun Li, Steve Di Biase, Syed Q. Rizvi and **Suresh S. Narine** (In Press, 2011), *Lubricating and Waxy Esters, I: Synthesis, Crystallization and Melt behavior of Linear Monoesters,* Chemistry and Physics of Lipids.

4. Sinoj Abraham and **Suresh S. Narine**, (2011), *Facile synthesis of lipid stabilized gold nanoparticles: A step towards biodegradable biosensors*, Journal of Nanoscience and Nanotechnology, **11,** 7033 – 7036.

5. Jiaqing Zuo, Shaojun Li, Laziz Bouzidi and **Suresh S. Narine** (2011) *Thermoplastic Polyester Amides Derived from Oleic Acid,* Polymer, **52(20),** 4503 – 4516.

6. Wen Li, Xiaohua H. Kong, Ereddad Kharraz, Laziz Bouzidi, and Suresh S. Narine, (2011), *Expoloration of Potential Applications of Natural Oils for Green Hot melt Adhesives: A Comparative Experimental Investigation on paraffin and Soybean Waxes,* Journal of Adhesion, **87(2)**, 95 – 110.

<u>Manuscripts published in 2010</u>

7. Lech Ozimek, Edward Pospiech, and **Suresh S. Narine**, (2010), *Nanotechnologies in Food and Meat Processing,* Acta. Sci. Pol., Technol. Aliment., **9(4)**, 401 – 412.

8. Leila Hojabri, Xiaohua Kong and **Suresh S. Narine,** (2010), *Functional Thermoplastics from Linear Diols and Diisocyanates Produced Entirely from Renewable Lipid Sources,* Biomacromolecules, **11**, 911 – 918.

9. Tolibjon S. Omonov, Laziz Bouzidi, **Suresh S. Narine**, (2010), *Quantification of Oil Binding Capacity of Structuring Fats: A Novel Method and its Application*, Chemistry and Physics of Lipids, **163**, 728 – 740.

10. Marc V. Boodhoo, Laziz Bouzidi, Tomas Kutek, Vladimir Filip and **Suresh S. Narine**, (2010), *The binary phase behavior of 1, 3 – dilauroyl-2-stearoyl-sn-glycerol and 1, 2 – dilauroyl-3-stearoyl-sn-glycerol,* Chemistry and Physics of Lipids, **163**, 607 – 629.

11. Marie Josee Dumont, Xiaohua Kong, **Suresh S. Narine,** (2010), *Polyurethanes from benzene polyols synthesized from vegetable oils: dependence of physical properties on structure*, Journal of Applied Polymer Science, **117**, 3196 – 3203.

12. Marie Josee Dumont and **Suresh S. Narine**, (2010), *Physical properties of new polyurethanes foams from benzene polyols synthesized from erucic acid*, Journal of Applied Polymer Science, **118(6)**, 3211 – 3217.

13. Ewa Oledzka and **Suresh S. Narine**, (2010), *Organic acid catalyzed polymerization of ε-caprolactone: Synthesis and characterization*, Journal of Applied Polymer Science, **119(4)**, 1873 – 1882.

14. Ewa Oledzka, Xiaohua Kong and **Suresh S. Narine**, (2010), *Synthesis and characterization of novel lipid functionalized poly(ε-caprolactone)s for biomedical applications*, Journal of Applied Polymer Science, **119(3)**, 1848 – 1856.

15. Anu S. Mathews and **Suresh S. Narine**, (2010), *Poly [N-Isopropyl acrylamide] -co-Polyurethane copolymers for Controlled Release of Urea*, Journal of Polymer Science Part A: Polymer Chemistry, **418**, 3236 – 3243.

16. Leila Hojabri, Xiaohua Kong and **Suresh S. Narine**, (2010), *Novel long chain unsaturated diisocyanate from fatty acid: Synthesis, characterization and application in bio-based polyurethane,* Journal of Polymer Science Part A: Polymer Chemistry, **48**, 3302 – 3310.

17. Laziz Bouzidi and **Suresh S. Narine**, (2010), *Evidence of critical cooling rates in non-isothermal crystallization of Triacylglycerides: A Case for the Existence and Selection of Growth Modes of a Lipid Crystal Network,* Langmuir, **26(6),** 4311 – 4319.

Patents Filed in 2011

18. U.S. Patent Application (filed February, 2011*) "Esters for use as a base stock and in lubricant applications",* **Suresh S. Narine**, Laziz Bouzidi, Shaojun Li, Ali Mahdevari, Steve DiBiase and Syed Abbas.

Book Chapters Published in 2011

19. Laziz Bouzidi and **Suresh S. Narine** (2011), *Phase Behavior of Saturated TAGS: Influence of Symmetry and Chain Length Mismatch*, in Cocoa Butter and Related Fats - Properties and Applications, *Eds.* Nissim Garti and Neil Widlak, AOCS Press, Champaign, IL, U.S.A.

A P P E N D I X I

Course OUTLINE

Topics in Biomaterials: Lipid Based Materials - Green Chemistry and Materials Physics

Course Outline 2011-2012

1. Course Summary

This course will examine a series of lipid-based materials through Green Chemistry and Materials Physics lens. Seminal publications detailing the synthesis of lipid-based biomaterials and their physical properties will be discussed by students. A critical analyses of the chemistry and biochemistry utilized in the preparation of these materials will be discussed by students, in context of the principles of green chemistry. The physical properties and functionality of the materials will be discussed as a function of molecular and supra-molecular structure. Theoretical basis for the physical properties measurements will be discussed from a materials physics/solid state perspective.

2. Instructor Information

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3. Course Timetable

The course will be delivered in a reading class format with readings, and twelve 2 hour meetings for discussion. Note that due to the schedule of the instructor, the weekly meetings will not be during a set period of time, but will vary significantly.

4. Required Text and Course Materials

Course instructor will provide an essential bibliography. Students will augment this essential bibliography on a weekly basis through their own research.

5. Course Format

Pre-class reading will be assigned from the essential bibliography.

Instructor will summarize the main points of the topic, and a student will be responsible for presenting the main points of the day's discussion based on the essential bibliography *and their own, additional sources of information.* The additional sources of information will be added to the essential bibliography and students will be required to read this additional information in preparation for the final examination.

The discussion sessions will be peer-evaluated, and this will represent 20% of the course mark. Students will be asked to grade their peers according to the following criteria, equally weighted:
i. overall understanding of the material.
ii. Evaluation of the materials from a Green Chemistry perspective.
iii. Discussion of the physical properties from a structural perspective.
iv. Clarity of the presentation of the material.

Students will also be asked to pick a topic from among those discussed in the course and write a detailed critical literature review on the topic. This literature review will be worth 40% of the course mark.

There will be a final examination, worth 40% of the course mark.

6. Course Evaluation

Discussion (Peer Assessed)	20 %
Critical Review Paper	40 %
Final Exam	40 %

7. Topics Covered

1. Lipid based Polyols
2. Lipid based Diisocyanates
3. Lipid based Polyurethanes
4. Omega Hydroxy Fatty Acids
5. Lipid Based Polyesters
6. Lipid based diacids and nylon
7. Lipid based monoglycerides
8. Lipid-based lubricants
9. Lipid-based expoxides and adhesives
10. Lipid-based waxes
11. Oleo-gels
12. Oil Binding capacity of crystallized lipids

8. Academic Integrity

Academic dishonesty, which includes plagiarism and cheating, is an extremely serious academic offence and carries penalties varying from a 0 grade on an assignment to expulsion from the University. Definitions, penalties, and procedures for dealing with plagiarism and cheating are set out in Trent University's Academic Integrity Policy. You have a responsibility to educate yourself – unfamiliarity with the policy is not an excuse. You are strongly encouraged to visit Trent's Academic Integrity website to learn more – www.trentu.ca/academicintegrity.

9. Access to Instruction

It is Trent University's intent to create an inclusive learning environment. If a student has a disability and/or health consideration and feels that he/she may need accommodations to succeed in this course, the student should contact the Disability Services Office (BH Suite 132 , 748-1281, disabilityservices@trentu.ca) as soon as possible. Complete text can be found under Access to Instruction in the Academic Calendar.