TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	July 11	July 12	July 13	July 14	July 15
9.00 - 9.45	Registration	Steigmann	Deseri	Arroyo	Arroyo
9.45 - 10.30	Steigmann	Steigmann	Steigmann	Arroyo	Arroyo
11.00 - 11.45	Deseri	Arroyo	Guven	Guven	Deseri
11.45 - 12.30	Deseri	Arroyo	Guven	Guven	Steigmann
14.00 - 14.45	Deserno	Healey	Healey	Deserno	
14.45 - 15.30	Deserno	Healey	Healey	Deserno	
16.00 - 16.45	Guven	Deseri	Deserno	Healey	
16.45 - 17.30	Guven	Deseri	Deserno	Healey	

ADMISSION AND ACCOMMODATION

The registration fee is of 575,00 Euro + VAT taxes*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday subject to numbers), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: http://www.cism.it or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than two weeks prior to the start of the course.

If cancellation occurs less than two weeks prior to the start of the course, a Euro 50,00 handling fee will be charged. Incorrect payments are subject to Euro 50,00 handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel or students' dormitories, if available.

Requests should be sent to CISM Secretariat by **May 11, 2016** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on our web site, or can be mailed upon request.

* Italian VAT is 22%.

For further information please contact:

CISM
Palazzo del Torso
Piazza Garibaldi 18
33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
fax +39 0432 248550
e-mail: cism@cism.it

ACADEMIC YEAR 2016

The Leipholz Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

THE ROLE OF MECHANICS IN THE STUDY OF LIPID BILAYERS

Advanced School
coordinated by

David Steigmann
University of California
Berkeley, CA, USA

Udine ***July 11 - 15*** 2016

THE ROLE OF MECHANICS IN THE STUDY OF LIPID BILAYERS

Lipid bilayers constitute the membrane that encloses every animal cell and many of its interior structures, including the nuclear envelope, the organelles and the endoplasmic reticulum. They possess some of the features of conventional engineering shell structures such as flexural resistance, but they are unusual in that they also possess the properties of two-dimensional curved fluid sheets. This combination is responsible for a myriad of remarkable mechanical and physical responses that make lipid bilayers a unique and fascinating topic of study. The basic molecular mechanism responsible for this range of behavior is the lipid molecule. It is polar, with one end – the molecular tail - being hydrophobic, and the other –the head group - hydrophilic. The lipids constitute the two leaves of the bilayer, with the hydrophobic tails juxtaposed in such a way as to exclude the surrounding aqueous solution. Thus the bilayer is the product of a self-assembly process driven by a clear physical mechanism.

In recent years the study of this subject has been undertaken by experts in physics and mechanics. The perspective brought to bear by the mechanics community has facilitated a large number of significant advances, not only with respect to an improved understanding of the foundations of the subject, but also with respect to the modeling of phenomena that had heretofore been treated on an ad hoc basis without the benefit of the overall intellectual viewpoint that modern mechanics brings to bear. Thus the broad framework afforded by mechanics has led to important conceptual advances in such topics as phase equilibria in lipid bilayers, diffusion and transport phenomena, cell adhesion and motility, tubule formation, coupled electromechanical response, edge and pore effects, intra- and extra-membrane viscous flow, inter-leaf friction, the role of tilt (known to the shell theorist as transverse shear deformation), bifurcation and instability, membrane rheology, models based on molecular considerations, and so on. Indeed the field is nowadays extremely active, and has grown into a major discipline lying at the intersections of mechanics, bio-physics and applied mathematics.

One of the most important conceptual aspects of the subject is the profound interplay it exhibits between mechanics and geometry. Thus the field makes essential use of advanced topics in the differential geometry of surfaces. Indeed it requires considerable facility with the latter subject, and provides an opportunity to exercise our knowledge of virtually that entire branch of applied mathematics. For this reason much modern work on bilayers is primarily geometric in nature.

The presentations will be carefully crafted overviews of the basic theory and its various enhancements and extensions from several points of view. They will also include surveys of relevant differential geometry and variational methods that are essential to a proper understanding, overviews on the foundations of the subject from various perspectives, applications of modern bifurcation theory to the analysis of membrane equilibria, and further developments encompassing a range of coupled-field phenomena. The course is addressed to doctoral students, post-doctoral researchers and academics interested in the use of mechanics to model, analyze and understand the physics of lipid bilayers. Lipid bilayers are ubiquitous in biology, and related structures occur in fluid interfaces and experimental vesicles. While the course is largely self-contained, students would benefit from prior exposure to courses on continuum mechanics, tensor analysis and elementary electromagnetism.

PRELIMINARY SUGGESTED READINGS

Rahimi, M. and Arroyo, M. (2012), Shape dynamics, lipid hydrodynamics, and the complex viscoelasticity of bilayer membranes. Phys. Rev. E 86, 011932. http://dx.doi.org/10.1103/PhysRevE.86.011932.

Deseri L., Zurlo G., (2013) The stretching elasticity of biomembranes determines their line tension and bending rigidity, BIOMECH. MODELING IN MECHANOBIOLOGY-BMMB, DOI: 10.1007/S10237-013-0478-Z.

Deseri L., Piccioni M.D., Zurlo G., (2008), Derivation of a new free energy for biological membranes, CONT. MECH. THERMODYNAMICS 20 (5), 255-273.

Deserno, M. (2015), Fluid lipid membranes: From differential geometry to curvature stresses. Chem. Phys. Lipids, 185, 11–45. DOI: 10.1016/j.chemphyslip.2014.05.001.

Healey, T. and Kielhöfer, H. (2013), Global symmetry-breaking bifurcation for the van der Waals-Cahn-Hilliard model on the sphere S2. Journal of Dynamics and Differential Equations, online, 1-16.

Steigmann, D.J. (2013), A model for lipid membranes with tilt and distension based on three-dimensional liquid crystal theory. Int. J. Non-lin. Mech. 56, 61-70.

INVITED LECTURERS

Marino Arroyo - Universitat Politecnica de Catalunya, Barcelona, Spain
6 lectures on: Interfacial hydrodynamics. Models based on the bilayer architecture. Confined bilayers. Rheology of membrane inclusions in the presence of curvature. Bilayer dynamics coupled to interfacial chemistry: interactions with proteins. Lipid composition. Membrane area/tension regulation.

Luca Deseri - Università di Trento, Italy
6 lectures on: Effective energies of elastic lipid bilayers. Line tension and insights from gradient flow. Viscoelasticity of lipid bilayers. The role of the bilayer in cell response: energetics, lateral pressure and conformational energy. Diffusion across lipid bilayers, multi-component diffusion model. Coupled multiphysics, including membrane flexoelectricity.

Markus Deserno - Carnegie Mellon University, Pittsburgh, PA, USA
6 lectures on: Physical basis of membranes: lipids, assembly, thermodynamics, aggregate formation, uniqueness of two-dimensional assembly. Measurement of bending moduli via simulation. Bilayer buckling: spheres, cylinders, boundary conditions. Casimir interactions and thermal fluctuations.

Jemal Guven - University of Mexico, Mexico City, Mexico
6 lectures on: Variational principles: Euclidean symmetry, reparametrization invariance and conservation laws. Boundaries. Global vs. local geometric constraints. Anisotropies, Constrained metric variations. Conformal invariance of two-dimensional bending energy. Distribution of stress in vesicles. Constriction of membrane necks. Modeling the rough endoplasmic reticulum.

Timothy J. Healey - Cornell University, Ithaca, NY, USA
6 lectures on: Models for 2-phase vesicles: phase field and purely mechanical. Formulations of the field equations: difficulties with traditional Eulerian and Lagrangian descriptions for analysis and computation. Singularity-free radial map description. Liinearization and onset of bifurcation. Bifurcation analysis: local and global. Global bifurcation in the presence of symmetry: selection via group-theoretic ideas.

David Steigmann - University of California at Berkeley, CA, USA
5 lectures on: Two dimensional theory of lipid membranes via dimension reduction from three-dimensional liquid crystal theory. Lipid tilt, constraints and the extended Helfrich theory. Distension-induced gradient capillarity. Coupled field problems including surface diffusion of transmembrane proteins, intra-surface viscous flow and electromechanical response.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site, instructions will be sent to accepted participants.

THE ROLE OF MECHANICS IN THE STUDY OF LIPID BILAYERS

Udine, July 11 - 15, 2016
Application Form
(Please print or type)

Surname _____

Name _____

Affiliation_____

Address_____

_____

E-mail _____

Phone _____Fax_____

Method of payment upon receipt of confirmation (Please check the box)

The fee is 575,00 Euro + 22% Italian VAT taxes, where applicable (bank charges are not included).

❑ *I shall send a check of Euro* _____

❑ *Payment will be made to CISM - Bank Account No. 094570210900, VENETO BANCA - Udine (CAB 12300 - ABI 05035 - SWIFT/BIC VEBHIT2M - IBAN CODE IT46 N 05035 12300 09457 0210900). Copy of the receipt should be sent to the secretariat*

❑ I *shall pay at the registration counter with check or VISA Credit Card (Mastercard/Eurocard, Visa, CartaSi)*

IMPORTANT: CISM is obliged to present an invoice for the above sum. Please indicate to whom the invoice should be addressed.

Name _____

Address _____

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C.F.* _____

VAT/IVA* No _____

(*) Only for EU residents or foreigners with a permanent business activity in Italy.

Only for Italian Public Companies

❑ *I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).*

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.
Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.

Date _____ Signature _____