Vladimir Lorman (1959-2016) and the Physics of Unconventional

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DE MONTPELLIER

Workshop on Physical Virology - ICTP – 17-21/07/17

Vladimir Lorman and the Physics of Unconventional Systems

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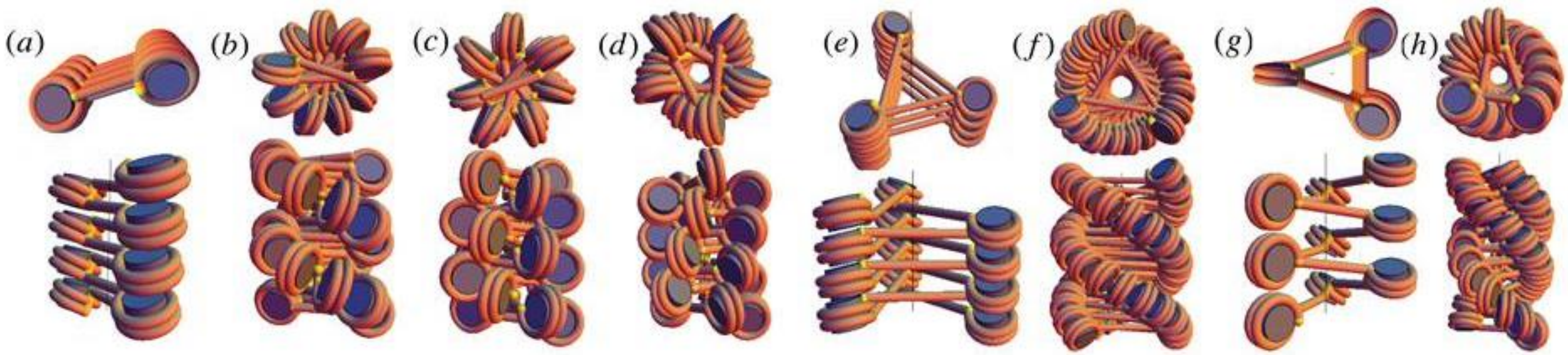
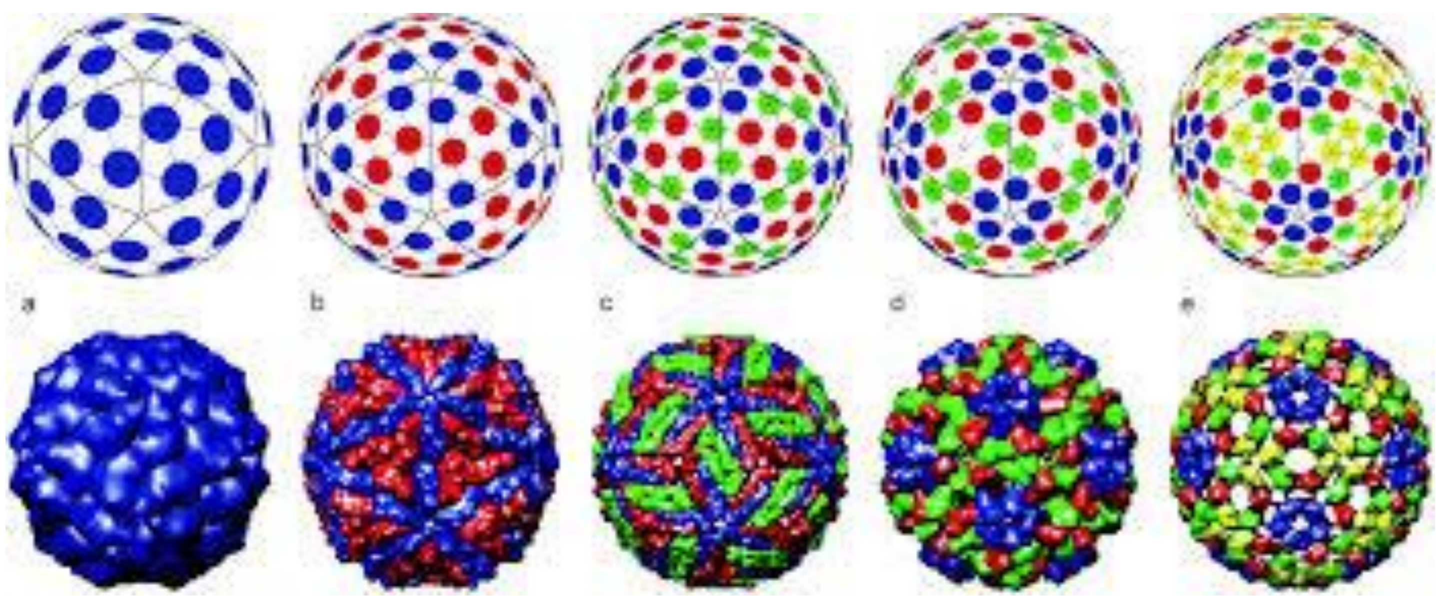
The beauty of order and symmetries of the physical world

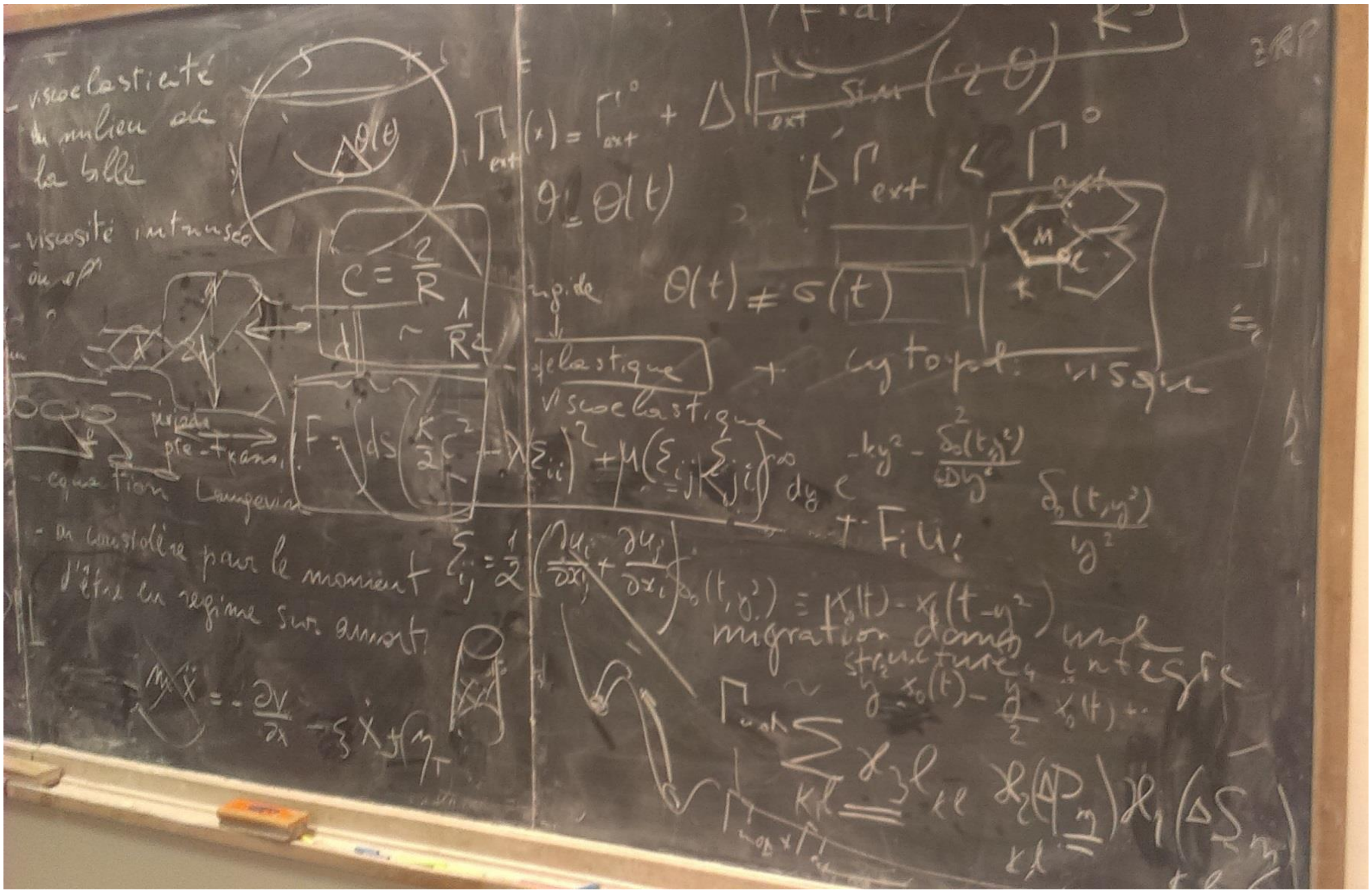


Garces, Podgornik, Lorman, PRL 2015



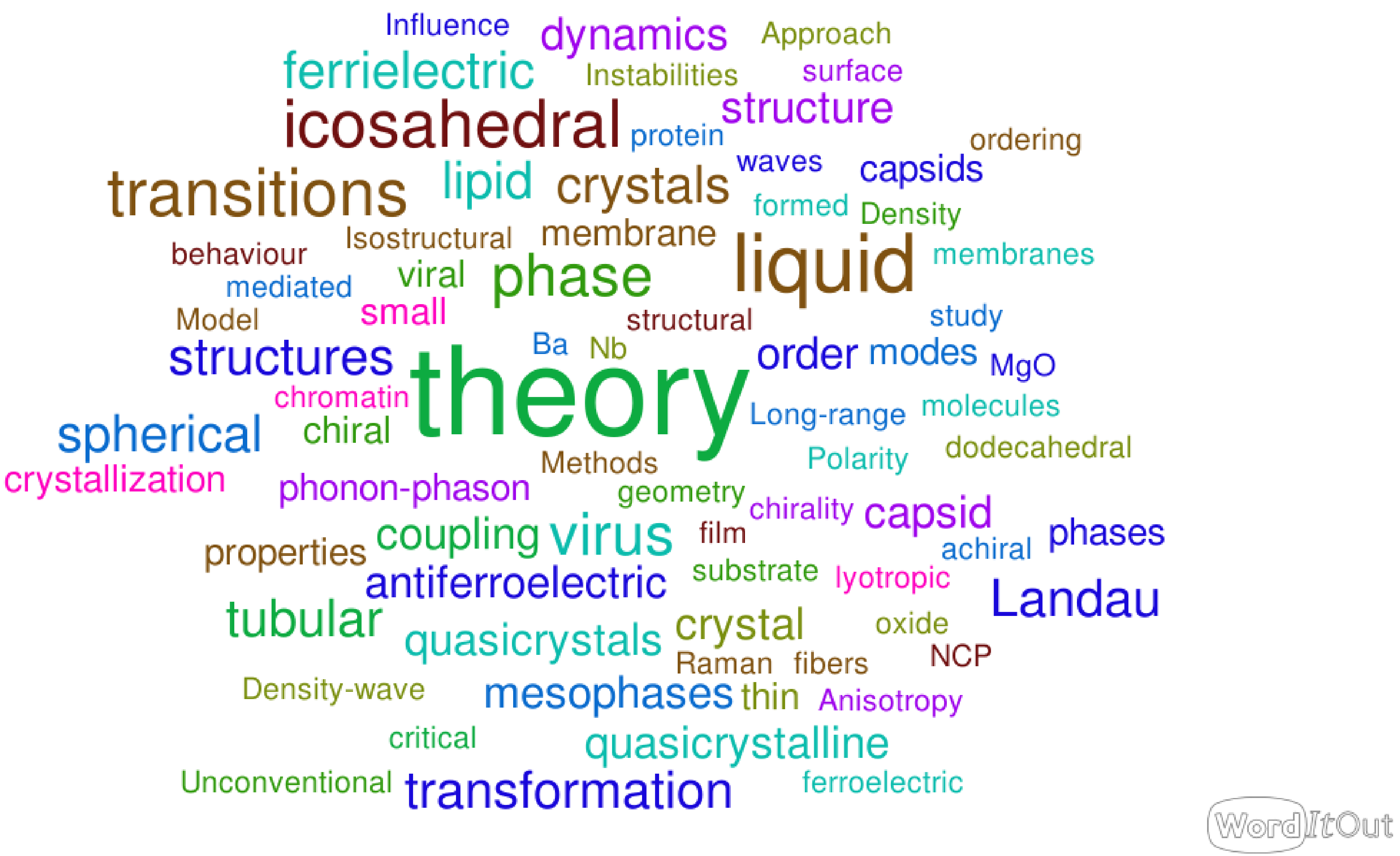
Rochal, Konevtsova, Myasnikova, Lorman, Nanoscale 2016

Last blackboard of discussions on the physics of developmental biology processes

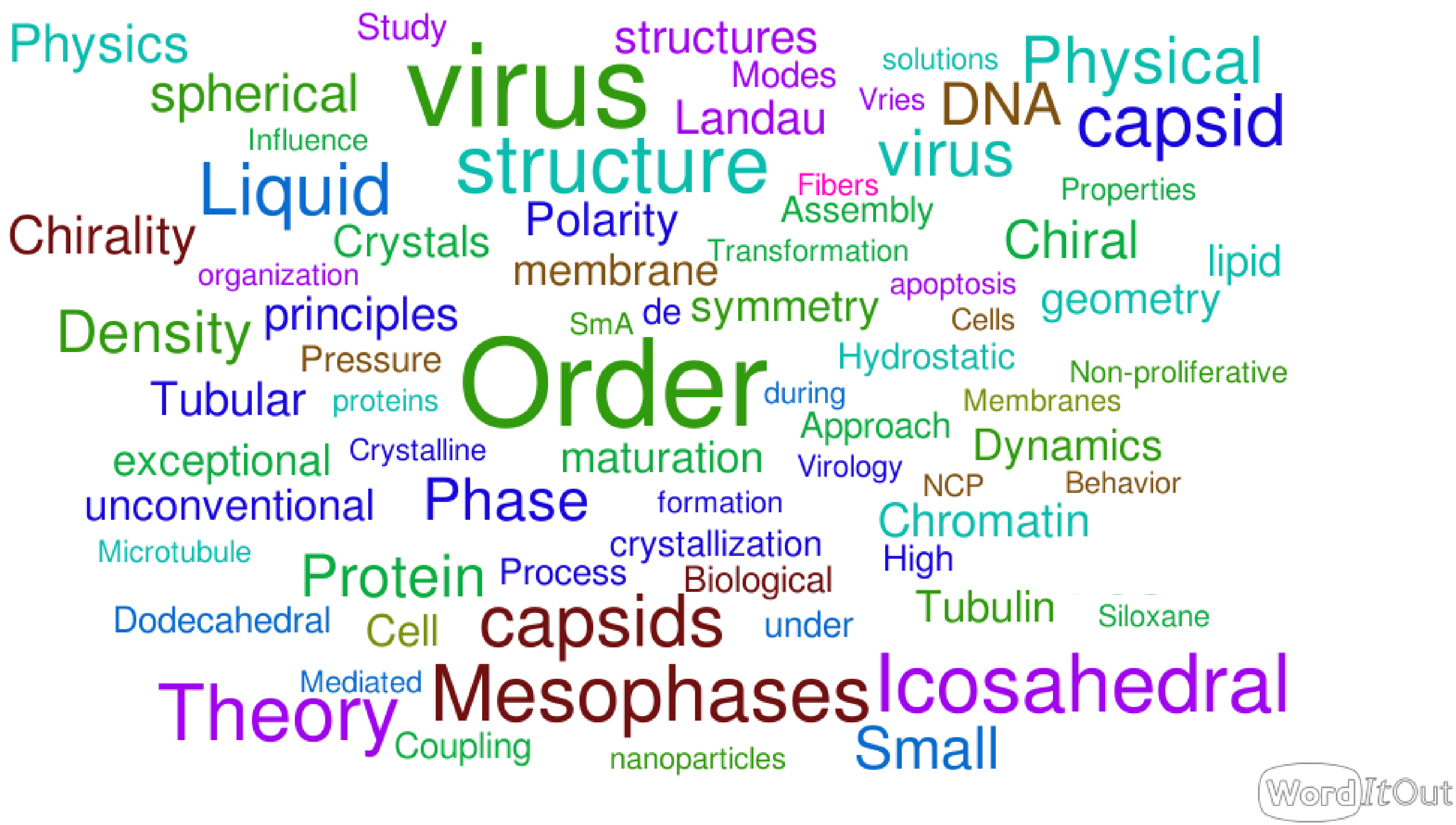


Primosten 2009

Word chart from the last 20 years of publications by Vladimir



Word chart from the last 20 years of publications + communications by Vladimir



Vladimir Lorman's scientific life facts

(only few of them)

Vladimir Lorman's scientific life facts
(only few of them)

- **Studies and Diplomas:**
  - 1981: Diploma (summa cum laude) in Theoretical Physics of Condensed Matter at the Rostov University on the Don (Russia)
  - 1988: Thesis of Doctorate of State in Theoretical Physics of Condensed Matter, University of Rostov on Don (Russia) and A.M. Prokhorov General Physics Institute, Academy of Sciences of Russia (Moscow)

Vladimir Lorman’s scientific life facts
(only few of them)

- **Career:**
  - 1982-1990: "Junior" researcher, then "senior" researcher at the Institute of Physics of Rostov on Don University
  - 1990-1992: Post-doctoral researcher at the University of Picardie
  - 1992-1999: Lecturer at the University of Picardie
  - 1999-2004: Associate Professor at the University Montpellier II
  - 2004-2010: Full Professor at the University Montpellier II
  - 2010-2016: Professor of “Exceptional Class” at the University Montpellier

Vladimir Lorman's scientific life facts
(only few of them)

- **Career:**
  - 1982-1990: "Junior" researcher, then "senior" researcher at the Institute of Physics of Rostov on Don University
  - 1990-1992: Post-doctoral researcher at the University of Picardie
  - 1992-1999: Lecturer at the University of Picardie
  - 1999-2004: Associate Professor at the University Montpellier II
  - 2004-2010: Full Professor at the University Montpellier II
  - 2010-2016: Professor of "Exceptional Class" at the University Montpellier

- **Responsibilities:**
  - Responsible of the interdisciplinary axis Physics-Biology of the Institute of Physics of Montpellier
  - Member of the GPS (governance committee) of the Laboratory of Excellence «NUMEV»
  - Responsible for the Physics Education and teaching of the University Montpellier II (2001-2010)
  - Responsible of the Physics Master of the University Montpellier II
  - Deputy Director of the Charles Coulomb Laboratory, UMR 5221 CNRS - UM;
  - Director of the Department of Theoretical Physics at the Charles Coulomb Laboratory, UMR 5221 CNRS - UM.

A possible historical reconstruction from “facts told-lived” and thoughts

A possible historical reconstruction from "facts told-lived" and thoughts

- **Studies and Diplomas:**
  - 1997: French Habilitation to be PhD Supervisor, University of Picardy, Amiens. President of the Jury: Jacques Prost (ESPCI)

A possible historical reconstruction from "facts told-lived" and thoughts

- **To understand Vladimir's contribution and scientific pathway: some key indicators**
  - 1992-1997 assistant professor in University of Picardie (Amiens) intense work on the theory liquid crystals (Vladimir's contribution is known by J. Prost)
  - 1996 birth of Physico-Chimie Curie Lab, Curie Institute (Dir. J. Prost ← F. Brochard and P.G. De Gennes)
  - 1997: Habilitation to be PhD thesis supervisor and finally Principal Investigator
  - 1998: "Physics at the Scale of the Cell" Summer School in Cargese (by B. Fourcade, J. Prost)

A possible historical reconstruction from "facts told-lived" and thoughts

- **To understand Vladimir's contribution and scientific pathway: some key indicators**
  - 1999: Professor in theoretical physics at Montpellier
  - Early 2000s: start to build the interdisciplinary axis with biology (in Montpellier the physicists to biologists ratio is less then 1/20!) ← A. Neveu, string theorist (owner of the previous blackboard)

http://www.ilp-france.com/wp-content/uploads/Activites-culturelles.jpg

Not a big fast food,
but monument of yin-yang in Japanese
in front of the UM Triolet campus!

Scientific pathways: from the 80s to 2017

- The period of 80s-90s
- The 90s
- The new century!
- 2007-2017
- In the meanwhile up to 2017

Scientific Pathways: 80s and 90s

- **80s-90s:** theory of phase transitions and crystallization to study condensed matter of metals and alloys, magnetism, use of symmetries to develop Landau's theory of phase transitions in strong relations with the geometric approach to singularities, bifurcations, and catastrophes theory (see V. Arnold)
  (he learned to find the answer from first principles before making the computation)

Singularities, bifurcations, and catastrophes

V.I. Arnol'd

M. V. Lomonosov. Moscow State University

Usp. Fiz. Nauk **141**, 569–590 (December 1983)

The theories of smooth-mapping singularities and dynamical-system bifurcations are reviewed. Mention is made of the applications to optics (caustic and wave-front metamorphoses) and to theories of short-wave asymptotics, the origin of large-scale structure in the universe, and loss of equilibrium and self-oscillation stability ("catastrophe theory").

PACS numbers: 02.30. — f, 03.40.Kf

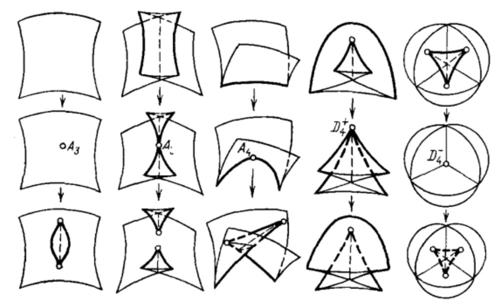


FIG. 6. The metamorphoses of generic wave fronts.

1025 Sov. Phys. Usp. **26** (12), December 1983 0038-5670/83/121025-13$01.80 1025

Scientific Pathways: 80s and 90s

- **80s-90s:** theory of phase transitions and crystallization to study condensed matter of metals and alloys, magnetism, use of symmetries to develop Landau's theory of phase transitions in strong relations with the geometric approach to singularities, bifurcations, and catastrophes theory (see V. Arnold)
  (he learned to find the answer from first principles before making the computation)

Methods of the theory of singularities in the phenomenology of phase transitions

E. I. Kut'in, V. L. Lorman, and S. V. Pavlov

State Pedagogical Institute, Rostov-on-Don, Scientific-Research Institute of Physics at the State University, Rostov-on-Don, and M. V. Lomonosov State University, Moscow

(Submitted May 3, 1990; resubmitted after revision October 18, 1990)
Usp. Fiz. Nauk **161**, 109–147 (June 1991)

A review is presented on the methods of the theory of singularities applied to the Landau phenomenological theory of phase transitions. Constructive algorithms are presented that eliminate arbitrariness in the choice of the Landau potential and make it possible to exclude from consideration models with nonphysical results. The methods of singularity theory are illustrated by application to several real thermodynamic systems.

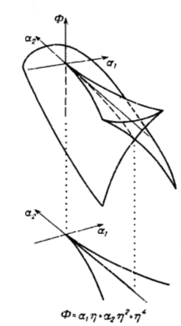


FIG. 6. Relation between the phase diagram and the bifurcation diagram of a singularity. An example of a thermodynamic potential in the neighborhood of a critical point of the liquid-vapor type.

497 Sov. Phys. Usp. **34** (6), June 1991 0038-5670/91/060497-18$01.00 497

Scientific Pathways: the 90s

- **90s:** theory of liquid crystals and quasicrystals: modeling the structure and phase transitions of smectics ferroelectric liquid crystals and anti-ferroelectrics of achiral components

N·H
ELSEVIER
2 September 1996
PHYSICS LETTERS A
Physics Letters A 220 (1996) 111–116

Local mechanism for crystal–quasicrystal transformations

S.B. Rochal [a], V.P. Dmitriev [a], V.L. Lorman [b], P. Tolédano [b]
[a] Institute of Physics, Rostov State University, 344104 Rostov on the Don, Russian Federation
[b] University of Amiens, 33 Rue Saint-Leu, 80039 Amiens Cedex, France

Received 8 May 1996; accepted for publication 10 June 1996
Communicated by L.J. Sham

Abstract

It is shown that the transformation mechanism which takes place at a crystal–quasicrystal transformation preserves a lattice of nodes in whose vicinity the crystal and quasicrystal structures are similar. Between the nodes fusion of neighbouring positions and creation of new positions occur, resulting in a disordering of the quasicrystal state.

VOLUME 82, NUMBER 5 PHYSICAL REVIEW LETTERS 1 FEBRUARY 1999

Unconventional Mesophases Formed by Condensed Vector Waves in a Medium of Achiral Molecules

V. L. Lorman[1] and B. Mettout[2]
[1]*LPMC, Université de Picardie, 33 rue Saint-Leu, 80039 Amiens, France*
[2]*LPS, ESPCI-CNRS, 10 rue Vauquelin, 75231 Paris Cedex 05, France*
(Received 1 October 1998)

A phenomenological theory that describes the phase transitions from a liquid of achiral molecules to the periodic antiferroelectric mesophases is presented. The transitions are shown to be driven by the vector-wave condensation mechanism. Resulting ordered phases have the structure of a vector wave with linear, circular, or elliptic polarization. The phase diagram, the stability with respect to spatial modulation, and the behavior in an external field are discussed in relation with the recently discovered achiral antiferroelectric liquid crystals. [S0031-9007(98)08201-5]

PACS numbers: 61.30.Cz, 64.70.Md

LIQUID CRYSTALS, 1996, VOL. 20, NO. 3, 267–276

Ferrielectric smectic phases: Liquid crystal structure and macroscopic fluctuations†

by V. L. LORMAN*
Laboratoire de Physique de la Matière Condensée, Université de Picardie, 33 rue Saint Leu, 80039 Amiens Cedex, France

(*Received 21 July 1995; accepted 26 September 1995*)

The work concerns the structures and properties of multilayer smectic phases with complex tilt and dipolar order. The symmetry and thermodynamical classification of multilayer antiferroelectric and ferrielectric phases is given. The main attention is paid to the difference of these phases with respect to classical ferroelectric S_C^*. A two-layer model of the ferrielectric smectic phase is generalized to describe the sequence of the first order phase transitions ferro–ferri–antiferro-electric and to show the possibility of existence of two isostructural ferrielectric phases, which differ in the value of the helical pitch and in the sense of the helix.

- *Theory of reorientational transitions in ferrielec*
- *Minimal model of the phonon-phason dynamics* … *rnal friction in the i-AlPdMn alloy*
- *Dielectric permittivity of antiferroelectric liquid*
- *A comparative Raman study of ferroelectric PbT*
- *Unconventional mesophases formed by condens*
- *Antiferroelectric and ferrielectric structures indu*
- *Phase transitions in (Ba 0.7 Sr 0.3) TiO 3/(001) N*
- *Ferrielectric smectic phases: Liquid crystal struct*

A lot of work with experimentalists!

Scientific Pathways: new century!

- **Early 2000 and after: “on the roads of Watson, Crick and Caspar-Klug”**
  - DNA crystalline phases + nucleosomes (see F. Livolant experiments): new DNA mesophases, models of chromatin fibers (nucleosomes)

    Impact of physical constraints in genome structure and dynamics (physical genomics)

VOLUME 87, NUMBER 21 PHYSICAL REVIEW LETTERS 19 NOVEMBER 2001

Positional, Reorientational, and Bond Orientational Order in DNA Mesophases

V. Lorman,[1] R. Podgornik,[2,3,4] and B. Žekš[5,3]
[1]*Laboratoire de Physique Mathematique et Theorique, Universite Montpellier II, F-34095 Montpellier, France*
[2]*Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia*
[3]*Department of Theoretical Physics, J. Stefan Institute, SI-1000 Ljubljana, Slovenia*
[4]*LPSB/NICHD, Building 12A Room 2041, National Institutes of Health, Bethesda, Maryland 20892-5626*
[5]*Institute of Biophysics, Medical Faculty, University of Ljubljana, SI-1000 Ljubljana, Slovenia*
(Received 6 June 2001; published 1 November 2001)

We investigate the orientational order of transverse polarization vectors of long, stiff polymer molecules and their coupling to bond orientational and positional order in high density mesophases. Homogeneous ordering of transverse polarization vector promotes distortions in the hexatic phase, whereas inhomogeneous ordering precipitates crystallization of the 2D sections with different orientations of the transverse polarization vector on each molecule in the unit cell. We propose possible scenarios for going from the hexatic phase, through the distorted hexatic phase, to the crystalline phase with an orthorhombic unit cell observed experimentally for the case of DNA.

PHYSICAL REVIEW E **75**, 030901(R) (2007)

Screwlike order, macroscopic chirality, and elastic distortions in high-density DNA mesophases

F. Manna,[1] V. Lorman,[1] R. Podgornik,[2,3,4] and B. Žekš[3,5]
[1]*Laboratoire de Physique Mathematique et Theorique, Universite Montpellier II, F-34095 Montpellier, France*
[2]*Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia*
[3]*Department of Theoretical Physics, J. Stefan Institute, SI-1000 Ljubljana, Slovenia*
[4]*LPSB/NICHHD, Building 12A, Room 2041, National Institutes of Health, Bethesda, Maryland 20892-5626, USA*
[5]*Institute of Biophysics, Medical Faculty, University of Ljubljana, SI-1000 Ljubljana, Slovenia*
(Received 29 August 2006; published 16 March 2007)

We investigate a new screwlike liquid-crystalline ordering in solutions of helical biopolymers and its influence on the state of individual molecules. In the resulting mesophase translational and rotational motions of molecules are coupled in screw fluctuations. We show that in contrast to the case of conventional chiral liquid crystals the elastic distortion does not twist the screw order but leads to overwinding of individual helical molecules. This explains the peculiarities of high-density DNA mesophases.

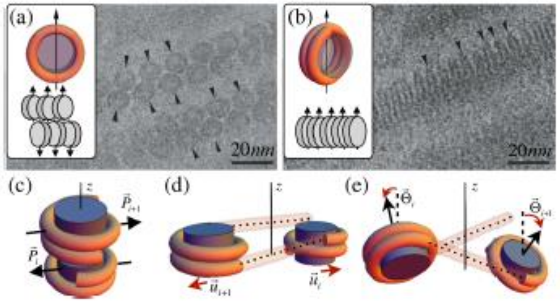
PRL **114,** 238102 (2015) PHYSICAL REVIEW LETTERS week ending 12 JUNE 2015

Antipolar and Anticlinic Mesophase Order in Chromatin Induced by Nucleosome Polarity and Chirality Correlations

R. Garcés,[1] R. Podgornik,[2,3] and V. Lorman[1]
[1]*Laboratoire Charles Coulomb, UMR 5221 CNRS-Université Montpellier 2, F-34095 Montpellier, France*
[2]*Department of Theoretical Physics, J. Stefan Institute, SI-1000 Ljubljana, Slovenia*
[3]*Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, 1000 Ljubljana, Slovenia*
(Received 17 October 2014; published 9 June 2015)

Contrary to the usual “rigid supermolecular assembly” paradigm of chromatin structure, we propose to analyze its eventual ordered state in terms of symmetry properties of individual nucleosomes that give rise to mesophase order parameters, like in many other soft-matter systems. Basing our approach on the Landau–de Gennes phenomenology, we describe the mesoscale order in chromatin by antipolar and anticlinic correlations of chiral individual nucleosomes. This approach leads to a unifying physical picture of a whole series of soft locally ordered states with different apparent structures, including the recently observed *heteromorphic chromatin*, stemming from the antipolar arrangement of nucleosomes complemented by their chiral twisting. Properties of these states under an external force field can reconcile apparently contradictory results of single-molecule experiments.

DOI: 10.1103/PhysRevLett.114.238102 PACS numbers: 87.16.Sr, 64.70.mf, 87.16.A-



Scientific Pathways: 2007-2017

- **From 2007 up to now: “on the roads of Watson, Crick and Caspar-Klug”**
    - Viral capsid assemblies → Landau theory for capsid crystallization + Caspar-Klug generalization + relation with quasicrystals

PRL **98,** 185502 (2007) PHYSICAL REVIEW LETTERS week ending 4 MAY 2007

Density-Wave Theory of the Capsid Structure of Small Icosahedral Viruses

V. L. Lorman[1] and S. B. Rochal[1,2]
[1]*Laboratoire de Physique Theorique et Astroparticules, CNRS-Universite Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France*
[2]*Physical Faculty, South Federal University, 5 Zorge Street, 344090 Rostov-on-Don, Russia*
(Received 21 November 2006; published 30 April 2007)

We apply Landau theory of crystallization to explain and to classify the capsid structures of small viruses with spherical topology and icosahedral symmetry. We develop an explicit method which predicts the positions of centers of mass for the proteins constituting the viral capsid shell. Corresponding density distribution function which generates the positions has a universal form without any fitting parameter. The theory describes in a uniform way both the structures satisfying the well-known Caspar and Klug geometrical model for capsid construction and those violating it.

DOI: 10.1103/PhysRevLett.98.185502 PACS numbers: 61.50.Ah, 64.70.Dv, 81.16.Dn, 87.15.Nn

PHYSICAL REVIEW B **77**, 224109 (2008)

Landau theory of crystallization and the capsid structures of small icosahedral viruses

V. L. Lorman[1] and S. B. Rochal[1,2]
[1]*Laboratoire de Physique Theorique et Astroparticules, CNRS, Universite Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France*
[2]*Physical Department, South Federal University, 5 Zorge Street, 344090 Rostov-on-Don, Russia*
(Received 9 February 2008; revised manuscript received 27 April 2008; published 19 June 2008)

A new approach to the capsid structures of small viruses with spherical topology and icosahedral symmetry is proposed. It generalizes Landau theory of crystallization to describe icosahedral viral shells self-assembled from identical asymmetric proteins. An explicit method which predicts the positions of centers of mass for the proteins constituting the shell is discussed in detail. The method is based on irreducible density distribution function which generates the protein positions. The universal form of the density distribution function which contains no fitting parameter permits to classify the capsids structures of small viruses. The theory describes in a uniform way both the structures satisfying the well-known Caspar and Klug geometrical model for capsid construction and those violating it. A group theory analysis of the Caspar and Klug model and of the “quasiequivalence” principle for protein environments in viral capsids is given. The molecular basis of difference in protein environments and peculiarities in the assembly thermodynamics are also discussed.

DOI: 10.1103/PhysRevB.77.224109 PACS number(s): 64.70.dg, 64.70.Nd, 61.44.Br

Physics Letters A 377 (2013) 1215–1220
Contents lists available at SciVerse ScienceDirect
Physics Letters A
www.elsevier.com/locate/pla
ELSEVIER

Unconventional Landau theory of quasicrystalline structure formation

CrossMark

O.V. Konevtsova[a,b,*], S.B. Rochal[a], V.L. Lorman[b]
[a] *Faculty of Physics, Southern Federal University, 5 Zorge str., 344090 Rostov-on-Don, Russia*
[b] *Laboratoire Charles Coulomb, CNRS – Université Montpellier, 2 pl. E. Bataillon, 34095 Montpellier, France*

A R T I C L E I N F O

Article history:
Received 18 January 2013
Accepted 6 March 2013
Available online 13 March 2013
Communicated by A.R. Bishop

Keywords:
Landau crystallization theory
Non-linear order parameter
Quasicrystal
Cluster approach
Constrained minimization

A B S T R A C T

We propose an unconventional theory which unifies the description of quasicrystal thermodynamics and quasicrystal structure formation by combining the Landau theory of crystallization and the cluster approach to quasicrystals. The theory is illustrated on the example of pentagonal Penrose quasilattice. It employs the notion of non-linear order parameter dependent on the atomic coordinates which was developed in the theory of reconstructive phase transitions. The coordinates of the quasilattice nodes are calculated by minimizing the Landau free energy with the constraint imposed by internal organization of clusters. The correspondence is shown between the theory proposed and the conventional projection method.

PHYSICAL REVIEW E **80**, 051905 (2009)

Theory of a reconstructive structural transformation in capsids of icosahedral viruses

S. B. Rochal[1,2] and V. L. Lorman[2]
[1]*Physical Faculty, South Federal University, 5 Zorge Str., 344090 Rostov-on-Don, Russia*
[2]*Laboratoire de Physique Theorique et Astroparticules, CNRS–Universite Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France*
(Received 4 September 2008; revised manuscript received 7 July 2009; published 6 November 2009)

A theory of a reconstructive structural transformation in icosahedral capsid shells is developed for a whole family of virulent human viruses. It is shown that the reversible rearrangement of proteins during the virus maturation transformation is driven by the variation in the wave number *l* associated with the protein density distribution function. The collective displacement field of protein centers from their positions in the initial (procapsid) and the final (capsid) two-dimensional icosahedral structures is derived. The amplitude of the displacement field is shown to be small and it minimizes the calculated free energy of the transformation. The theory allows us to propose a continuous thermodynamical mechanism of the reconstructive procapsid-to-capsid transformation. In the frame of the density-wave approach, we also propose to take an equivalent plane-wave vector as a common structural feature for different icosahedral capsid shells formed by the same proteins. Using these characteristics, we explain the relation between the radii of the procapsid and capsid shells and generalize it to the case of the viral capsid polymorphism.

DOI: 10.1103/PhysRevE.80.051905 PACS number(s): 87.16.Gj, 64.70.Nd, 87.16.dr

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ROYAL SOCIETY OF CHEMISTRY
PAPER
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Cite this: *Nanoscale*, 2016, **8**, 16976

Hidden symmetry of small spherical viruses and organization principles in “anomalous” and double-shelled capsid nanoassemblies

S. B. Rochal,[a] O. V. Konevtsova,[a] A. E. Myasnikova[a] and V. L. Lorman[b]

Received 19th June 2016,
Accepted 30th August 2016
DOI: 10.1039/c6nr04930c
www.rsc.org/nanoscale

We propose the principles of structural organization in spherical nanoassemblies with icosahedral symmetry constituted by asymmetric protein molecules. The approach modifies the paradigmatic geometrical Caspar and Klug (CK) model of icosahedral viral capsids and demonstrates the common origin of both the “anomalous” and conventional capsid structures. In contrast to all previous models of “anomalous” viral capsids the proposed modified model conserves the basic structural principles of the CK approach and reveals the common hidden symmetry underlying all small viral shells. We demonstrate the common genesis of the “anomalous” and conventional capsids and explain their structures in the same frame. The organization principles are derived from the group theory analysis of the positional order on the spherical surface. The relationship between the modified CK geometrical model and the theory of two-dimensional spherical crystallization is discussed. We also apply the proposed approach to complex double-shelled capsids and capsids with protruding knob-like proteins. The introduced notion of commensurability for the concentric nanoshells explains the peculiarities of their organization and helps to predict analogous, but yet undiscovered, double-shelled viral capsid nanostructures.

Scientific Pathways: in the meanwhile up to now

- **In the meanwhile - up to now: modeling structured membranes and protein-membrane interactions**
  - Mechanics of membranes as thin solid shells (lipid membrane + cytoskeleton) → strong interest for red blood cells + tubular membrane under "unconventional" conditions, protein membrane interactions

PRL **96,** 248102 (2006) PHYSICAL REVIEW LETTERS week ending 23 JUNE 2006

Cytoskeleton Influence on Normal and Tangent Fluctuation Modes in the Red Blood Cells

S. B. Rochal[1,2] and V. L. Lorman[2]
[1]*Physical Faculty, Rostov State University, 5 Zorge Street, 344090 Rostov-on-Don, Russia*
[2]*Laboratoire de Physique Theorique et Astroparticules, CNRS, Universite Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France*
(Received 27 October 2005; published 22 June 2006)

We argue that the paradoxal softness of the red blood cells (RBC) in fluctuation experiments is apparent. We show that the effective surface shear modulus μ_s of the RBC obtained from fluctuation data and that measured in static deformation experiments have the same order of magnitude. In the RBC model developed for this purpose the spectrin network cytoskeleton with the bulk shear modulus estimated as $\mu \approx 105$–165 Pa contributes to both normal and tangent fluctuations of the system and confines the membrane fluctuations. The calculated ratio of the mean-square amplitudes $\langle X_n^2 \rangle / \langle X_t^2 \rangle$ is 2–3 orders of magnitude smaller than it is in the free membrane with the same bending and shear moduli.

DOI: 10.1103/PhysRevLett.96.248102 PACS numbers: 87.68.+z, 83.60.−a, 87.16.−b, 87.17.−d

PHYSICAL REVIEW E **71**, 021905 (2005)

Viscoelastic dynamics of spherical composite vesicles

S. B. Rochal,[1,2] V. L. Lorman,[1] and G. Mennessier[1]
[1]*Laboratoire de Physique Mathematique et Théorique, CNRS–Université Montpellier 2, Place Eugene Bataillon, 34095 Montpellier, France*
[2]*Physical Faculty, Rostov State University, 5 Zorge Street, 344090 Rostov-on-Don, Russia*
(Received 6 October 2003; revised manuscript received 21 October 2004; published 11 February 2005)

A micromechanical model for the low-frequency dynamics of spherical composite vesicles (CVs) is proposed. Solidlike viscoelastic properties of the CVs are taken into account. The equations of motion of a CV surrounded by a viscous liquid are derived. They have discrete solutions which describe linearly coupled stretching and bending relaxation modes and an independent shear mode. The qualitative difference between the bending modes excited in a spherical vesicle and that in a flat membrane is demonstrated. The shear elasticity of the CVs gives an essential contribution to the relaxation rate of the bending mode at small wave numbers. It is also shown that even in an incompressible spherical vesicle with a finite shear modulus, the bending mode involves both radial and tangent displacements. These reasons make both in-plane and out-of-plane low-frequency responses of the CV quite different with respect to those of the flat membrane. To compare our theoretical results with published experimental data, the power spectra of the actin-coated CV are calculated.

DOI: 10.1103/PhysRevE.71.021905 PACS number(s): 87.16.Dg, 82.70.Uv, 46.35.+z

PRL **105,** 028102 (2010) PHYSICAL REVIEW LETTERS week ending 9 JULY 2010

Long-Range Protein Coupling Mediated by Critical Low-Energy Modes of Tubular Lipid Membranes

Sylvain Monnier,[1,2] Sergei B. Rochal,[3] Andrea Parmeggiani,[2] and Vladimir L. Lorman[1]
[1]*Laboratoire de Physique Théorique et Astroparticules, CNRS, Université Montpellier II, Pl. E. Bataillon, 34095 Montpellier Cedex 5, France*
[2]*Laboratoire de Dynamique des Interactions Membranaires Normales et Pathologiques, CNRS, Université Montpellier II, Pl. E. Bataillon, 34095 Montpellier Cedex 5, France*
[3]*Physical Department, South Federal University, 5 Zorge Street, 344090 Rostov-on-Don, Russia*
(Received 4 September 2009; published 8 July 2010)

We develop a theory of a resonant effect in protein-membrane coupling taking place in the vicinity of instabilities in tubular lipid membranes (TLMs) under longitudinal force and pressure difference constraints. Two critical low-energy modes defining the stability domain boundaries are found. We show that these modes mediate long-range TLM-protein coupling and interactions between absorbed proteins. Besides, TLM mechanical instabilities strongly influence protein desorption and protein cluster nucleation on TLMs. Model predictions can be tested over a large spectrum of mechanochemical conditions.

Biophysical Journal Volume 103 December 2012 2475–2483 2475

Red Blood Cell Membrane Dynamics during Malaria Parasite Egress

Andrew Callan-Jones,* Octavio Eduardo Albarran Arriagada, Gladys Massiera, Vladimir Lorman, and Manouk Abkarian*
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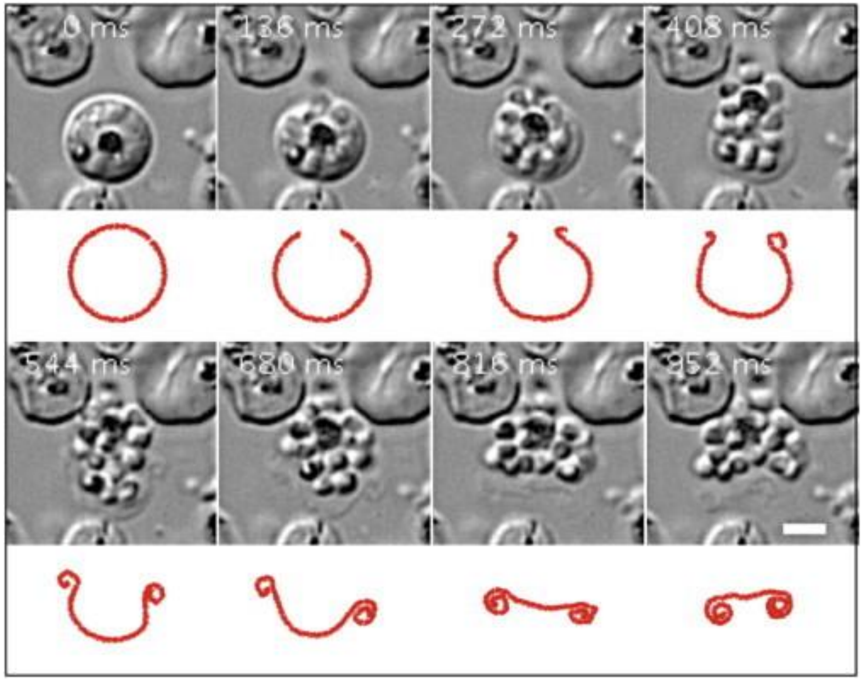
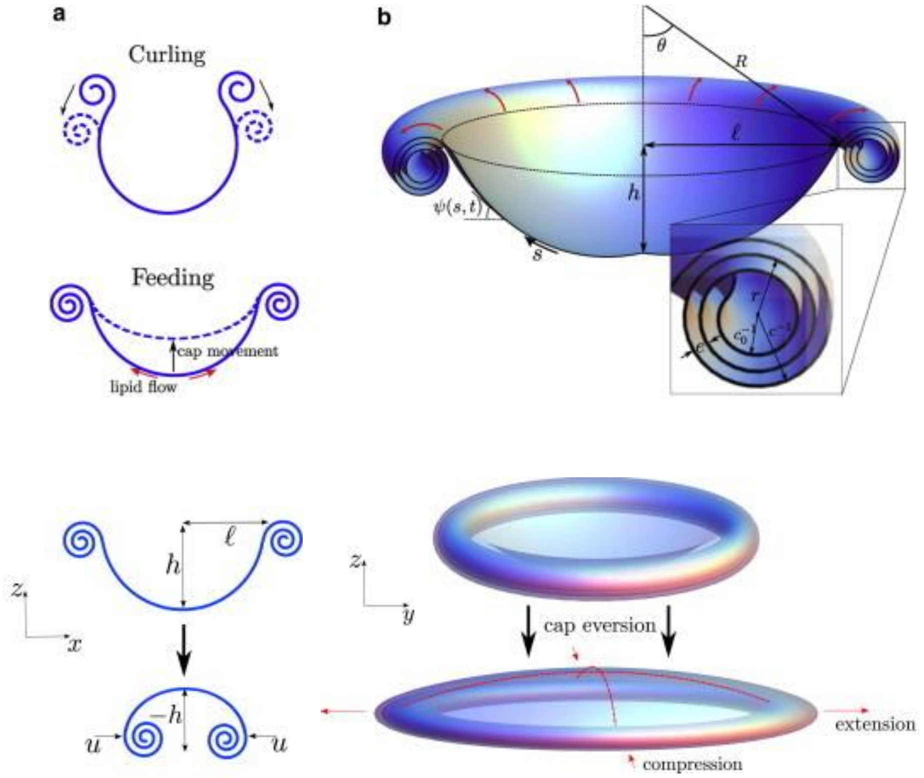
ABSTRACT Precisely how malaria parasites exit from infected red blood cells to further spread the disease remains poorly understood. It has been shown recently, however, that these parasites exploit the elasticity of the cell membrane to enable their egress. Based on this work, showing that parasites modify the membrane's spontaneous curvature, initiating pore opening and outward membrane curling, we develop a model of the dynamics of the red blood cell membrane leading to complete parasite egress. As a result of the three-dimensional, axisymmetric nature of the problem, we find that the membrane dynamics involve two modes of elastic-energy release: 1), at short times after pore opening, the free edge of the membrane curls into a toroidal rim attached to a membrane cap of roughly fixed radius; and 2), at longer times, the rim radius is fixed, and lipids in the cap flow into the rim. We compare our model with the experimental data of Abkarian and co-workers and obtain an estimate of the induced spontaneous curvature and the membrane viscosity, which control the timescale of parasite release. Finally, eversion of the membrane cap, which liberates the remaining parasites, is driven by the spontaneous curvature and is found to be associated with a breaking of the axisymmetry of the membrane.

Scientific Pathways: in the meanwhile up to now

- **In the meanwhile - up to now: modeling structured membranes and protein-membrane interactions**
  - Mechanical instabilities of malaria parasites egress from red blood cells

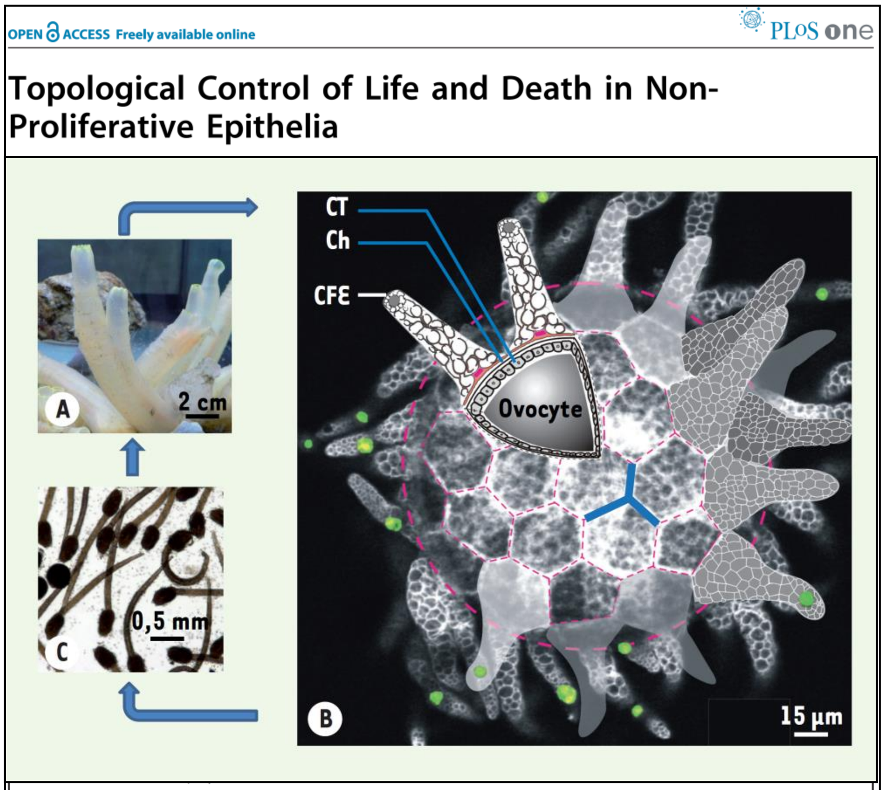


Pore nucleation followed by curling and buckling instabilities



Scientific Pathways: in the meanwhile up to now

- **In the meanwhile - up to now: tissue mechanics in developmental biology**
  - Opening to soft tissues ordering, structure and function (Apoptotic control in *Ciona Intestinalis* and EHT in *Zebrafish*): implications for cancer research.
    Are mechanical constraints controlling organism molecular genetics?
    (D'Arcy Thompson's hypothesis)



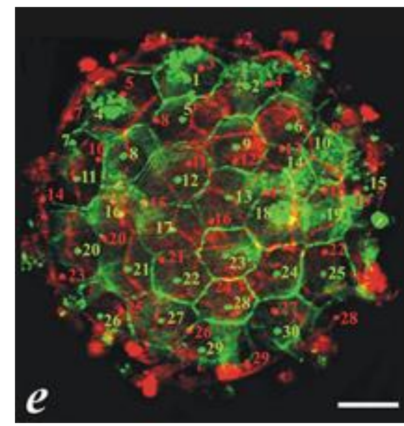
"**<u>A theory of apoptotic controllers</u>**"

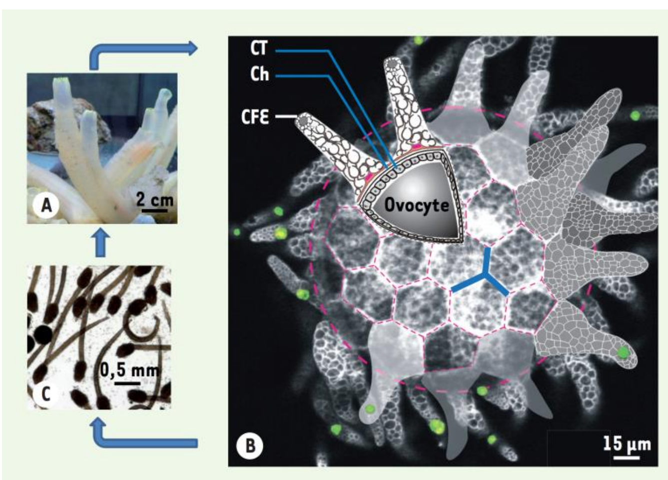
To note:

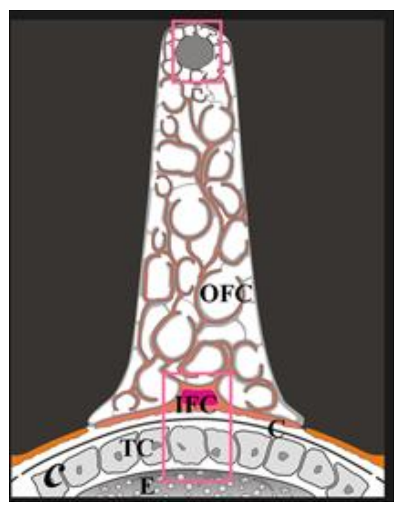
- *Ciona Intestinalis*: example of descendent evolution: from tadpole to digesting tube!
- tissue icosahedral symmetry (to maximize volume)
- about 60 floater cells form the egg
- soft interactions vs rigid interaction in viruses
- position is not casual, but mechanical constraints
- position plays a fundamental role in apoptotic signaling pathway

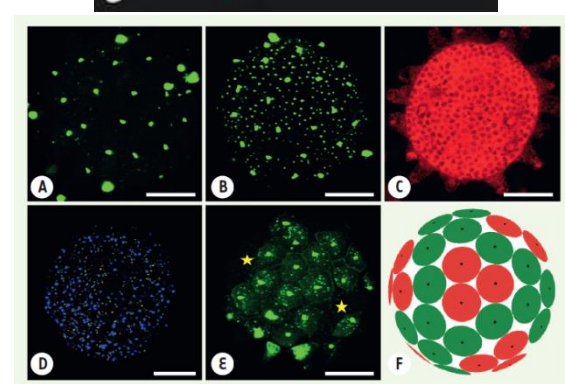
Scientific Pathways: in the meanwhile up to now

- **In the meanwhile - up to now: tissue mechanics in developmental biology**
  - Opening to soft tissues ordering, structure and function (Apoptotic control in *Ciona Intestinalis* and EHT in *Zebrafish*):
    Are mechanical constraints controlling organism molecular genetics?
    (D'Arcy Thompson's hypothesis)
    - Floaters position cells are not randomly distributed, but are optimized depending on a soft short range cell-to-cell interactions
    - Their apoptosis controls inners control cells apoptosis and organism egress: **"Theory of apoptotic controllers"?**



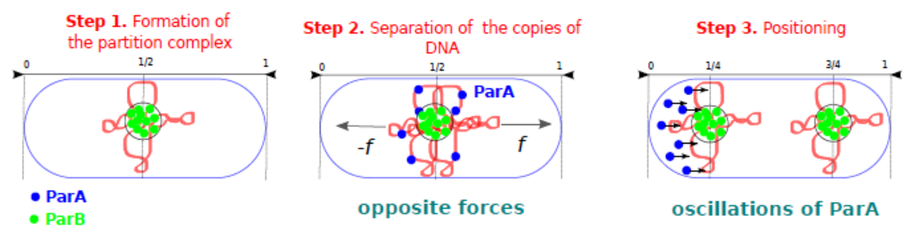






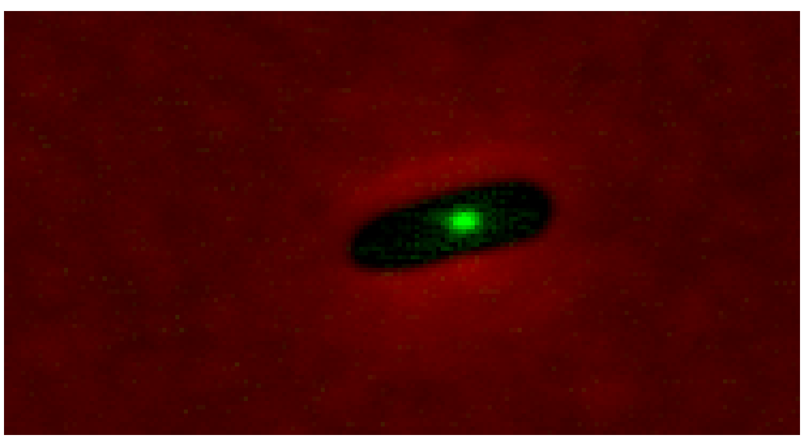
Scientific Pathways: in the meanwhile up to now

- **In the meanwhile - up to now:**
  - Dynamical instabilities and symmetry breaking in DNA active segregation systems of bacteria: the stochastic control of DNA segregation and positioning in bacteria
  - Physical genomics and bioinformatics
  - Physical virology and genomic virology

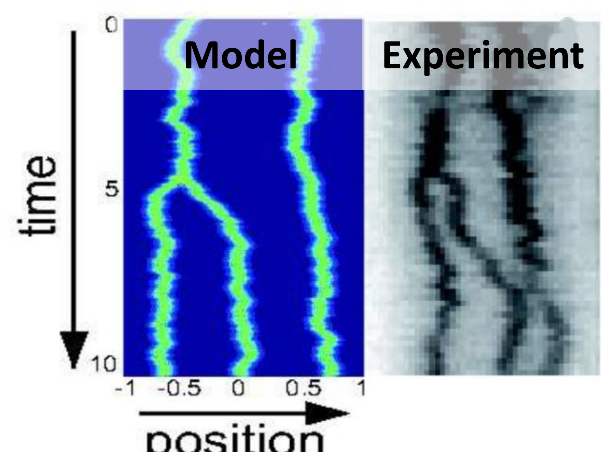


Surfing on Protein Waves: Proteophoresis as a Mechanism for Bacterial Genome Partitioning

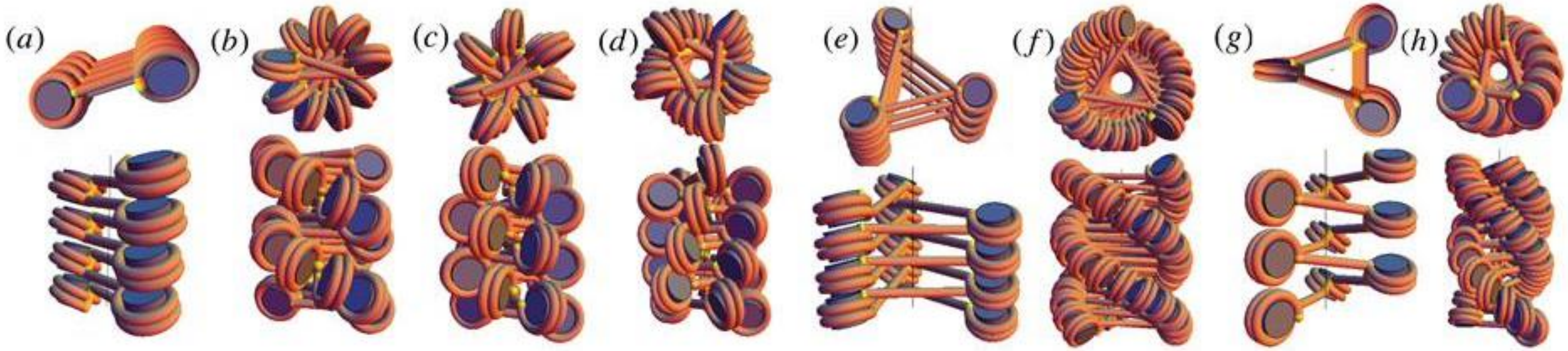
J.-C. Walter, J. Dorignac, V. Lorman, J. Rech, J.-Y. Bouet, M. Nollmann, J. Palmeri, A. Parmeggiani, and F. Geniet
Phys. Rev. Lett. **119**, 028101 – Published 13 July 2017



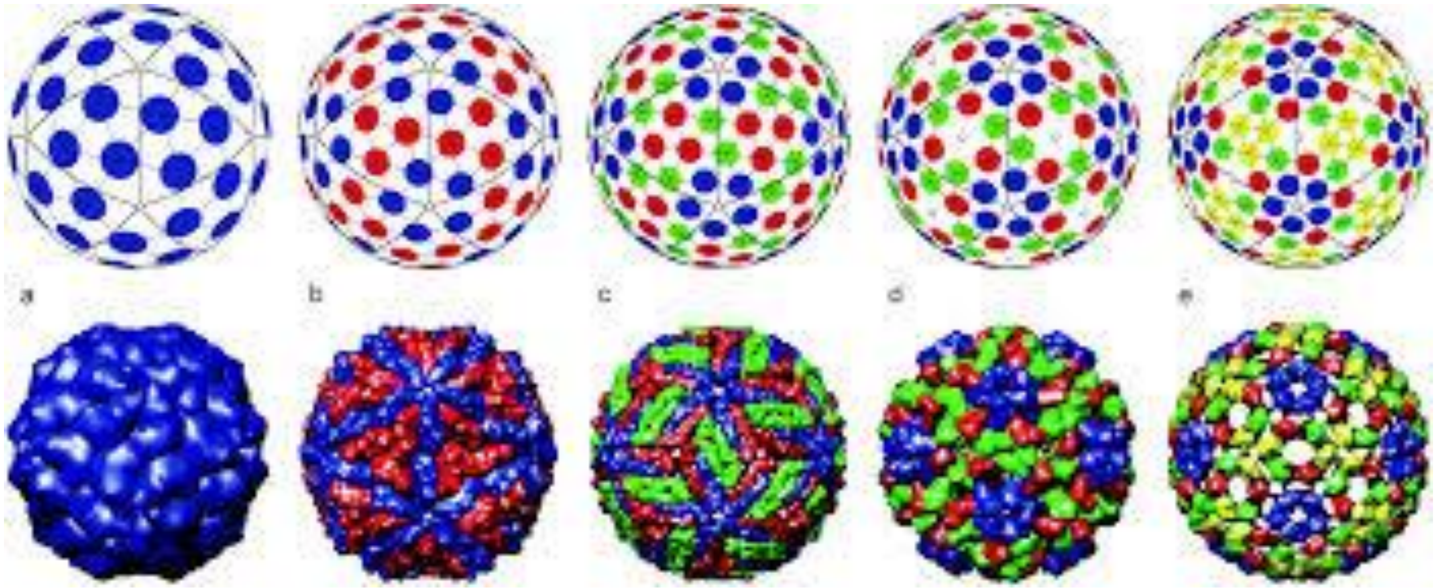
3 components:
a) 2 proteins (ParA & ParB)
b) specific binding sites (*parS*)



The beauty of order and symmetries of the physical world



Garces, Podgornik, Lorman, PRL 2015



Rochal, Konevtsova, Myasnikova, Lorman, Nanoscale 2016

Vladimir's in the Scientific Community

A friend who taught us to love the beauty of physics and nature by the kindness of his personality, but also by the firmness in the science he knew perfectly.

(From a colleague of the Engineering and Robotics Department)