INTERNATIONAL SOLVAY INSTITUTES BRUSSELS

# 2017 Jacques Solvay International Chair in Physics

## Professor Uri Alon

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Rehovot, Israel

## *Program*

### Inaugural Lecture: Tuesday 10 October (4.00 - 5.00 P.M., Solvay Room)

**Physics of joint creativity and togetherness**

Can physics help us make sense of human experiences that are hard to define? In this easy to understand talk, I'll describe emerging research on moments of joint creativity that seem to occur in arts, scientific conversations and sports. The experiments use an exercise from theatre called the mirror game as a simple behavioral system in which people spontaneously create new motion without leader and follower. Precise measurements and theory help us identify how people create together.

***FOR THE INAUGURAL LECTURE, COFFEE AND TEA WILL BE SERVED AT 3.45 P.M. AND DRINKS AT 5.00 P.M. IN FRONT OF THE SOLVAY ROOM***

### Lecture 1: Thursday 12 October (10.00 - 12.00., Solvay Room)

**Network motifs: simple circuits building blocks of complex biological networks**

Complex gene regulation networks seem hopelessly complicated. I'll describe the discovery that complex networks in biology are much simpler than first thought, they are made of a small set of recurring interaction patterns called network motifs. These motifs include coherent and incoherent feedforward loops. I'll show how each network motif carries our specific computational functions, and how motifs can be combined to generate the intricate computations of the cell. I'll discuss how evolution rediscovered the same motifs again and again, evidently because they are the simplest and most robust circuits that carry out each function.

### Lecture 2: Thursday 12 October (4.00 - 6.00 P.M., Solvay Room)

**Symmetry and scaling in the sensory systems of cells and organisms**

Cells and animals sense the environment and act accordingly. On the level of both cells and animals, many sensory systems share unifying features, such as exact adaptation and scaling of input signals. At the basis of these universal features is the unifying property of fold change detection (FCD): response dynamics that depend only on relative changes in input, and not absolute changes. FCD was defined about a decade ago based on symmetry considerations, and was experimentally found in diverse sensory systems including human vision, bacterial chemotaxis and major cell signaling pathways such as wnt, NFkb and TGF beta, and explains their impressive dynamic range and resistance to protein noise. A common network motif from the previous lecture, the incoherent feedforward loop, is one of the very few possible circuits that provide FCD.

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## Lecture 3: Friday 13 October (9.00 -11 P.M., Solvay Room)

### Symmetry and scaling in hormone circuits and tissues

Our bodies regulate our inner states, such as our blood glucose, using hormones, which act across tissues. How hormone circuits adjust themselves to unavoidable parameter variations is a burning question: for example the parameter called insulin resistance varies by an order of magnitude across people and across time, and yet insulin keeps glucose levels and post-meal dynamics under very strict control to within 10%. I'll describe design principles of hormonal circuits which use a slow feedback loop to buffer parameter variations by controlling the mass of the gland that secretes the hormone at play. Ill also discuss how mathematical modelling can shed light on breakdown of such circuits, potentially leading to diseases such as type 2 diabetes in which blood glucose control fails. These breakdowns are due to mechanisms that evolved to make hormone circuits resistant to invasion by mutants that missense the feedback signal showing a tradeoff between resistance to mutants and fragility to disease.

## Lecture 4: Tuesday 17 October (4.00 - 6.00 P.M., Solvay Room)

### Multi-objective optimality in biology

When a biological system needs to carry out multiple tasks, it faces a fundamental tradeoff: no phenotype can be optimal at all tasks at once. I'll describe a theory, called pareto task inference (ParTI), that shows how such tradeoffs lead to striking patterns in biological data. This theory employs Pareto optimality from engineering and economics. In engineering, one knows the tasks in advance, say the tasks needed from a car such as speed versus safety versus environmental friendliness but in biology we do not often know the tasks a priori. Thus ParTi allows solving the inverse problem: detecting the evolutionary tasks directly from the data. To do this, ParTi shows that when k tasks are at play, the data in trait space fills out a polytope with k vertices (or at least a shape that can be smoothly deformed to give a polytope), e.g. a triangle for three tasks and a tetrahedron for four tasks. The vertices are phenotypes optimal at each task, allowing tasks to be inferred. I'll demonstrate tasks and tradeoffs in animal morphology, cancer gene expression and individual-cell transcriptomics.

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