CURRENT RESEARCH ACTIVITIES

2021

Weizmann Institute of Science
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The Weizmann Institute of Science is one of the world's leading multidisciplinary basic research institutions in the natural and exact sciences. The Institute's five faculties Biology, Biochemistry, Chemistry, Physics, Mathematics and Computer Science are home to scientists and students who embark daily on fascinating journeys into the unknown, seeking to improve our understanding of nature and our place within it. The Institute has been the venue of pioneering research in neuroscience, nanotechnology and alternative energy, the search for new ways of fighting disease and hunger and creating novel materials and developing new strategies for protecting the environment. Mathematicians and computer scientists working together with biologists are uncovering unseen patterns in everything from our DNA to the ways our cells age to personal nutrition. From participating in the discovery of the Higgs boson at CERN to joining in scientific missions to the planets in our solar system, Weizmann Institute researchers are helping lead international science. The campus comprises of 1.1sq km (280 acres) and includes over 240 buildings, research facilities, administration and housing; 2,500 faculty and staff; 1,400 students and postdocs Research volume annually is of more than $100m total worth of grants for Weizmann Institute research projects.
The Department of Biological Regulation is comprised of approximately 170 people organized in 14 research groups. We are located in the Candioty and Britannia buildings, which are equipped with all the cutting-edge facilities required for running excellent research endeavors. Our research is concentrated on the regulation of processes responsible for the concerted action of cells, tissues, and organs. A diversity of methodologies and experimental approaches are being used in order to tackle these pivotal issues in biology. These include biochemical, molecular and physiological methods, organ and tissue cultures, and whole animal studies utilizing mice and fish. In addition, some researchers of the Department are using methodologies and concepts of systems biology, host-pathogen interactions and a variety of imaging methods, including magnetic resonance imaging (MRI). Since de-regulation of biological control circuits often underlies human diseases (e.g., malignant transformation, stroke, infertility, and defective tissue regeneration after injury), we make many efforts to implement the results of our studies in research projects leading to the development of new tools for early diagnosis, along with novel compounds suitable for pharmacological interventions.

**The main projects that are currently performed in the department are:**

Host-pathogen interactions - Dr. Roi Avraham

Cell metabolism in health and disease - Dr. Ayelet Erez

Gut tissue dynamics -Dr. Moshe Biton

Mitochondria Biology- Prof. Atan Gross

Protein degradation by the ubiquitin/proteasome system - Prof. Ami Navon

Vascularization during pregnancy and cancer development - Prof. Michal Neeman

ECM remodeling: from biophysical principles to drug design - Prof. Irit Sagi

Intracellular signaling cascades in health and disease - Prof. Rony Seger

Epigenetics in stem cells and cancer: developing and applying single-molecule imaging technologies to study the epigenetic code - Dr. Efrat Shema

Epigenetics in development and disease - Prof. Amos Tanay
Dr. Avraham Roi

- The lab of host-pathogen genomics is interested in how individual encounters between host and pathogenic bacteria can ultimately define the outcome of infection. This is achieved by applying cross-disciplinary single-cell analysis platforms that collectively enable us to extensively profile and precisely monitor host-pathogen interactions within the context of in vivo infections.
- The work in the lab centers on salmonella infection of mouse macrophages as a tractable in vitro host-pathogen system. We use this model to develop state of the art high throughput genomic tools and interdisciplinary approaches, and then apply them to various in vivo infection models to address critical biological aspects of host-pathogen biology.
- Using comprehensive, quantitative, unbiased tools to analyse the molecular interactions that underlie distinct host-pathogen subpopulations and their impact on disease outcome.
- Using a powerful combination of cutting-edge single cell genetic and genomic approaches, we wish to address what forms the basis for successful immune clearance, from the level of individual infected cells to that of the whole organism, and why, in some cases, sterilization is incomplete?

Dr. Moshe Biton

- Stem cell - Immune interactions
  - Epithelial stem cell biology.
• The role of epithelial MHCII in maintaining tissue homeostasis and in tissue pathologies such as IBD and cancer.

• Understanding the role of epithelial cells in shaping the landscape of mucosal adaptive immunity.

• Exploring novel cell-cell interactions in food allergies, IBD and cancer.
• T helper cells’ role in maintaining tissue homeostasis.

Prof. Hadassa Degani

• Perfusion and angiogenesis in lung cancer: The role of the bronchial and pulmonary vascular network using Fluorescence and magnetic resonance imaging methods

• Molecular magnetic resonance imaging of the estrogen receptor

  Collaboration with: Professors David Milstein and Joel Sussman, Weizmann Institute
  • Synthesis of new, high affinity ligands of the estrogen receptor as probes for molecular imaging
  • Structural studies (x-ray crystalography and NMR) of the estrogen receptor - targeted ligands complex
  • Functional activities and molecular imaging of the new targeted ligands in estrogen receptor positive huaman breast cancer cells
  • Mechanisms of lymphatic metastasis in breast cancer; In vivo fluorescence and magnetic resonanc imaging

• Advanced non invasive MRI methods for breast cancer detection and diagnosis; clinical investigations

  Collaboration with: Dr. Myra Shapiro, Meir medical Center
  • 3D Tracking of the mammary tree using diffusion tensor magnetic resonance imaging
  • Advanced methods for analysis of dynamic contrast enhanced MRI based on a combined model free and model based method.

• Hyperpolarized magnetic resonance spectroscopy and imaging of cancer metabolism; searching for novel metabolic markers of cancer

  Collaboration with: Professor Lucio Frydman, Weizmann Institute

• Renal function through sodium grandients; Non-invasive, high resolution sodium MRI.

  Collaboration with: Dr. Edna Haran, Weizmann Institute

• Estrogen regulation of angiogenesis and perfusion of breast cancer; from molecular mechanisms to functional MRI of the microvascular physiology

Prof. Nava Dekel

• Molecular characterization of the ovulatory cascade
• Mechanisms involved in successful implantation.
• Regulation of the meiotic cell cycle: use of rodent oocytes as a model system.
• Cell-to-cell communication: regulation of expression, posttranslational modification, degradation and function of the gap junction proteins, Cx43 and Cx37.

Dr. Erez Ayelet

Collaboration with: Eytan Ruppin Uri Tabori Angel Progador
• Cancer Metabolic Rewiring
• Metabolic regulation of anti-cancer immune response

• Metabolic adaptations during cancer cachexia
• Metabolism in senescence
• Metabolic cross talks in the tumor miceroenvironment

Prof. Atan Gross

• How do changes in mitochondria function effect the initiation/progression of Parkinson's Disease?
• How do changes in mitochondria function effect the initiation/progression of Fibromyalgia?
• Establishing the role of mitochondrial carrier homolog 2 (MTCH2) in regulating the shape of mitochondria, metabolism and apoptosis
• Develop inhibitors for MTCH2 as potential therapies of diseases such as acute myeloid leukemia (AML) and obesity

Prof. Michal Neeman

• MRI of angiogenesis
  Collaboration with: Prof Nava Dekel, Weizmann Prof Lucio Frydman, Weizmann Prof Joel Garbow, Washington Univ. St Louis Prof Silvio Aime, Univ Torino
  • COVID-19 in pregnancy
  • Vascular remodelling in cancer
  • Vascular remodelling in reproduction and development
  • Protocols, Reporter genes and Probes for molecular imaging

Prof. Rony Seger

• The nuclear translocation of signaling protein as a drug target for cancer and inflammation
  • The nuclear translocation of ERK
  • The nuclear translocation of JNK and p38
  • Develop peptide inhibitors of the nuclear translocation of ERK/JNK/p38 for the
cure of cancer and inflammation
• Development of small molecular weight inhibitors of the nuclear translocation of ERK for the cure of cancer
• The subcellular localisation of AKT
• The mechanisms and roles of MEK nuclear translocation

• ERK1c in the regulation of Golgi fragmentation
  • The mechanisms of golgi translocation of ERK1c
  • Substrates of ERK1c in the Golgi
  • Mechanism of ERK1c-regulated Golgi architecture

Prof. Philipp Selenko

• Neuronal alpha-synuclein aggregation in Parkinson's disease
  Collaboration with: Daniella Goldfarb, Hagen Hofmann, Ori Avinoam, Atan Gross, Ami Navon
  • Structural Biology, Cell Biology, Neurobiology, Biophysics
  • NMR, EPR, smFRET, cryoEM, CLEM, optical microscopy, correlative imaging methods, advanced mammalian cell models.
• Cellular regulation of CPEB4 liquid-liquid phase separation
  Collaboration with: Daniella Goldfarb, Hagen Hofmann, Koby Levi
  • Structural Biology, Cell Biology, Neurobiology, Biophysics
  • NMR, EPR, smFRET, cryoEM, CLEM, optical microscopy, correlative imaging methods, advanced mammalian cell models.

Prof. Alex Tsafriri

• Molecular regulation of ovulatory changes in mammals.
  Collaboration with: Helena Ashkenazi, Shmulik Motola, Xiumei Cao, Malka Popliker, Seymour Pomerantz, Marco Conti, Stanford
  • The roles of gonadotropins and EGF-like factors in triggering ovulation.
  • The resumption of meiosis and its regulation.
  • Ovulation as a tissue remodeling process.
• The development and demise of ovarian follicles <i>in vivo</i> and <i>in vitro</i>: the role of apoptosis.
  Collaboration with: Atan Gross, KerenYacobi

Dr. Igor Ulitsky

• Functions and modes of action of long RNAs
  • Functions of long noncoding RNAs in establishing cell identify
  • Sequence determinants RNA functions
  • Genome evolution
  • RNA localization within cells
  • Regulation of RNA turnover
The immune system was originally recognized for its role in defense of the organism against pathogens, including bacteria and viruses. However, we have come to realize that the system not only reacts to exogenous pathogen attacks, but also to internal challenges posed by tissue remodeling, aging, metabolic unbalance and cancer. Moreover, immune cells are also critically involved in normal developmental processes and the maintenance of adult homeostasis in light of innocuous and beneficial environmental challenges such as the microbiome.

Research in the Department of Immunology addresses the challenge to understand contributions of immune cells to physiology and pathophysiology, with the aim to deepen our knowledge and develop new strategies for therapeutic intervention. Accordingly, our research spans a wide range from studying basic mechanisms of development, inter-cellular communication, cell trafficking and effector functions of immune cells to the definition of their specific roles in aging, autoimmune disorders, allergies and cancer.

Department members investigate cellular and molecular mechanisms underlying immune disorders, such as aging, immunodeficiencies, innate immunopathologies, autoimmunity, as well as infectious diseases. Using pre-clinical mouse models and patient samples, we develop novel therapeutic strategies including check-point blockade, immunotherapies and improved vaccination protocols. We develop and employ state-of-the-art approaches ranging from intra-vital imaging and conditional gene manipulation, to advanced bulk and single cell genomics and proteomics to uncover physiological and pathological roles of the immune system.

For more details on our exciting research projects and specific groups in the Immunology Department, please see our web page https://www.weizmann.ac.il/immunology/

Research activities
Dr. Jakub Abramson

• Understanding how breakdown of this process results in autoimmunity.
• Deciphering the molecular and cellular mechanisms that control the establishment of central immune tolerance.

Prof. Ronen Alon

• Integrin and chemokine signals for leukocyte diapedesis, differentiation and killing
  **Collaboration with:** Ziv Shulman (WIS) Steffen Jung (WIS)
• Leukocyte-type specific roles of ICAM-1 and ICAM-2 in leukocyte emigration across the pulmonary vasculature
  **Collaboration with:** Natalio Garbi (Bonn)
• Role of lymph node ICAMs in lymphocyte priming and differentiation
• Trafficking cues for leukocyte emigration and function in lung and skin infections
• Mechanical properties of nuclei in solid tumors: implications in cell barrier crossing, survival and metastasis
• Breast cancer killing in primary tumors and inside the lung vasculature: regulation by tumor cell ICAM-1
• The role of antigens on lung metastatic lesions in the recruitment and killing capacity of circulating CTLs and TILs

Prof. Ido Amit

• Genomics and Systems Biology of the Immune System.
• Decoding the mammalian transcriptional Regulatory Code in health and disease.

Prof. Ruth Arnon

• Pathological mechanism in the CNS of various multiple sclerosis animal models.
  **Collaboration with:** R. Aharoni
• Neuroprotection, neurogenesis and remyelination – consequences of Glatiramer Acetate treatment in EAE.
  **Collaboration with:** R. Aharoni; M. Sela
• Mechanism of action of Copolymer 1 (Copaxone®), a therapeutic vaccine against multiple sclerosis.
  **Collaboration with:** M. Sela; R. Aharoni
• Involvement of peptides in animal models of Alzheimer disease and its amelioration
  **Collaboration with:** R. Maron; M. Wilchek

Prof. Gideon Berke

• Immunopathology in AIDS: Killing of HIV-infected CD4 T cells induced by Autologous CD8 T cells is Modulated by Nef expression
Collaboration with: Hassin D. and Sevilya Z.; Assuta Ashdod Medical Center.

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Prof. Irun R. Cohen

• Development and clinical applications of an antigen microarray device and informatics analyses aimed at diagnosis, prognosis, monitoring and management of autoimmune and other inflammatory diseases â€” the ImmunArray Ltd iCHIP (Israel and USA); now in clinical use.
• Treatment of inflammatory bowel disease, arthritis and other autoimmune conditions using DNA plasmids encoding human HSP90 or HSP70 â€” Alma Bio Therapeutics (France).
• Treatment of ALS using a synthetic peptide that inhibits apoptosis and fosters cell growth â€” Immunity Pharma Ltd. (Israel); entering clinical trials.

Dr. Rony Dahan

• Antibody response in cancer
• Anti-tumor mechanisms of immune checkpoint antibodies
• Therapeutic window of antibody-based immunotherapies

Prof. Lea Eisenbach

• immunotherapy of cancer
  Collaboration with: yardena samuels, david bassan, adam solomon, esther tzechoval
  • tumor antigens, engineered lymphocytes, lynch syndrome vaccines
• Cancer Stem Cells and immunotherapy
• the role of small interferon induced genes in tumorigenicity and apoptosis
• cryoimmunotherapy
• tumor escape and tolerance
• T cell receptor evolution for immunotherapy
  Collaboration with: David Bassan
• Antigen presentation by engineered MHC molecules
  Collaboration with: Dr Gideon Gross

Prof. Zelig Eshhar

• Development of universal vaccine for the control of allergic responses.
• Study of colorectal induced tumors in colitis.
• Redirecting regulatory T cells for adoptive cell therapy of autoimmune inflammation.
• Redirecting effector T cells for adoptive cell treatment of cancer.

Prof. Nir Friedman

• Applications of TCR-seq: Autoimmunity, Neuroimmunology, Vaccination.
  **Collaboration with:** R. Arnon, M. Schwartz, B. Chain - UCL
• Mapping T cell receptor repertoire using high-throughput sequencing (TCR-seq): developing methodologies and bioinformatic tools.
• Live cell imaging of T cell activation and differentiation using microfluidics devices.
• Studies of intercellular cytokine communication networks in T-cell development and differentiation.
• Studies of CD4 T cell differentiation combining experimental single cell approaches and mathematical modeling.

Prof. Sara Fuchs

• The basis of D2 dopamine receptor diversity: Cloning, signal transduction, development, and correlation with disease.
• The nicotinic acetylcholine receptor: Structure, function, and regulation of gene expression.
• Myasthenia gravis: Regulatory mechanisms, epitopes, and immunodulation.

Prof. Steffen Jung

• Monocyte and Brain Macrophage Functions in Experimental Autoimmune Encephalomyelitis (EAE), a model for multiple sclerosis (MS)
  **Collaboration with:** Marco Prinz, University of Freiburg, Germany Pablo Blinder, TAU, Israel
• Microglia contributions to relapsing remitting EAE
• Contributions of perivascular macrophages to EAE.
• Modules ensuring microglia quiescence and restoration of the microglia ground state following activation, with a particular focus on the IL-10 axis
• Contributions of IL-23 producing monocytes in the generation of pathogenic T cells in EAE
• Comparative analysis of HSC-derived engrafted brain macrophages and host microglia in health and disease
• The role CX3C chemokine axis in intercellular communication.
• Contributions of Dendritic cell, Macrophages and Monocytes Contributions to Gut Health and Inflammatory Bowel Disease (IBD).
• Studying Molecular Cues guiding Mononuclear Phagocyte Differentiation
  • Definition of monocyte development in physiology and pathophysiology (IBD, obesity)
• Study of differentiation of monocytes into tissue macrophages in small and large intestine and blood

• Studying Interactions of Macrophages with Sympathetic Nerve System

**Collaboration with:** Avraham Yaron, Weizmann Institute

**Prof. Tsvee Lapidot**

• Metabolic regulation of Blood and Bone forming Stem Cells by Daily Light and Dark Cues (NE, TNF, Melatonin and PGE2).

• Regulation of Human and Murine Hematopoietic Stem Cell Migration and Development by Coagulation Cascades (both aPC/EPCR/Par1 anti-inflammatory signals and Thrombin/PAR1 pro-inflammatory signals).

• Studying Molecular Cues guiding Human and murine Hematopoietic Stem Cells Homing and Bone Marrow (BM) recognition, retention and mobilization to the circulation.

• Metabolic regulation of BM Neutrophils activation and recruitment by Lactatae and GPR81 Signaling.

• Metabolic regulation of BM Neutrophils by Daily Light and Dark Cues.

• Energy sharing, Chemotherapy Resistance and Stress induced Mitochondria Transfer between Blood and Bone forming Stem Cells.

• AML AF9 Leukemic Stem Cells Metabolic interactions with BM Stromal Cells and Chemotherapy Resistance.

• Dynamic regulation of the Blood Bone Marrow Endothelial Barrier and Hematopoietic Stem Cell Niches.

**Prof. Edna Mozes**

• Systemic lupus erythematosus (SLE): Induction and development in various animal models.

• The role of various cell types (APC, T, B) and cytokines in the pathogenesis of autoimmune diseases.
  • The status and role of T regulatory cells in autoimmune diseases.

• Specific immunomodulation of the autoimmune diseases, Systemic lupus erythematosus and Sjogren Syndrome by a synthetic, tolerogenic peptide.

**Collaboration with:** Prof. Zev Sthoeger, Kaplan Medical Center.

• Elucidation of the mechanisms (effects on main pathways, cell types, cytokines and other pathogenic molecules) by which the tolerogenic peptide ameliorates autoimmune disease manifestations in animal models and in patients with SLE and Sjogren Syndrome.

• Development of the tolerogenic peptide as a novel specific drug for the treatment of SLE and Sjogren Syndrome.

**Prof. Roald Nezlin**
• Immunoglobulin properties and functions. Immune complexes.

**Collaboration with:** No

• Detection of Immune complexes with antigens.

**Prof. Israel Pecht**

• Electron transfer mechanisms in proteins.

• Antigen recognition and trans-membrane signaling by immuno-receptors.

**Prof. Yair Reisner**

• Immature dendritic cells: investigating a novel granule mediated killing mechanism and the therapeutic potential for the prevention of Graft versus Host Disease.

• Crossing allogeneic and xenogeneic barriers by growing organs in-vivo from embryonic tissues: potential curative approaches for diabetes, hemophilia and lung diseases.

• Hematopoietic size control: A novel role for coagulation cascade factors in regulating the interplay between dynamic bone structure and long term survival and mobilization of hematopoietic stem cells.

• Developing a protocol for the production of human central memory CD8 T cells, to induce tolerance in allogeneic stem cell transplantation.

• Investigating the use of activated CD8 T cells as novel cell therapy for the treatment of autoimmune diseases.

• Role and mechanism of tolerance induction by activated CD8 T cells: A novel cell therapy for chimerism induction, stem cell transplant engraftment and enhanced Graft versus Lymphoma / Leukemia effect.

**Prof. Michael Sela**

• Importance of negligible amounts of a partner in antibody combinations

• An aptamer strategy to target oncogenic signaling in ErbB2 carrying human tumors.

  **Collaboration with:** G. Mahlknecht, Y. Yarden

  G. Mahlknecht

• Synergy of antibodies towards decreasing pancreatic cancer.

  **Collaboration with:** R. Maron, B. Schechter, Y. Yarden

• Towards vaccination: Generation of peptide mimotopes specific for anti ErbB-2 monoclonal antibodies.

  **Collaboration with:** E. Witsch, Y. Yarden

• Mechanism of action of Copolymer 1 (Copaxone), a therapeutic vaccine against multiple sclerosis.

  **Collaboration with:** R. Arnon

• Effective synergism by anti ErbB-2 mAb combinations comprising one mAb against the dimerization site of ErbB-2.
Collaboration with: Y. Yarden

• Monoclonal antibodies (mAbs) to ErbB-1 and ErbB-2 receptors and their role in potential anti-tumor strategy.

Collaboration with: B. Schechter, Y. Yarden

• Synergistic effects of combinations of mAb against distinct epitopes on EGFR/ErbB-1 and ErbB-2 receptors: accelerated receptor aggregation, down regulation and inhibition of tumor growth.

Collaboration with: B. Schechter, Y. Yarden

Prof. Idit Shachar

• Analyze the pathway regulating the survival cascades in Chronic lymphocytic leukemia

Collaboration with: Dr Michal Haran, Kaplan Medical center

• Follow the mechanisms controlling homing of immune cells in health and disease.
• Determine the mechanisms regulating peripheral B cell maturation and survival in health and disease.

Dr. Liran Shlush

• EPIC project

Collaboration with: John Dick Phillip Awadella

Department of Molecular Cell Biology

Department Head: Prof. Eldad Tzahor

The molecular mechanisms underlying cell structures, dynamics and fate, and their involvement in embryonic development and cancer are among the primary topics of interest of the Department. These include studies on the mode of action of growth factors and the nature of signals triggered by them in target cells following binding to specific surface receptors. Growth regulation is also approached through the study of suppressor genes encoding such proteins as p53, which inhibit proliferation and drive cells towards differentiation or apoptosis. These studies, focusing on the mechanisms stimulate cell proliferation, differentiation, or death, can elucidate the basis for cancerous transformation in a large variety of systems. Overproduction or hyperactivation of growth-promoting systems was shown to have an oncogenic (cancer-causing) effect, and a similar process may be induced when growth-suppressor or apoptosis-inducing genes fail to function. The levels at which cell structure, activity and fate are studied in this department and the focus of these studies are many and diverse, including the characterization of soluble growth factors and their receptors, the nature of complex signal transduction pathways, the action of specific regulators of cytokine action, rearrangement of genes associated with oncogenic processes, and the properties of tumor suppressor and apoptosis promoting genes. Since such processes involve
networks of interacting factors, we are also interested in mathematical modeling and computerized analysis of biological gene circuits.

In addition, there is broad interest in the molecular mechanisms of cell adhesion and their involvement in the regulation of cell fate. These studies include characterization of the basic rules underlying adhesive interactions, the binding of surface-associated adhesion molecules with the cytoskeleton, and the nature of growth- and differentiation-promoting signals triggered by adhesive interactions. Of special interest are proteins such as β-catenin, which play a crucial role in reinforcing cell-cell adhesions as well as triggering gene expression.

**Research activities**

**Prof. Uri Alon**

- Combining theoretical and experimental methods to discover design principles of biological circuits
- Systems level analysis of gene regulation networks, with E. coli as a model system.
- Systems Immunology
  **Collaboration with:** Nir Friedman
- Evolution

**Prof. Abraham Amsterdam**

- Plasticity of gene expression during differentiation in the gonads.
- Crosstalk among signals that control apoptosis.
- Carcinogenesis in endocrine glands.

**Prof. Avri Ben-Ze’ev**

- Epithelial-mesenchymal transition (EMT), cancer stem cells (CSCs) and Wnt target genes in colon cancer metastasis
- The interplay between the role of beta-catenin in cell adhesion and signaling during colon cancer development.
- The molecular basis and signaling roles of nerve cell adhesion receptors in colon cancer metastasis
- The role of novel beta-catenin target genes in tumor development and metastasis

**Prof. Alexander D. Bershadsky**

- Integrin-mediated cell-matrix adhesions as mechanosensors: molecular requirements for the force-induced focal adhesion growth.
- Cell-cell contact-dependent regulation of the actin cytoskeleton and microtubule system: Role of p120 catenin and other components of cadherin adhesion complex.
• Role of myosin-driven contractility in the retrograde surface flow and cell motility.
• Cooperation between neuregulin, ErbB-family receptors, and cell surface heparan sulfate proteoglycans in the regulation of cell motility and morphogenesis.

Prof. Eli Canaani

• Comparison of the properties of the leukemogenic ALL-1 fusion proteins with those of normal ALL-1.
• Transcription profiles of primary tumors with ALL-1 rearrangements.
• Functions of the human ASH1 protein.
• Studies of the ALR gene.

Prof. Benjamin Geiger

• Molecular diversity of adhesion complexes
• The roles of mechanical force in adhesion development
• Role of phosphorylation in regulating cell adhesion and migration
• Signaling from the ECM
• Cell adhesion and migration in cancer
• Quantitative automated microscopy and high throughput screens

Dr. Shalev Itzkovitz

• Design Principles of mammalian tissues
• Spatially resolved single cell genomics
• mRNA localization in tissues

Professor Emeritus Zvi Kam

• Cellular Biophysics
  **Collaboration with:** Benjamin Geiger, John Sedat, David Agard (UCSF)
  • Quantitative analysis of structural features and dynamic changes in cells using microscope imaging
  • High throughput high-definition microscopy application in systems cell biology
  • Adaptive optics methods applied to thick sample imaging
  • Cell level informatics

Dr. Valery Krizhanovsky

• The role of cellular senescence in human disease
• Mechanisms of interaction of senescent cells with their microenvironment
• Cellular senescence in cancer development and treatment

Prof. Sima Lev
• Breast cancer progression and metastasis.
  • Signal transduction therapy for triple negative breast cancer (TNBC).
  • PYK2 and FAK as potential therapeutic targets for breast cancer metastasis.
  • Chemotherapy resistance and recurrence of breast cancer.

Prof. Gil Levkowitz

• hypothalamus
• Developmental neurobiology
• Molecular neurophysiology
• Genetics
• Neuroendocrinology

Prof. Moshe Oren

• Role of p53 in tumor-host interactions.
  Collaboration with: Prof. Michal Lotem, Hadassah Medical Center
  Prof. Yinon Ben-Neriah, Hebrew University Medical School
• Gain of function of mutant p53 in cancer.
  Collaboration with: Prof. Varda Rotter, Weizmann Institute; Prof. Vassilis Gorgoulis, Athens University Medical School
• Molecular biology of p53.
• Regulation of the Hippo pathway and its deregulation in cancer
• Crosstalk between the p53 and Hippo pathways

Prof. Varda Rotter

• Molecular mechanisms controlling the expression of p53 in normal cells and its deregulation in cancer cells
  • Involvement of p53 in cell differentiation and apoptosis: in vivo and in vitro models.
  • Cellular proteins that specifically complex with the p53 protein.
  • Cellular proteins that are induced upstream or downstream to the p53 protein following genotoxic stress.

Prof. Yardena Samuels

• Synthetic lethal interaction network of melanoma
• Identification of melanoma hub interactomes
• CRISPR screens to reveal driver gene interactions and drug resistance genes
• Decipher the immuno-genetic interactions between melanoma and T cells
• HLA peptidome analysis of metastatic melanoma lesions

Prof. Oren Schuldiner
• A genetic dissection of developmental axon regeneration
• Molecular mechanisms of neuronal remodeling during development: Developmental axon pruning in Drosophila
  • The role of cell-cell interaction in regulating developmental axon pruning
  • The role of intracellular signaling in regulating developmental axon pruning
  • The role of trafficking in regulating developmental axon pruning
  • Glia and their effect on neuronal growth and remodeling

Dr. Yonatan Stelzer

• DNA methylation dynamics during cell fate decisions
• Epigenetic reprogramming during gametogenesis
• Mammalian parental imprinting as an epigenetic paradigm
• Environmental effects on the epigenome
• Epigenetic perturbations in disease and cancer

Dr. Ravid Straussman

• Tumor microenvironment-mediated chemoresistance
• Tumor microbiome
• Ex-vivo Cultures of Tumor Tissues for Rapid Tailoring of Anti-Cancer Therapy
• Phenotypic and Mechanistic Characterization of Drug Tolerant Persister Cancer Cells
• Signalome: A Novel Approach for the Analysis of Signaling Pathway Activity in Cancer

Dr. Itay Tirosh

• Intra-tumor heterogeneity: combining computational and experimental approaches to understand the diversity of cells within tumors, their functions, interactions and clinical significance.
  Collaboration with: Mario Suva, Massachusetts General Hospital. Sid Puram, Washington University.
  • Single cell analysis of clinical tumor samples, with a focus on glioma
  • Computational modeling of the tumor ecosystem
  • Testing the function of tumor subpopulations in cell and animal models

Prof. Eldad Tzahor

• Head muscle patterning and differentiation
  • Characterization of head muscle derived satellite cells
  • Dissecting the myogenic programs in head muscle progenitors
  • Involvement of p53 in cranial myogenesis
• Cardiac and skeletal muscle progenitors during vertebrate embryogenesis
• Studying the crosstalk between BMP and FGF signaling pathways in cardiac progenitors
• Regulation of Islet1 gene expression using novel imaging techniques in live embryos
• The origin of the heart endocardium: Focus on the role of endothelial cells in cardiogenesis

Prof. Yehiel Zick

• Mode of action of galectin-8, a mammalian lectin
• The molecular basis of Insulin Resistance: a Phosphorylation based Uncoupling of Insulin Signalling
• The insulin receptor as a model system for transmembrane signaling: Mode of interaction of the insulin receptor with its downstream effector molecules.
• Mammalian lectins as regulators of cell adhesion, cell growth, and apoptosis.
• Receptor trafficking: Regulation of endocytosis and recycling of the insulin receptor.
• Role of Galectin-8 in bone remodeling

Department of Neurobiology

Department Head: Prof. Alon Chen

Research in Neuroscience in the Department of Neurobiology encompasses a wide variety of subjects, in areas including cellular and molecular biology, neuroanatomy, functional magnetic resonance imaging (fMRI), physiology, pharmacology, psychophysics, and computational sciences.

Basically, the research of the various groups of the Department covers, among others, the following topics: Analysis of the molecular and cellular basis of neuronal and synaptic function. Imaging of neuronal activity underlying higher brain functions. Tracing and characterization of neuronal communication profiles. Characterization of the CNS response to trauma and lesion; developing molecular and cellular therapeutic agents. Determination of the underlying processes and mechanisms of vision, perception, learning, and memory in behaving rodents and primates. Computer modeling of brain function.

At the Neurobiology Department, the structure, function, development, and plasticity of the nervous system are studied at various levels of analysis, using different types of cell and experimental animal models. The groups studying neuronal function at the molecular and cellular levels use in vitro systems ranging from non-neuronal and neuronal cell lines to primary neuronal and glial cells of cerebellar, hippocampal and cortical origin. In many cases, the cells studied are transfected with genes of interest. These cell systems allow
The study of the roles of various components of the nervous system, including cell surface membrane components, specific enzymes, neurotransmitters, neuromodulators, growth factors, neuroreceptors, lipid components, ionic channels and cytoskeletal constituents. Algorithms for the synaptic plasticity between neurons, and the role of dendritic ion channels in synaptic input and information processing, are also being studied. Injury models of nerve lesion and oxidative stress paradigms are applied to examine the principles of CNS regeneration, rescue from ischemia and stroke, and apoptotic cell death and senescence.

The groups studying the CNS at the system level are striving to understand the complex neuronal mechanisms underlying learning, memory, and sensory processing (vision, taste, smell), and to determine the relationship between brain and mind. Using track tracing methods, the rules governing the interconnections in the visual cortex are being unraveled. Behavioral studies focus on principles of learning and consolidation, cortical information processing, learning disabilities, and addiction. Functional brain imaging of the human visual cortex is being studied by various techniques, including fMRI. Psychophysical approaches are being used to define processes involved in image segmentation, learning and memory skill acquisition, motor control, and language. Nearly 20 groups of researchers carry out both independent studies and collaborative research with colleagues from within the Department and outside it.

**Research activities**

**Prof. Ehud Ahissar**

- Active sensing: Mechanisms of closed loop perception.
- Biomimetic technology for active vibrissal touch
- Object localization
- Sensory substitution - from vision to touch

**Prof. Shabtai Barash**

- Neuroscience of looking and seeing

**Prof. Yadin Dudai**

- The role of saliency-and novelty-detectors in the acquisition and retention of memory in brain.
- Mechanisms of memory consolidation, reconsolidation and extinction in the mammalian brain.
- Theories of learning and memory.

**Prof. Amiram Grinvald**

- The Interactions between evoked and on-going activity and their potential functional
role in cortical processing.

**Collaboration with:** D. Omer, M. Tsodyks

- The space-time dynamics of cortical activity as revealed by population activity (EEG, LFP and real-time optical imaging) coupled with single-unit and intracellular recordings.
  **Collaboration with:** D. Omer, L. Rom M. Tsodyks

- Cortical correlates of attention in behaving monkeys.
  **Collaboration with:** D. Omer, L. Rom

- The functional architecture underlying visual perception.
  **Collaboration with:** D. Omer, L. Rom,

- The dynamics of cortical representations in the visual cortex.
  **Collaboration with:** S. Naaman

**Prof. Tali Kimchi**

- Neuronal Basis of Sexually Dimorphic Behaviors
  - Sexually dimorphic pheromone signals - perception, processing and biology function
  - Characterizing novel pheromone-mediated responses in wild-caught mouse colonies
  - Identifying the genetic basis of sex-typical social and reproductive behaviors
  - Mapping brain circuits controlling innate social and reproductive behaviors

**Prof. Yitzhak Koch**

- Regulation of GnRH expression in the mammary gland.
- Development of cytotoxic analogs of gonadotropin-releasing hormone (GnRH).
- Expression and functions of GnRH-II in the brain and in T lymphocytes.

**Prof. Ilan Lampl**

- Synaptic plasticity induced by sensory stimulation in the cortex
- Construction of receptive field properties in the somatosensory cortex
  - studying functional connectivity in the barrel cortex
  - Mechanisms of adaptation in the cortex
- Noise and synchrony in the mammalian cortex
  - Dynamic properties and mechanisms of ongoing activity in the cortex
  - Patterns in neuronal activity in the cortex

**Dr. Yoav Livneh**

- Interoception - perception of internal bodily signals
- Cortical computations for modulation of bodily physiology
- Continuous updating in the brain-body loop
Prof. Rony Paz

- Psychiatric disorders from pathologies in the amygdala-prefrontal pathway (e.g. autism, anxiety-disorders, post-traumatic-stress-disorder (PTSD), epilepsy)
- Computational approaches to coding mechanisms in the brain
- Motivational and emotional modulation of memory
- Extinction of memory
- Generalization and specificity of learning
- Neurobiology of learning and memory
- Neuronal circuits and interactions between the amygdala and the prefrontal cortex

Dr. Michal Ramot

- Integration across large-scale networks and the link to behavior in humans
- Decomposing complex tasks
- Testing causality through neurofeedback
- Developing new behavioral tools
- Probing the limits of plasticity through implicit training

Dr. Michal Rivlin

- Mechanisms underlying the computation of motion direction in the retina.
- Dynamic computations in retinal circuits.
- How do retinal targets integrate and interpret the visual signal?
- Role of dopamine in retinal processing.

Prof. Dov Sagi

- Human vision, with an emphasis on processes involved in image segmentation, learning, and memory.

Dr. Rita Schmidt

- Developing new tools for human MRI, especially at ultra-high field 7T MRI scanner, aiming to better understand the human brain function
  - Developing new methods to improve the spatial and temporal resolution in functional brain MRI
  - Developing new contrast methods for functional MRI to study brain function
  - Advancing dedicated MR pulse sequences to achieve fast and ultrafast high quality MR imaging and spectroscopic imaging
  - Boosting the accessible MR signal in localized functional brain trials

Prof. Elad Schneidman
• Biological networks
• Decision making and learning
• Animal swarming and collective behavior
• Computational Neuroscience
  • Neural Coding
  • Information and noise in neural populations
  • Decoding neural activity
  • Network organization and design
  • Natural Scenes

Prof. Michal Schwartz

• The cross-talk between the immune and nervous systems – autoimmunity as a mechanism of tissue repair: Molecular, cellular, physiological and behavioral aspects.
• Immunological aspects of neuronal loss in neurodegenerative and mental disorders (AlzheimerÂ’s, ALS, Huntingdon, Glaucoma).
• Spinal cord injury and repair
• Development of vaccination for neurodegenerative disorders.
• Neurogenesis (stem cells) and inflammation in the CNS.

Prof. Menahem Segal

• Intracellular calcium and structural/functional plasticity in cultured neurons.
  Collaboration with: Dr. Eduard Korkotian
• Human Embryonic Stem Cells of Fragile X patients
  Collaboration with: Prof. Dalit Ben Yosef (TAU)
• Network activity in cultured neurons
  Collaboration with: Professor Elisha Moses (Physics)

Prof. Israel Silman

• Localization and anchorage to the plasma membrane of acetylcholinestera.
• Regulation of folding and assembly of acetylcholinesterase.
• Three-dimensional structure of acetylcholinesterase and acetylcholinesterase-anticholinesterase complexes.

Prof. Michail Tsodyks

• Information transmission through dynamic synapses.
  Collaboration with: H. Markram
• Modeling of cortical neuronal populations: From microcircuits to large scale networks.
• Population activity in visual cortex.
  Collaboration with: A. Grinvald, D. Sagi
Prof. Nachum Ulanovsky

- Neural basis of natural behaviors
- Wireless electrophysiology in freely flying bats
- Place cells, grid cells, head-direction cells, goal-direction cells
- Neural codes for 1-D, 2-D and 3-D space in flying bats
- Neural coding of very large spaces (~1 kilometer), and of complex environments (large mazes)
- Neurobiology of learning and memory: a systems neuroscience approach
- Social-spatial cognition: Representation of other individuals in the brain, during social interactions

Prof. Zvi Vogel

- Molecular mechanisms of opiate addiction, tolerance and withdrawal.
- The cannabinoid ligands, their endogenous ligands and signal transduction. **Collaboration with:** Raphael Mechoulam
- Regulation of microglial activation by cannabinoids: Possible role in neurodegenerative and neuroinflammatory diseases

Prof. Ephraim Yavin

- Signal transduction and protein kinase C isozymes in brain of normal and growth-retarded fetuses.
- Free radicals and lipid modulators in the developing and aging brain.
- Novel genes during oxidative stress in utero and role of docosahexaenoic acid.

Dr. Ofer Yizhar

- Mapping the synaptic organization of prefrontal cortex circuits
- Development of novel optogenetic methods for light-based control of neural activity
- Functional dissection of the brain circuits underlying social motivation
The scientific activities in the department of Biomolecular Sciences span several areas in the Life Sciences. The common thread is the study of the biochemistry of life and disease. Emphasis is given to the examination of proteins, whether soluble or membrane-bound, and their key biological functions and we seek a molecular understanding of their evolution, cellular interactions, structures and functions. A variety of biochemical, biophysical, structural, molecular-biological, and state of the art imaging methodologies are employed in our department. Overlapping interests and inter-group cooperations signify the spirit of our research. The department has more than 20 research groups whose activities are centered around the following foci of interest:

Protein science and macromolecular machines. Several groups investigate the basic principles governing protein-protein interactions; composition, assembly, and architecture of multi-enzyme and other large complexes; catalytic mechanisms and the evolution of proteins and enzymes. A major aim is to understand how the findings relate to intricate biological processes.

DNA and regulation of gene expression. Various aspects of nucleic acids research are addressed in our department including: DNA repair and mutagenesis in mammals; basal and activated transcription; mRNA translation; specific gene expression in the pancreas; phylogenetic analysis of accumulated somatic mutations.

Structure, function, and biogenesis of membrane proteins. We investigate important integral membrane proteins on the biochemical, biophysical, structural, and physiological levels. This includes Na+ and K+ channels, Na+/K+ ATPase and its FXYD protein regulators, multidrug transporters, intra-membrane proteases, and peptides that integrate into membranes in various systems.

Membranes, lipids, and organelle structure, function, and biogenesis. Studies in our department include the biosynthetic pathway of membrane proteins; intracellular protein traffic, especially during the process of autophagy; lysosome biogenesis and lipid homeostasis; Calcium homeostasis; and, assembly and function of membrane proteins involved in the immune response, infectious diseases, and viral envelopes.

Signaling within and between cells. Several researchers in the department are interested in problems related to signal transduction. Cell guidance and navigation; axon guidance; cell death and tissue damage; long distance intracellular signaling; regulation of expression of virulence factors; regulation of the circadian rhythm; epigenetic gene silencing; epigenetics and developmental regulation.

Molecular basis of disease. Many research programs in our department involve human disorders, diseases, and syndromes. This includes inflammation, infections and antibiotic resistance, organophosphate detoxification, obesity and diabetes, cancer, and lysosomal storage diseases. Many of these disorders are investigated at the molecular level.
A variety of methodologies are being utilized, with an emphasis on biochemistry, biophysics, molecular genetics, advanced light microscopy, computation methods, and structural tools (such as crystallography, atomic force microscope, mass spectrometry). Additional information can be obtained in the department's Home Page.

**Research activities**

**Dr. Ori Avinoam**

- The mechanisms of protein mediated membrane sculpting in health and disease
  - Spatial and temporal organization of the molecular machines driving vesicle formation.
  - Endocytosis and membrane trafficking in eukaryotes.
  - Caveolae in muscle biogenesis, homeostasis and atrophy.
  - Cell-to-cell fusion
- Imaging Across Scales
  - Correlative light and 3D electron microscopy at room temperature and in cryo.
  - Advanced light microscopy techniques.

**Prof. Ed Bayer**

- Structural and functional aspects of the multi-enzyme cellulosome complex from cellulose-degrading bacteria.
  - The cohesin-dockerin couple - Protein-protein interactions that mediate recognition and specificity in cellulosome assembly.
  - Cellulose-binding domains as models for protein-sugar interactions.
  - Bioinformatics of cellulases and cellulosome components
  - Comparative genomics of cellulosome components.
  - Structure determination of cellulosome components.
  - Enzymology of cellulosomes for conversion of biomass to biofuels
  - Designer cellulosomes - Selective engineering of chimaeric cellulosome constructs for nanotechnology.
  - Avidin-biotin system - Mutated avidins and streptavidins

**Prof. Eitan Bibi**

- Membrane protein biogenesis in E. coli
  - **Collaboration with:** Gert Bange, Marburg University, Marburg, Germany. Moran Shalev-Benami, Weizmann Institute of Science, Rehovot, Israel
  - FtsY, the essential prokaryotic SRP-receptor: biogenesis and function
  - Membrane targeting and association of ribosomes in E. coli.
- Multidrug transport by the E. coli secondary transporter MdfA
  - **Collaboration with:** Daniella Goldfarb, Weizmann Institute of Science, Rehovot, Israel. Moran Shalev-Benami, Weizmann Institute of Science, Rehovot, Israel
  - Conformational behavior of MdfA
• Structural studies on membrane embedded MdfA

Prof. Rivka Dikstein

• Transcription and translation control in health and disease
  
  Collaboration with: Yuki Yamaguchi, Idit Shachar, Nahum Sonenberg, Yuri Svitkin, Franck Martin, Katsura Asano, Igor Ulitsky, Michael Walker, Neta Regev-Rudsky

  • Mechanism of rapid transcriptional induction of inflammatory genes
  • Links between mammalian transcription and mRNA translation
  • Developing pharmacological tools to address fundamental questions in mRNA translation and for therapeutic purposes
  • Mechanism of start site selection in transcription and translation and its role in cancer and neurodegenerative diseases


Prof. Michael Eisenbach

• Chemotaxis of bacteria
  • Molecular mechanisms and function of acetylation of the response regulator
  • Molecular mechanism of function of the switch of the bacterial flagellar motor

• Sperm guidance in mammals
  • Molecular mechanism of sperm thermotaxis

Prof. Zvulun Elazar

• Molecular mechanisms of autophagy
  • Mechanism of autophagosomes biogenesis
  • Autophagy and neurodegeneration
  • Regulation of autophagy in yeast and mammals

• Mechanism of intracellular protein trafficking
  • Regulation of intra-Golgi protein transport

Prof. Michael Fainzilber

• Molecular mechanisms underlying spatial signaling within neurons and other large cells
  • Retrograde signaling mechanisms in healthy, diseased or injured neurons.
  • Molecular mechanisms of axonal communication and neuronal regeneration.
  • Size sensing mechanisms in neurons and other large cells.

Dr. Sarel-Jacob Fleishman

• Computational design of protein function
Collaboration with: Dan Tawfik Deborah Fass Gilad Haran Eitan Bibi
• Computational enzyme design
• Computational antibody design
• Design of optimised proteins, including stability, affinity, catalytic efficiency, and selectivity
• Design of smart libraries
• Membrane protein design

Prof. Anthony H. Futerman

• The regulation of ceramide synthesis
• The molecular mechanisms of sphingolipid storage diseases (Gaucher disease).

Prof. Steven J.d Karlish

• Development of isoform-selective drugs
• Molecular mechanisms involved in generation of essential hypertension.
• Regulation of Na/K-ATPase by FXYD proteins.
• Crystalization and function of Na/K-ATPase.

Prof. David Mirelman

• Molecular pathogenesis of the human intestinal parasite *Entamoeba histolytica*.
  Collaboration with: Rivka Bracha
  • Molecular biology and genome organization in the lower eukaryot *Entamoeba histolytica*.
  • Selective inhibition of expression of virulence genes by Antisense RNA.
  • Transcriptional epigenetic gene silencing mechanisms
  • Pathogenesis of Amoebiasis
  • Development of vaccine against *Entamoeba histolytica*.
• Mode of action and therapeutical potential of Allicin from Garlic
  Collaboration with: Aharon Rabinkov, Elena Appel
  • Uses of derivatives of Allicin against hypertension and obesity
  • Antifungal delivery system which produces in situ toxic allicin molecules
  • A delivery system for the in-vivo killing of cancer cells by Allicin

Dr. Ruth Scherz-Shouval

• Tumor microenvironment
  • Transcriptional profiling of stromal cells within tumors,
    Characterization of stromal stress responses

Prof. Yechiel Shai
• Membrane-protein interaction and molecular recognition within the membrane milieu. Implication to the function and structure of membrane proteins.
• Assembly and organization of pore forming toxins and ion channels in membranes: Studies with isolated fragments and intact proteins.
• Molecular mechanism of membrane fusion and its inhibition: Studies with HIV and Sendai Virus.
• Molecular basis for cell selectivity by cytolytic antimicrobial peptides.

Prof. Michal Sharon

• Studying large protein complexes involved in the protein degradation pathway using a novel mass spectrometry approach.
  • Developing novel methodological approaches for structural mass spectrometry
  • Structure-function relationship of the signalosome complex
  • Investigation of the 20S ubiquitin-independent degradation pathway

Prof. Yoram Shechter

• Mechanism of insulin action: Post-binding events in insulin action
  • Post-receptor agents mimicking insulin.
  • Effect of vanadium in vivo and in vitro.
  • Role of protein tyrosine kinases and protein phosphotyrosine phosphatases in insulin effects.
  • Inhibitors of tyrosine kinases.
  • Chemical modifications of peptides and protein drugs.
  • Novel technologies to prolong life time of peptide and protein drugs.

Prof. Dan Tawfik

• Evolution and mechanism of enzymes
  • Molecular evolution in man-made cell-like compartments.
  • Directed evolution of tailor-made hydrolases (esterases, phosphoesterases, organophosphate hydrolases, and amidases) and DNA-modifying enzymes.
  • Structure, mechanism and evolution of serum paraoxonases (PONs)
  • The role of promiscuity and conformational plasticity in protein evolution.
  • Directed evolution of DNA-methyltransferases and DNase inhibitors
  • The stability effects of mutations
  • Protein evolvability
  • Chaperones and protein evolution

Prof. Michael Walker

• Selective gene expression in pancreatic beta cells:
  • Role of specific transcription factors in expression of the insulin gene in pancreatic beta cells and in control of pancreatic development.
• Novel beta cell specific genes: isolation, characterization and use as potential tools in diagnosis and therapy of diabetes.

Prof. David Wallach

• Regulation of cell death and tissue damage:
  • Proteins involved in the signaling for the cell-killing (apoptotic and necrotic), immunoregulatory, and inflammatory functions of cytokines of the tumor necrosis factor (TNF) family, and in the regulation of these functions.
  • In vivo models for the functions of the signaling mechanisms activated by ligands of the TNF family and for their pathological aberrations.
  • Natural antagonists to ligands of the TNF family, for protection against the deleterious effects of these cytokines in autoimmune and infectious diseases.
  • Regulation of the activity of the NF kappa B transcription factors.
  • The caspases, their functions and mechanisms of activation.
  • Molecular mechanisms for chronic inflammatory skin diseases.
  • Contributions of aberrations in the function of signaling proteins activated by ligands of the TNF family to cancer
  • cancer-cells' survival factors

Prof. Meir Wilchek

• Study and application of molecular bioreognition
  Collaboration with: retired, Dr. Talia Miron.
  • Avidin-biotin system: Studies of the strong binding using chemical, physical and biological methods; new applications of the system.
  • Affinity chromatography: Studies to improve purification of protein by developing new carriers, new activation methods and new principles.
  • Affinity therapy: Development of methods to couple drugs and toxins to biological carriers, such as antibodies, and their delivery to target cells.
  • Fluorescence, FRET.

Prof. Avraham Yaron

• Signaling mechanisms of axonal guidance cues
• Mechanisms of axonal degeneration

Department of Molecular Genetics

Department Head: Prof. Yitzhak Pilpel

The molecular basis of genetics and related biological processes are under investigation in our Department. The investigators approach these processes from the most reduced and reconstructed systems up to more systemic and computational analysis. Different organisms are employed including virus, yeast, Drosophila, mouse and human. These
animal models and cell culture systems are used to study the mechanisms of:
a. Basic processes in gene expression, such as transcription, translation and protein degradation.
b. Cellular responses to various stimuli, such as cytokines, growth factors and exposure to DNA-damage.
c. Regulation of cell growth, senescence, differentiation and death.
d. Development; Mechanistic view of zygote to embryo transition and development of various organs, such as brain, muscles, bones and pancreas.
e. Genetic and acquired diseases such as cancer and virus infection. Embryonic stem cell biology, early development and advance human disease modeling.
f. Study of pluripotent stem cell biology and epigenetic reprogramming.
g. Computational and system biology. The function/evolution of genes and their diversification.

Research activities

Dr. Yaron Antebi

• Developing a systems-level framework to characterize signal integration at the single cell level.
• Defining the role of perception and integration of complex stimuli in determining cellular fate.
• Analyzing multi-ligand information processing in the BMP/TGFβ pathway and its effect on mesenchymal stem cell differentiation.
• Studying signal processing capabilities of additional pathways (e.g. JAK/STAT, Wnt, FGF)

Prof. Eli Arama

• Caspases without death and death without caspases in Drosophila development
• Paternal mitochondrial formation and elimination after fertilization in Drosophila

Prof. Ari Elson

• Protein Tyrosine Phosphatases and Cell Signaling
  • Role of tyrosine phosphatases in regulating production and function of bone-resorbing osteoclasts
  • Osteoclast-related diseases: osteoporosis, osteopetrosis, cancer-related bone loss
  • Roles of tyrosine phosphatases in regulating body mass.
  • Roles of tyrosine phosphatases in diabetes and blood glucose homeostasis

Prof. Jeffrey Gerst

• Intracellular and Intercellular mRNA trafficking
• Intracellular mRNA trafficking in yeast and its role in organelle biogenesis and cell physiology
• Intercellular trafficking of mRNAs in mammalian cells and its role in cell physiology
• Genome-wide mapping of mRNA localization in yeast
• Specialized ribosomes in the control of protein translation
• Identification of genes involved in chemotropism and chemotaxis

Prof. Yoram Groner

• Runx transcription factor 1 and 3 in development and disease


Absence of Runx3 expression in normal gastrointestinal epithelium calls into question its tumour suppressor function.


- Dynamic combinatorial interactions of RUNX1 and cooperating partners during megakaryocytic differentiation

**Collaboration with:** Amos Tanay Department of Computer Science & Applied Mathematics

- Biological function of the RUNX transcription factors
- Positive and negative transcriptional regulation by Runx3
- The Human Leukemia Associated Transcription Factor RUNX1/AML1 and Down
Deciphering Cellular Reprogramming

Following a breakthrough that was made in 2006 (by Takahashi & Yamanaka), today we can reverse cellular differentiation, and generate induced pluripotent stem cells from somatic cells by epigenetic reprogramming. We investigate what are the dramatic molecular changes happening in the cell during reprogramming and how they are connected to similar in-vivo processes. We pointed out two chromatin regulators that play a role in this process, one is essential for reprogramming (Utx, Mansour et al 2012), and the other (Mbd3/NuRD, Rais et al 2013) is an obstacle, which upon its near-removal the reprogramming becomes dramatically faster and synchronized.

Understanding Naïve and Primed Pluripotent States

Being able to generate all cell types, mouse embryonic stem cells are a most valuable tool for research. They can be found in the developing mouse embryo in two distinct states: naïve in the blastocyst, and primed in the post-implantation epiblast. These two states are distinct in various aspects, most notable, only naïve cells can contribute efficiently to chimera. Naïve and primed cells can be sustained in-vitro, and are dependent on distinct signaling. In human, naïve stem cells were out of reach for a long time. We investigate the regulation of naïve and primed pluripotent stem cell in mouse and human. Specifically, we were able to maintain human stem cells in a naïve state, with distinct molecular and functional properties, including enhanced ability to contribute to cross-species mouse chimeric embryos (Gafni et al, 2013). In addition, we found that mRNA methylation has a critical role in facilitating degradation of pluripotent genes, an essential step during the switch from naïve to primed states, both in-vitro and in-vivo (Geula et al, 2014). Our current studies involve elucidating molecular regulation of these states across different species, and define how their molecular architecture dictates their functional competence.

Human-Mouse Cross-Species Chimerism

Human stem cells that are sustained in naïve culture conditions, can be injected to mouse blastocyst and contribute to cross-species chimera (Gafni et al, 2013). We investigate these chimeric mice, which are valuable tool for human disease modeling in a whole-organism context.

Prof. Eran Hornstein

- miRNA role in human disease
  - miRNA role in motor neurons and amyotrophic lateral sclerosis
  - miRNA role in pancreas and diabetes
  - miRNA stem cells

Prof. Adi Kimchi
• Programmed Cell Death: from single genes and molecular pathways towards systems level studies
  • Deciphering the roles of the DAP genes in programmed cell death
  • Systems biology analysis of the programmed cell death network
  • Functional annotations of a family of death-associated kinases: DAPk, DRP-1 and ZIPk
  • Protein translation control during cell death: structure/function analysis of the DAP5 gene

Prof. Doron Lancet

• Bioinformatic tools for disease gene discovery, Origin of life on earth
  Collaboration with: Prof. Rafi Zidovetzki, University of California Riverside
  Prof. Philippe Schmitt-Kopplin, Helmholtz Center Munich
  Prof. Daniel Segre, Boston University
  • Gene and disease databases, Identification of disease-related mutations by next generation DNA sequencing (NGS), development of software tool for the analysis of NGS results
  • Computer simulations of emergence, selection and evolution at the origin of life. Chemical kinetic models for mutually catalytic sets, Systems Chemistry

Prof. Shmuel Pietrokovski

• Developing computational methods for using and identifying protein motifs and applying them for the analysis of particular protein families.
  • Developing advanced methods for comparing protein motifs.
  • Applying protein motif comparisons for functional and structural predictions and to database annotation.
  • Analysis of inteins (“protein splicing” elements) and homing endonucleases.
• Genetic variations in humans and different gene usage in women and men
  • Gene variations causing human disease, in particular infertility in men and various cancers.
  • Different gene usage in women and men leading to differential selection between the sexes and allowing the accumulation of deleterious mutations.

Prof. Yitzhak Pilpel

• Systems biology of genetics regulatory networks

Prof. Orly Reiner

• Formation of the brain structure in human is a complex process. One of the most striking features of the human brain is characteristic convolutions. These convolutions are lacking in a severe human brain malformation known as lissencephaly (smooth brain).
• Identification of genes that are downstream to Lis1 mutation using microarray technology.
• Study of LIS1 and DCX functions through characterization of protein interactions
• Analysis of the developmental function of LIS1, DCX and Doublecortin-like-kinase using gene targeting in the mouse.
• Functional Analysis of Genes Involved in Lissencephaly.

Prof. Michel Revel

• Applications of IL-6 Chimera and Interferon-beta in neurology, hematopoiesis, and oncology.
  Collaboration with: J. Chebath
• Interleukin-6 Chimera, a superactivator of the gp130 receptor system: role in nerve myelination, neuroprotection and in the development of neuro-glial cells from embryonic tissues and stem cells.
  Collaboration with: J. Chebath
• Transdifferentiation of neural crest cell derived melanoma into myelinating Schwann cell. Genes controlling cell growth, differentiation, melanogenesis and synthesis of myelin proteins.
  Collaboration with: J. Chebath

Prof. Menachem Rubinstein

• In vivo gene therapy and targeted viral oncolysis
  Collaboration with: Gideon Schreiber Zvi Lapidot
  • cancer research
    Hematopoietic stem cells

Prof. Maya Schuldiner

• Uncovering tethers, functions and regulators of membrane contact sites in yeast
  • Mitochondria-ER contact sites
  • Peroxisome-Lipid Droplet contact sites
  • Nucleus-Mitochondria contact sites
  • The proteome of contact sites
  • Golgi contact sites
• Targeting and translocation to Organelles
  • Uncovering a role for the Ssh1, the alternative, translocon in yeast
  • Deciphering targeting of proteins to mitochondria
  • Targeting of membrane proteins to peroxisomes
  • Targeting of low-hydrophobicity SS proteins to the ER
• Uncovering new peroxisomal proteins and their functions
  **Collaboration with:** Dr. Einat Zalckvar
  • Metabolite transport across the peroxisome membrane

• Peroxisome contact sites
• Peroxisome quality control
• Peroxisome targeting
• New peroxisomal enzymes and their functions
• Novel methodologies for systematic exploration of yeast organelle protein functions
  • Creation of versatile yeast libraries

• High throughput electron microscopy techniques
• Translocation sensors

**Prof. Yosef Shaul**

• The molecular basis of virus-host cell interaction. How HBV modifies cell behavior.
  **Collaboration with:** Charles Rice  the Rockefeller university
• Proteasomes as a target in cancer therapy
• Proteasome composition, dynamics, function and regulation and various conditions.
• Proteasomal degradation of intrinsically disordered proteins (IUP or IDP). The concept of degradation by default

**Prof. Rotem Sorek**

• Microbial genomics and systems biology
• CRISPR-Cas, an antiviral microbial defense system
• Interactions between bacteria and phages
• Communication between viruses
• RNA-mediated regulation in bacteria
• Computational discovery of novel natural antimicrobials

**Dr. Noam Stern-Ginossar**

**Prof. Talila Volk**

**Prof. Ernest Winocour**

• virology, viral vectors for gene therapy, viruses associated with cancer

**Prof. Elazar Zelzer**
• the roles of the VEGF pathway in different steps during skeletal development.
• Studying the role of mechanical load on embryonic bone development

Department of Plant and Environmental Sciences

Department Head: Prof. Yuval Eshed

Plants offer the world its only renewable resource of foods, alternative energy and biotherapeutic compounds. Plants have highly sophisticated short and long-term adaptive mechanisms to the environment as a result of the simple fact that they cannot alter their location during environmental change. Basic understanding of how plants react to the environment and why they grow the way they do are central to devising a rational approach to address three important global challenges, namely to secure more and healthier food, to develop novel plant-based products associated with biotherapeutics and to produce alternative energy resources in the form of biofuels. Research activities in the Department of Plant Sciences are associated with all of the above-mentioned global challenges and range from studies on the function and regulation of isolated genes to their interactive behavior in the context of the whole plant. We have developed extensive in-house genomic, bioinformatics and transgenic infrastructure that enables us to isolate novel genes by gene trapping, knockout or map-based cloning. Cloned genes are manipulated and studied by transgenic analysis to establish their potential in the whole plant. Our research as listed below integrates methodologies of molecular biology, protein modeling, genomics, metabolomics, bioinformatics, system biology, genetics, biochemistry and physiology.

Harnessing light energy and energy transduction in the plant cell: Research is carried out on the basic biophysical phenomenon of photon absorption by chlorophyll through transduction of this energy to ATP and the regulation of energy flux by the plant redox state.

Adaptive response in the plant to the biotic and abiotic environment: Molecular mechanisms that drive the cellular response are investigated under environmental perturbation. Research is directed in understanding the elements that play a role in the recognition of pathogens and the subsequent mounting of plant defense responses as well as in the response of plants to abiotic stresses, such as salt stress.

Plant metabolism and growth: Research is centered around elucidating regulatory metabolic networks for production of essential primary and secondary metabolites as well as understanding gene expression and hormonal networks that control plant metabolism, growth, reproduction and productivity.

Plant genome organization: Molecular tools have been developed to examine the fluidity of the plant genome, as described by transposon element, and the evolution of polyploid plants.

Research activities

Prof. Asaph Aharoni
• Genetic Regulation of Metabolic Pathways and its Co-ordination with Developmental and Stress Response Programs in Plant Biology
  • The Primary-Secondary Metabolism Interface
  • Regulation of Plant Surface Formation
  • Regulation of Secondary Metabolism Associated Metabolic Pathways
  • Plant and Yeast Metabolomics
  • Riboswitches in Plants: Post Transcriptional Regulators of Metabolic Pathways

**Prof. Avihai Danon**

• RNA-binding proteins controlling light-regulated translation.
• Mode of action of redox-signal transduction factors.

**Prof. Marvin Edelman**

• Duckweed biotechnology
  **Collaboration with:** Barak Cohen, Ron Vunsh
  • Volumetric growth of Wolffia
  • Polyploidization of duckweeds for biomass increase and metabolic vigor
  • Mutagenesis from photoautotrophy to photoheterotrophy
  • Transgenic duckweed for veterinary products
  • Genomic analysis of calcium dependent protein kinases in duckweeds

**Prof. Robert Fluhr**

• Plant Response to Environmental Stress
  • Reactive oxygen species in plant stress response
  • Cellular REDOX state
  • Gene expression networks in abiotic and biotic stress
  • Proteases and their inhibitors in the regulation of programmed cell death

**Dr. Assaf Gal**

• Intracellular mineralization by phytoplankton
  • Silica formation in diatoms, from intracellular condensation of silica to morphogenesis of the cell-wall structure.
  • Mechanisms of calcite precipitation by coccolithophores. The role of intermediate mineral pools inside the cell and the interactions between biomacromolecules with the inorganic phase.

**Prof. Gad Galili**

• Association of metabolism and cell biology with plant development and response to
Collaboration with: Zevulun Elazar, Aviah Zilberstein, Rachel Amir, Yoram Kapulnik, Alisaider Fernie

- Gene expression programs and metabolic networks associated with seed maturation and germination
- Metabolic engineering of high-lysine plants
- Genetic, genomic and bioinformatics approaches to elucidate metabolic networks in plants
- Regulatory interactions between primary and secondary metabolism of plants
- Cell biology and physiology of autophagy-associated processes in plants

Prof. Jonathan Gressel

- Developing slow release herbicide formulations

Collaboration with: Michael Burnet

- Designing tandem constructs to mitigate gene flow from transgenic crops to weeds

Dr. Tamir Klein

- Tree carbon metabolism
  - Tree-Tree root carbon transfer
  - Whole-tree carbon balance
  - Tree-mycorrhiza interaction
  - Starch metabolism in woody tissues
- Tree water transport
  - Tree drought resistance
  - Xylem recovery from embolism
  - The role of aquaporins in woody tissues

Prof. Ron Milo

- Environmental Sustainability Indicators
  Collaboration with: Gidon Eshel - Bard College
- Synthetic carbon fixation pathways
- Cell Biology by the Numbers
  Collaboration with: Rob Phillips - Caltech
- Design principles in energy and carbon fixation

Prof. Avigdor Scherz

- Quantification of atoms, groups and molecules electronegati using metal substituted bacteriochlorophylls and application to chemical reactivity.
- Resolving the forces which drive membrane protein assembly.
- The mechenism behind generation of reactive oxygen species (ROS) by illuminating...
novel bacteriochlorophyll derivatives and their application in photodynamic therapy (PDT) of tumors.

Prof. Assaf Vardi

• The ecological and evolutionary role of programmed cell death in single-celled marine photosynthetic microorganisms
• The role of infochemicals and their regulation of cell fate and cell-cell interactions in marine photosynthetic microorganisms
• Sensing Environmental Stress and Acclimation Strategies in Marine Algae
• Cell Signaling Pathways and their role in the Chemical “Arms Race” during Algal Host-Virus and Predator-Prey interactions
The Chemical and Biological Physics Department provides an interdisciplinary home to a broad range of topics spanning Physics, Chemistry and Biology. The Department is composed of over 20 tenured and tenure-track physicists and chemists, evenly split between theorists and experimentalists, and working on the following broad areas:

- **Fundamental quantum frontiers are explored with advanced theoretical tools**, including topics in the quantum control of atomic and molecular dynamics (Ilya Averbukh, Eli Pollak, David Tannor); light-matter interactions (Ilya Averbukh, Gershon Kurizki, David Tannor, Efi Shahmoon); fundamental issues in quantum information, control and thermodynamics (Gershon Kurizki, David Tannor, Efi Shahmoon); ab-initio quantum chemistry and surface scattering (Eli Pollak); and real time quantum dynamics methods (Eli Pollak, David Tannor).

- The department has a strong program at the interface between classical physics, chemistry and biology. Eran Bouchbinder studies the plasticity of disordered systems, glassy phenomena, dynamic fracture, frictional interfaces and biophysics. Itamar Procaccia studies turbulence, as well as the physics of fractals, glass formation and mechanical properties of amorphous systems. Theoretical biological physics is the main thrust of research of Nir Gov, who models with predictive power emerging phenomena ranging from cellular shapes to the collective behavior of insects. Samuel Safran employs statistical thermodynamics to study the structure, phase behavior and dynamics of soft matter in biology.

- The chemistry/biology interface is also studied and evaluated experimentally by Roy Bar-Ziv, who develops and explores living-like systems in cell-free environments, and by Michael Elbaum, who employs advanced microscopic tools to elucidate the complex behavior of cells and biomolecules.

- **Experimental atomic and molecular spectroscopies are also mainstays of the Department.** Quantum optics is the focus of Barak Dayan’s experiments on atom mediated photon-photon interactions. Light matter interaction, nonlinear laser spectroscopy and plasmonics are the focus of the experimental research of Yehiam Prior. Edvardas Narevicius is a leader in using magnetic field control and the slowing down of molecular beams to study quantum effects in sympathetically cooled systems. Oren Tal has developed unique methods for the study of single molecule conductors, including electronic, spintronic and thermal conductivity effects. Molecular electronics and spin-chemistry are also main themes of research for Ron Naaman, who investigates...
these using organic-inorganic interfaces via self-assembled monolayers. Single molecule spectroscopy and its application to a broad range of topics, from protein dynamics to nanoplasmonics, are at the center of the experimental program of Gilad Haran. Baran Eren exploits new forms of microscopy and spectroscopy, to understand the chemistry and electronic behavior of solid surfaces under relevant conditions with unprecedented accuracy.

A centerpiece of the combined experimental/theoretical program in the Department rests on Magnetic Resonance research. Amit Finkler bridges this topic with optics, in a program relying on optically-detected magnetic resonance as an emerging form of quantum sensing. Lucio Frydman and his group focus on developing and utilizing new concepts and techniques in NMR and MRI, with applications ranging from Physics to Biology and Medicine. Assaf Tal’s group focuses on developing new spectroscopy and imaging tools for understanding the brain’s physiology in-vivo. Shimon Vega and Daniella Goldfarb are developing and utilizing dynamic nuclear polarization methods for NMR and EPR research, with the Vega group also deeply involved in solid state NMR, and the Goldfarb research also focused on multiple-resonance high-field EPR techniques applied to biophysics and materials science.

The diverse interests as represented above have created an atmosphere of outstanding scientific creativity. Members of the Department have overlapping interests and collaborations among themselves, with other scientists throughout the Weizmann Institute, and with scientists throughout the world. New training opportunities for students and postdocs are always emerging, at whose conclusion participating scientists will have been exposed to a broad spectrum of challenges and acquired state-of-the-art knowledge. If you are interested in joining this elite group of researchers as a M.Sc., Ph.D or postdoctoral trainee, do not hesitate to contact the expert(s) of your choice.

Research activities

Prof. Ilya Averbukh

• Manipulation of atoms and molecules by laser fields
• Laser control of molecular alignment and orientation. Control of chiral molecules
• Echo phenomenon
• Atomic and molecular wave packets, ultra-fast optical phenomena.

Prof. Roy Bar-Ziv

• Artificial biochemical circuits
  • Cell-free gene expression on a chip
  • Cell-free expression of protein nano-structures
  • Autonomous interrogation of the state of a living cell
• The physics of microfluidic crystals

Prof. Eran Bouchbinder

• Dynamic fracture
• Physics of sliding friction
• Glass physics
• Plasticity theory and non-equilibrium thermodynamics
• Biophysics and cell mechanics

Prof. Barak Dayan

• Experimental Quantum Optics
  • Cavity QED with single atoms coupled to chip-based micro-resonators
  • Nonclassical photon-photon interactions

Prof. Michael Elbaum

• Cellular Biophysics and Molecular Transport Machines
  • Single-molecule manipulations using optical tweezers.
  • Dynamics of DNA uptake into the cell nucleus.
  • Structure and function of the nuclear pore complex (with Z. Reich): application of atomic force microscopy and advanced optical spectroscopies.
  • Anomalous diffusion in polymer networks and living cells (with R. Granek).
  • Organization of forces driving cell movements (with A. Bershadsky): optical force measurements and particle tracking studies; influence of cell biochemistry on biophysical forces.
  • Novel surface-patterning lithographies.

Dr. Baran Eren

• Following surface reactions with ambient pressure XPS and polarisation modulated IRRAS
• Atomic structure of surfaces in the presence of reactant gases
• Developing new techniques to bridge the 'material gap' and the 'pressure gap' between surface science and industrial processes

Dr. Amit Finkler

• Quantum-assisted sensing, from the single-spin limit to coherent, macroscopic objects
• Nanoscale magnetic resonance imaging of molecules
• Observation of quantum coherence in chemical reactions

Collaboration with: Durga Dasari, University of Stuttgart
• Hybrid platforms: Molecular qubits and NV qubits
  **Collaboration with:** Danna Freedman, Northwestern University
• Hybrid platforms: NV qubits, phonons and superconducting qubits
  **Collaboration with:** Michael Stern, Bar-Ilan University Eyal Buks, Technion

**Prof. Lucio Frydman**

• Development of new methods in nuclear magnetic resonance and magnetic resonance imaging analysis.
• In vitro and in vivo hyperpolarized NMR and MRI
• Application of novel magnetic resonance methods to the study of cancer, fetal development, protein folding and unfolding.

**Prof. Nir Gov**

• Research of collective quantum effects in Super-fluid, solid and super-solid Helium. Including magnetic phase transitions in solid and liquid helium.
• The physics of large scale pattern formation of cells in cellular cultures, in morphogenesis and wound-healing.
• Theoretical problems in biological physics; active processes in cells involving molecular motors.
• Theoretical studies and modelling of the physics that determines the shapes and dynamics of cells.

**Prof. Gilad Haran**

• Functional Dynamics of Proteins
  **Collaboration with:** Amnon Horovitz, Weizmann, Rina Rosenzweig, Weizmann, Douglas Kojetin, Scripps Florida
• Membrane Organization and Dynamics
  **Collaboration with:** Ronen Alon, Weizmann, Frank Brown, UCSB, Andres Alcover, Pasteur Institute
  • Correlated motion in the membrane plan
  • Super-resolution microscopy of the organization of receptors on the membrane of the T cell
• Interaction of surface plasmons with quantum emitters
  **Collaboration with:** Ora Bitton, Weizmann, Lothar Houben, Weizmann, Lev Chuntonov, Technion, Javier Aizpurua, San Sebastian
  • Strong coupling of plasmons and quantum dots

**Prof. Gershon Kurizki**

• Quantum optics of cold atoms.
• Superluminal effects in optics.
• Quantum and nonlinear optics in photonic band gap structures.
• Control of quantum states and decoherence.

Prof. Ron Naaman

• Spin selectivity in electrons transmission through chiral molecules
  Collaboration with: Yossi Paltiel, Hebrew University David H. Waldeck, University of Pittsburghm USA Claudio Fontanessi, Modena University, Italy E. W. Meijer, Eindhoven, Netherland C. Achim, Carnegie Melon, USA
  • electron transfer in bio-molecules
  • spin selective electron transfer
  • spin dependent electrochemistry
  • spintronics with chiral molecules
  • enantio-selective interaction
  • Spin effect in water splitting

Prof. Yehiam Prior

• Strong field nonlinear optics.
• Alignment and orientation of atoms and molecules in strong laser fields.
  Collaboration with: Ilya Averbukh
• Molecular Dynamics with ultrashort shaped femtosecond pulses.
• femtosecond laser material processing

Prof. Itamar Procaccia

• Ageing in disordered materials
  Collaboration with: George Hentschel, Bhanu Bhowmik, Harish Charan
• Mechanical properties and instabilities in amorphus solids
  Collaboration with: Valery Ilyin, George Hentschel, Prasenjit Das,
• Fractal Growth Patterns.
  Collaboration with: Eviatar B. Procaccia
• Denisty of States in amorphous solid
  Collaboration with: Avanish Kumar
• Turbulence in classical and in quantum fluids
  Collaboration with: Victor L’vov, Anna Pomyalov

Prof. Samuel Safran

• Cell Mechanics - theory
Collaboration with: Dennis Discher, Univ. Pennsylvania - DNA damage in migrating cells as a model of metastasis: experiments Talila Volk, Weizmann Institute - muscle cells and nuclear deformation: experiments Gary Karpen, Berekely - phase separation in the cellular nucleus: experiments Frank Julicher - MPI Dresden - phase separation theory Tony Hyman - MPI Dresden - phase separation - biological experiments

- Soft Matter Physics Theory
- Electrostatics in soft matter - theory
- Cell shape and volume - theory

Dr. Ephraim Shahmoon

- Quantum optics theory, quantum science
- Collective light-matter interactions in quantum emitter arrays
- Novel platforms for quantum science and technology
- Quantum fluctuation forces
- Dipole-dipole interactions and QED in confined geometries

Prof. David Tannor

- Control of chemical reactions with tailored femtosecond pulses.
- Laser cooling of molecules.
- Quantum theory of dissipation and chemical reactions in solution.
- Semiclassical theory of reactive scattering.

Prof. Shimon Vega

- Proton NMR Spectroscopy of Solids
- Dynamic Nuclear Polarization

Collaboration with: Akiva Feintuch

- Surface mobility of molecules in mesoporous materials

Department of Earth and Planetary Sciences

Department Head: Prof. Yinon Rudich

The research in this department is dedicated to understanding the complex inter-relationships among the major Earth Systems and on the human impact on the Earth's environment and climate. In addition, a research is conducted on planetary atmospheres and planetary geomorphologies.

The Department's research activities have several general areas of activities. One focuses on water and includes hydrology, geochemistry, land-plant-atmosphere interactions, and oceanography. A second activity is in the use of stable isotopes for
reconstructions of paleoclimatic and of biosphere-atmosphere dynamics, and a third is in the area of atmospheric chemistry and dynamics, and cloud physics. The fourth area of research is in planetary sciences. Our research requires knowledge of the interdependent components that together constitute the "environment", as well as a commitment to protect this environment by improving the manner in which air, water, land, and energy are utilized by humans. The Department is distinguished by the interactions among scientists from different backgrounds and expertise, which is critical for achieving a comprehensive understanding of the global environment and planetary sciences.

The department promotes international collaborations based on short- and long-term visits for research and training by scientists who complement existing expertise in the Department. The interdisciplinary nature of the Department is well reflected in the academic training of the research students. Their backgrounds vary from physics, chemistry, and mathematics through geology to biology. We encourage the participation of students who are interested in not only investigating in depth a specific subject but who are also interested in a broader and integrative approach to science.

Research activities

Prof. Oded Aharonson

- Planetary Science

Prof. Brian Berkowitz

- Development of chemical methods for remediation of water polluted by organic compounds and heavy metals.
- Fluid flow and chemical transport in groundwater systems.
- Percolation, scaling and statistical physics models of structural and dynamic processes in geological formations.
- Experimental and theoretical analysis of reactive transport and precipitation/dissolution patterns in porous media.

Dr. Itay Halevy

- The long-timescale co-evolution of biogeochemical cycles, the chemical and isotopic composition of the oceans and atmosphere, and climate on Earth and other planets.
  - The geological, geochemical, and geobiological history of Earth, planets and satellites.
  - Global biogeochemical cycles and their interaction with the climate system.
  - Episodes of global climatic, biological or geochemical change, their causes and consequences, and their expression in the sedimentary rock record.
  - Fractionation of stable isotopes during metabolic activity, its governing factors, and its expression in modern environments and in the sedimentary rock record.
Dr. Yohai Kaspi

• Geophysical fluid dynamics
• Atmospheric dynamics on Earth and other planets
  • Storm track dynamics
  • Geostrophic turbulence
  • Superrotation
  • Climate dynamics
• Planetary interiors
  • Gravitational signature of internal dynamics on giant planets
  • Jets on giant planets
  • Internal tides
  • The Juno mission to Jupiter

Dr. Yael Kiro

Prof. Ilan Koren

• cloud and rain physics
• nonlinear dynamics
• ocean - atmosphere interactions
• radiation transfer and remote sensing

Dr. Shira Raveh-Rubin

• Weather systems dynamics
  • Extratropical cyclones
  • Tropical-extratropical interactions
  • Air-sea interaction
• Atmospheric transport
  • Moisture transport leading to heavy precipitation
  • Large-scale dust transport
• Extreme weather events
  **Collaboration with:** Philippe Drobinski, CNRS
  • Mediterranean cyclones
  • Heavy precipitation, strong winds, boundary layer instability, wildfires

Prof. Yinon Rudich

• Health effects of atmospheric particulate matter
  **Collaboration with:** Prof. Ralf Zimmermann - Helmholtz Center Munich and University of Rostock, Germany Prof. Astrid Kiendler-Scharr - Hemholtz Center Juelich, Germany
• Ice nucleation by atmospheric particles
  **Collaboration with:** Prof. Ido Braslvski - Hebrew University

• The transport of microorganisms in the atmosphere and their possible biogeochemical effects. Atmospheric microbiome.

• Optical properties of atmospheric organic aerosols
  **Collaboration with:** Dr. Steve Brown - NOAA, Boulder CO Prof. Alexander Laskin - Purdue University

Prof. Dan Yakir

• Developing the use of stable isotopes (in particular, 13C, 18O, 15N, 2H) as tracers of biogeochemical cycles on land.

• Environmental and climatic influence on the exchange of trace gases and energy between plants, soil and the atmosphere.

• Climatic influence on the natural abundance of carbon, oxygen and hydrogen isotopes in CO2, O2, H2O and organic matter.

### Department of Materials and Interfaces

*Department Head: Prof. Leeor Kronik*

Activities in the Department span a wide range of topics from soft, composite and hard materials to energy research, nanoscience, and biological materials. A unifying theme is the study of material functionality and its relation to fundamental properties at multiple scales. These properties may be mechanical, structural, chemical, electronic, magnetic, optical, and more. Some examples are:

How do shapes and sizes of nm-sized particles affect their properties?

How can we tune the properties of solar cells by manipulating their material interfaces?

How does friction in knee and hip joints depend on polyelectrolytes that lubricate them?

How can we design self-assembling (bio)chemical systems?

THE RESEARCH IS BASED ON AN INTERDISCIPLINARY APPROACH, and indeed the scientists bring complementary experience in chemistry and physics, including both theory and experiment.

**Research activities**

Prof. David Cahen
• Sustainable Materials - Solar Energy

**Collaboration with:** @WIS: G. Hodes, D. Oron, S. Cohen, L. Kronik, L Houben; A. Kahn (Princeton); Helmholtz Centre Berlin, HZB; M. BÄrr (Erlangen, HZB); H. Bolink (Valencia); P. Nayak (TIFR-H); S Avashti (IISc); H. Ishii (Chiba); P. Schultz, JF. Guillemoles (IPVF-CNRS); T. Kirchartz (Duisburg-JÄ¼lich).

- Self-healing materials & concepts;
- New optoelectronic materials;
- Halide Perovskites;
- Between hard and soft matter.

• Bioelectronics

**Collaboration with:** @ WIS: M. Sheves, I. Pecht; A. Vilan. M. Tornow (TU-Munich); G. Vattya (Budapest); J. Blumberger (Imp. College); L. Zotti (Sevilla); JC Cuevas (Madrid); H. Chen (Zhejiang U);

- Proteins as solid-state electronic materials;
- Fundamentals of electronic charge transport in and across proteins;
- Biomolecular electronics;
- Between soft & hard matter.

**Prof. Gary Hodes**

• Semiconductor-sensitized nanoporous solar cells and semiconductor film deposition

**Collaboration with:** D. Cahen (WIS)

- Electrochemical and chemical bath deposition of semiconductor films.
- Nanocrystalline solar cells; semiconductor-sensitized nanoporous cells
- Charge transfer in nanocrystalline films

**Prof. Ernesto Joselevich**

• Nanotubes and Nanowires: From Self-Organization to Functional Nanosystems

- Nanometer-scale materials can have unique properties due to their reduced dimensions, and serve as building blocks for the assembly of miniature functional systems. In macroscopic functional systems, wires, tubes and rods play critical roles of transporting energy, forces, matter and information. Which materials could play analogous roles at the smallest possible scale? How does the reduced dimensionality determine the properties of molecular wires? How can they be organized and integrated into functional systems?
- Our research focuses on the organization of one-dimensional nanostructures, such as carbon nanotubes, inorganic nanotubes and nanowires, their integration into functional nanosystems (mechanical, electronic, electromechanical, optoelectronic, electromagnetic, thermal, etc.) and their characterization by mechanical, electrical and optical measurements at the nanometer scale.

• Projects

- Guided growth of horizontal nanowires
- Epitaxial approaches to carbon nanotube organization
• Non-equilibrium self-organization of complex nanostructures
• Nanotube torsion and NEMS
• Surface-directed self-assembly
• Polymers as molecular wires
• Theory of molecular wires

Prof. Jacob Klein

• Biological lubrication; Hydration lubrication; surface interactions; nanotribology; soft matter
  • Biological lubrication and its relation to osteoarthritis: this is the theme of a major new ERC grant (2017 - 2022)
  • Lipids and liposomes as lubrication vectors
  • Hydration lubrication and Boundary lubrication under water, and its relation to ocular (eye) lubrication
  • Surface forces under strong electric fields
  • Properties of thin liquid films including aqueous electrolytes and polyelectrolytes.
  • Hydrogels
  • Soft matter at interfaces
• Surface-forces-measurement techniques at angstrom surface separations; polymers as molecular lubricants
  • ATRP growth of polymers from surfaces
  • Polyelectrolyte brushes
• Polymers, Complex Fluids, and Interfaces - Experimental studies of the behavior of confined simple and polymeric fluids.
  Collaboration with: Sam Safran
  • Nanotribology
  • Surface forces between heterogeneous surfaces
  • Confinement induced phase transitions

Prof. Leeor Kronik

•
• Our group's research is focused on understanding unique properties and behavior of materials and interfaces, using first principles quantum mechanical calculations based mostly on density functional theory and many-body perturbation theory. The group is actively engaged in prediction and interpretation of novel experiments, as well as in the development of formalism and methodology. For much more detailed information, please click the homepage link below.

Prof. Meir Lahav

  Collaboration with: Prof Igor Lubomirsky Dr.David Ehre
  • Organization of molecules at surfaces and interfaces;
• Chirality, Chemistry and the origin of life
• Pyroelectricity, Electrofreezing.

Prof. Leslie Leiserowitz

• Crystallography and Chemistry in 2- and 3-dimensions
  • Grazing incidence x-ray diffraction
  • Malaria

Dr. Michal Leskes

• Our research is focused on correlating structure and function in energy storage and conversion materials by advanced magnetic resonance methods. We aim to understand how the composition of materials affects their functionality and how we can control their functionality through deviation from ideal stoichiometry. In particular we are interested in materials for energy storage, such as Li and Na ion batteries, and in the role interfacial chemistry plays in the functionality of electrode and electrolyte materials. We use a wide range of magnetic resonance techniques: solid state NMR, Electron Paramagnetic Resonance (EPR) and Dynamic Nuclear Polarization (DNP). Additionally we investigate the process of polarization transfer from electron spins to nuclear spins in solids DNP utilizing external and internal polarization agents. For more detailed information, please click below and see our home page.

Prof. Igor Lubomirsky

• Ice Nucleation on Charged Surfaces (Electrofreezing)
  Collaboration with: Prof. Meir Lahav
  • Ice nucleation
  • design of polar crystals and surfaces by symmetry reduction
  • non-classical crystal growth
  • surface and bulk pyroelectricity
• Fundamentals of electro-chemo-mechanical effects
  • local symmetry reduction
  • non-classical electrostriction
  • ionic conductivity
  • elastic interactions in solids with a large concentration of point defects
Dr. Sivan Refaely-Abramson

• Excited-State Dynamics in Crystals
  • First-principles computations of scattering and time propagation processes of localized, long-lived excitons in crystals
  • New many-body methods to study exciton separation at heterojunctions
  • Excited-state processes in catalysis
    Collaboration with: Sara Barja, Centro de FÁ-sica de Materiales, CSIC-UPV/EHU and DIPC

Prof. Jacob Sagiv

• Supramolecular Architecture at Interfaces (with R. Maoz)
  • Supramolecular Surface Chemistry: Bottom-up Nanofabrication using Planned Self-Assembling Mono- and Multilayer Systems (with R. Maoz)
  • Constructive Lithography: Contact Electrochemical Surface Patterning on Lateral Length Scales from Nanometer to Centimeter (with R. Maoz)

Prof. Reshef Tenne

• Inorganic nanotubes from ternary "misfit" layered compounds
  Collaboration with: Dr. R. Arenal, Laboratorio de MicroscopÃ-as Avanzadas, Instituto de Nanociencia de AragÃ-n, Universidad de Zaragoza, 50018 Zara-goza, Spain Dr. Luc Lajaunie, Departamento de Ciencia de los Materiales e IngenierÃ-a MetalÃ³rgica y QuÃ-mica InorgÃ¡nica, Facultad de Ciencias, Uni-versidad de CÃ¡diz, Campus RÃ-o San Pedro S/N, Puerto Real 11510, CÃ¡diz, Spain Prof. Ernesto Joselevich, Department of Materials and Interfaces, Weizmann Institute, Rehovot 76100, Israel Dr. Lothar Houben, Chemical Research Support Department, Weizmann Institute, Rehovot 76100, Israel Prof. Alla Zak, Holon Institute of Technology, Israel Prof. Shmuel Kenig and Prof. Hanna Dodiuk, Shenkar College, Israel Prof. Yoshihiro Iwasa, University of Tokyo and the Riken Institute. Japan Prof. Janina Maultzsch, Department of Physics, FAU Erlangen-NÃ¼rnberg, 91058 Erlangen, Germany Dr. Iddo Pinkas, Chemical Research Support Department, Weizmann Institute, Rehovot 76100, Israel
  • Synthesis of nanotubes from misfit layered compounds (MLC), their structural electrical and optical characterization
  • Optical properties of WS2 and MoS2 nanotubes

Department of Organic Chemistry

Department Head: Prof. Milko van der Boom

The areas of research in the Department of Organic Chemistry include synthetic and mechanistic organic and organometallic chemistry, novel reactions for organic synthesis, bond activation by metal complexes, polymeric reagents and catalysis. Bioorganic
chemistry includes the studies of plant antiviral agents, the molecular mechanism of action of rhodopsin, artificial ion carriers and molecular sensors. Biological chemistry includes studies on structure, function, and mode of action of biologically active peptides and proteins; thermophilic enzymes; enzymes involved in DNA repair, DNA and RNA processing; studies of ordered, compact states of nucleic acids; and biomedical applications of EPR and NMR. Computational chemistry deals with the prediction of molecular properties by first principles (ab initio) and semiempirical quantum mechanical calculations.

Research activities

Prof. Mario D. Bachi

- Organic synthesis through free radical reactions.
- Synthesis of Yingzhaosu A and related antimalarial drug candidates.
- Stereocontrol through Sulfur-Mediated Temporary Intramolecularization of Reactions.

Prof. Yigal Burstein

- Thermophilic enzymes
  - Isolation, characterization and cloning of enzymes from extremophilic microorganisms.
  - Structure, function and thermal stability relationship studies of extremophilic enzymes.
  - Crystalization and determination of the three-dimensional structures of extremophilic enzymes.

Prof. Matityahu Fridkin

- Chemical-Biological and Clinical studies on novel drugs, primarily of peptidic nature, related to therapy of infectious, inflammatory and neoplastic diseases.
  **Collaboration with:** Y. Koch I. Gozes (TAU) I. Offek (TAU) R. Catane (TEL-HASHOMER)
  - Anticancer, Antibacterial Antiinflammatory
- Novel synthetic and analytical methodologies are being developed.
  - Solid-phase synthesis
  - Classical solution chemistry
  - Combinatorial technologies
- Studies include: drug design, pro-drugs, long-acting drugs and drug delivery.
  **Collaboration with:** Y. Shechter
- Novel iron chelatores as potential drugs for neurodegenerative diseases
  **Collaboration with:** M. Youdim (Technio9n)
  - small-molecules
  - amino acids and peptides
Dr. Nir London

- Discovery and design of specific covalent inhibitors
- Covalent personalized medicine for cancer
- Computational ligand/drug discovery

Prof. Gershom (Jan) Martin

- Computational Quantum Chemistry
  Collaboration with: D. Milstein, M. van der Boom, R. Neumann, M. A. Iron, L. Kronik
  - High-accuracy ab initio thermochemistry: method development and applications.
  - Development of novel, more universal, density functionals
  - Application of density functional methods to organometallic systems, with special reference to homogenous catalysis.
  - Ab initio prediction of rotation-vibration spectra beyond the harmonic approximation.
  - Intermolecular interactions

Prof. David Milstein

- Organometallic chemistry and catalysis
  - Bond activation by electron-rich transition metal complexes.
  - Rational design of homogeneous catalysis and synthetic methodology based on transition metal complexes.
  - Impact of molecular order on catalysis and reactivity.
  - Generation and stabilization of elusive (potentially biologically active) molecules

Prof. Boris Rybtchinski

- Organic self-assembly: nanoreactors and nanocapsules
- Solar fuels: photoinduced water splitting for hydrogen production
- Artificial photosynthesis: light-harvesting materials for solar energy conversion

Prof. Abraham Shanzer

- Supramolecular chemistry
  - Biomimetic ion binders, diagnostic tools in imaging technologies (fluorescent probes) and potential therapeutic agents. Synthesis, using classical and combinatorial chemistry methods and evaluation.
  - Synthesis and properties of molecular based devices; molecular sensors, switches and logical gates for application in nanotechnology.
  - Surface bound functional assemblies.

Department of Structural Biology
The functions of biological systems emerge from the structures of macromolecules, their conformational dynamics, and their higher order assembly. Determination of biomolecular structures and an understanding of their conformational changes and assembly properties provide great insights into biological mechanisms. Much of the research in structural biology at the Weizmann Institute is carried out in the Faculty of Chemistry, using a diverse set of cutting-edge research tools and methods. Investigators in the Structural Biology Department rely on the primary techniques for experimental structure determination, namely X-ray crystallography, NMR, and electron microscopy, but they also employ a variety of other specialized and emerging spectroscopic methods combined with creative molecular engineering to explore macromolecular structures, energetics, and dynamics. Experimental strategies are complemented by computational and theoretical approaches. Among the specific subjects of research in the department are ribosomes, protein chaperones, viruses, extracellular matrices, and biominerals. Processes being investigated include protein aggregation in cells, conformational dynamics of enzymes, formation of skeletal tissues, cell penetration by viruses, DNA recognition by proteins, and protein folding. Efforts are also directed towards the design of potential drugs. The wide variety of research activities in the department are based on a shared appreciation for the physical and chemical foundations of biological activities.

Research activities

Prof. Lia Addadi

- Antibodies that recognize crystal surfaces and 2-dimensional organized patterns.
  - antibody recognition of chiral crystal surfaces
  - structure of cholesterol/ceramide monolayer mixtures. Molecular organization of lipid rafts
  - Pathological crystallizations. Gout
  - antibody recognition of amiloid structures
- Mechanisms of crystal nucleation and modulation of crystal growth and properties in biomineralization (bone, mollusk shells, echinoderms).
  Collaboration with: S. Weiner
- Mechanism of cell adhesion using crystal substrates.
  Collaboration with: B. Geiger

Prof. Jacob Anglister

- The structure of the membrane proximal extra-cellular region of HIV-1 gp41 and its role in viral fusion
  Collaboration with: F. Naider
- The structure of the V3 loop of the HIV-1 envelope protein gp120 and its interactions with chemokines receptors
Collaboration with: F. Naider
• NMR structure of alpha Interferon complex with its receptor

Collaboration with: J. Piehler
• The interactions of scorpion toxins with sodium channels and the structures of the channels extra-cellular loops

Collaboration with: M. Gurevitz, D. Gordon

Dr. RonDiskin
• Viral glycoproteins - Structure, Function, & Immunogenicity
• Novel drug targets against Mycobacterium tuberculosis

Prof. Deborah Fass
• disulfide bond formation for oxidative protein folding and assembly
• extracellular matrix structure and assembly
• enzyme mechanism, regulation, and inhibition

Prof. Amnon Horovitz
• Linear free energy relationships (LFER) analysis of allostERIC transitions in proteins.
• Analysis of correlated mutations in proteins
  Collaboration with: Ron Unger (Bar Ilan University)
• Allostery in the structure and function of GroEL and CCT chaperonins.
  Collaboration with: Keith Willison (Imperial College, London); Michal Sharon;
• Chaperonin-mediated protein folding.
  Collaboration with: Gilad Haran

Dr. Emmanuel Levy
• Design of protein-based super assemblies
  Collaboration with: Jonathan Doye (Oxford) Samuel Safran (WIS)
• New methods to detect and measure protein interactions
• Computational analyses of protein structure

Prof. Koby Levy
• Dynamics, entropy and diffusion in biomolecular systems
• The mechanisms of protein-DNA recognition: understanding the driving forces for fast assembly

Dr. Rina Rosenzweig
• Chaperone interactions with substrates
• Protein disaggregation machinery
• NMR of large proteins

Prof. Zippora Shakked

• Crystal structure and solution studies of DNA oligomers.
  **Collaboration with:** Donald Crothers (Yale University)
  • DNA regulatory elements
  • DNA bending by adenine-thymine tracts
• Structural and biochemical studies of proteins involved in transcriptional regulation.
  • The tumor-suppressor protein p53 and its interaction with DNA and the basal transcription machinery
  • The leukemia-related RUNX1(AML1) transcription regulator

Dr. Moran Shalev-Benami

• Cellular communication in the CNS
• Structural Biology of membrane proteins
• Ribosome biology

Prof. Joel Sussman

• 3D Structure Function Studies or proteins related to Autism
  **Collaboration with:** Israel Silman
• 3D Structure Function studies of Paraoxonase
  **Collaboration with:** Dan Tawfik & Israel Silman
• Application of ultra rapid X-ray diffraction methods to study the enzymatic mechanism of AChE in real time.
  **Collaboration with:** Israel Silman
• Structure based drug design studies on AChE and beta-secretase, including studies of complexes with transition state analogs; potential drugs for the treatment of Alzheimer's disease; and snake neurotoxins.
  **Collaboration with:** Israel Silman
• X-ray structural analysis and molecular biology studies on proteins from the nervous system, including acetylcholinesterase (AChE), human, torpedo, drosophila, and krait; butyrylcholinesterase; neural cell adhesion proteins with sequence similarity to ACh
  **Collaboration with:** Israel Silman
• 3D Structure Function of proteins related to Gaucher Disease
  **Collaboration with:** Tony Futerman & Israel Silman
• Visualization of 3D Protein Structures via new web based tool Proteopedia
  **Collaboration with:** Jaime Prilusky & Israel Silman

Prof. Stephen Weiner
• Structure-function relations in vertebrate mineralized tissues  
  **Collaboration with:** Ron Shahar, Hebrew University of Jerusalem

• Archaeological science: revealing the microscopic archaeological record  
  **Collaboration with:** Elisabetta Boaretto,

• Biomineralization: mechanisms of mineral formation and growth in biology.  
  **Collaboration with:** L. Addadi, Leeor Kronick, Dan Oron

**Prof. Ada Yonath**

• Antibiotics targeting ribosomes
• Protein biosynthesis
• Ribosomal mechanisms
• Origin of life
• Next generation antibiotics
• Human genetic diseases â€“ structural and molecular bases
The principal interests of the department lie in the areas of computer science and applied mathematics. Research areas include (but are not limited to) algorithms, their design and analysis; biological applications, bioinformatics, system biology, biological modeling; computational complexity, probabilistic proof systems, hardness of approximation, circuit complexity, combinatorial games; computer vision, image processing; cryptography; differential equations; distributed and parallel computing; dynamical systems; fluid dynamics; logic of programs, specification methodologies; machine learning and mathematical statistics; numerical analysis; randomness and its relation to computation; robotics and motion control; visual perception and brain modeling.

The departmental computer facilities include multiple PCs, multiple unix servers, two Linux clusters with multiple nodes, and large data storage systems. In addition, the vision laboratories, robotics laboratories and computational biology laboratories have a combination of experimental equipment and large-scale computing clusters.

Research activities

**Prof. Achi Brandt**

- Multi-level computational methods, scientific computation.

**Prof. Irit Dinur**

- Probabilistically Checkable Proofs
- Hardness of Approximation

**Prof. Yonina Eldar**

- Signal and image processing
- Compressed sensing
- Medical imaging
- Deep learning and graphs
- Communication, radar and remote sensing
- Optimization

**Prof. Uriel Feige**

- Algorithms and computational complexity
- Coping with NP-hard combinatorial optimization problems
• Algorithmic game theory

Prof. Tamar Flash

• Robotics, motor control and learning, movement disorders, computational neuroscience, virtual reality.

Prof. Aviezri S. Fraenkel

• Complementary sequences of integers, Fraenkel conjecture
  **Collaboration with:** David Klein, Jamie Simpson
• Combinatorial game theory
  **Collaboration with:** Urban Larsson, Lior Goldberg, Haiyan Li, Sanyang Liu, Wen An Liu, Udi Peled, Vladimir Gurvich, Clark Kimberling, Nhan B. Ho, Eric Duchene
• Numeration systems and theory of partitions
  **Collaboration with:** George Andrews, James Sellers
• Judaic studies

Prof. Oded Goldreich

• Randomness and Computation
  • Property Testing
  • Probabilistic proof systems
  • Pseudorandomness
• Foundations of Cryptography
• Complexity theory

Prof. Shafi Goldwasser

• Probabilistic proofs, cryptography, computational number theory, complexity theory.

Prof. David Harel

• Software and systems engineering, visual languages, biological modeling, olfaction.

Prof. Michal Irani

• Computer Vision, Video information analysis and applications, Image Processing.

Prof. Robert Krauthgamer

• Design and analysis of algorithms, including massive data sets, data analysis, and combinatorial optimization
• Embeddings of finite metric spaces, high dimensional geometry

Prof. Yaron Lipman
• Geometric modeling, geometry processing, shape analysis, computer graphics, Discrete differential geometry

**Prof. Boaz Nadler**

• Mathematical Statistics, Statistical Machine Learning, Statistical Signal and Image Processing, Applied Mathematics

**Prof. Moni Naor**

• Concrete Complexity
• Distributed Computing
• Cryptography and Complexity

**Dr. Merav Parter**

• Distributed graph algorithms
• Spanners and fault tolerant network design

**Prof. David Peleg**

• Distributed algorithms
• Approximation algorithms
• Fault-tolerance

**Prof. Ran Raz**

• Complexity Theory: In particular: Boolean circuit complexity, arithmetic circuit complexity, communication complexity, probabilistically checkable proofs, quantum computation and communication, randomness and derandomization.

**Prof. Vered Rom-Kedar**

• Hamiltonian systems - theory and applications
  **Collaboration with:** M. Radnovic, A. Rapoport, E. Shlizerman, D. Turaev
  • Near-integrable systems
  • The Boltzmann ergodic hypothesis and soft billiards.
  • Chaotic scattering.
  • Resonant surface waves.
  • Perturbed nonlinear Schrodinger equation.
• Mathematical models of the hematopoietic system and their medical implications
  **Collaboration with:** R. Malka, E. Shochat.
• Chaotic mixing of fluid flows
  **Collaboration with:** R. Aharon, H. Gildor
Prof. Adi Shamir

- Cryptography, cryptanalysis, electronic money, smartcard security, internet security, complexity theory, the design and analysis of algorithms.

Dr. Ohad Shamir

- Theory of Machine Learning, machine learning and optimization

Prof. Ehud Shapiro

- Laying the Biological, Computational and Architectural Foundations for Human Cell Lineage Discovery

  **Collaboration with:** E. Shapiro, V. Adalsteinsson, H. Brodi, M. Minden, R. Halaban, C. Klein, M. Meyerson, C. Wu, T. Zukerman, R. Shalom

Prof. Edriss S. Titi

- Fluid Dynamics, Geophysical models, Oceanic and Atmospheric Dynamics
  - Oceanic and atmospheric dynamics models
  - Turbulence theory
  - Data assimilation of weather and climate prediction
  - Mathematical models of cloud formation
- Nonlinear Partial Differential Equations and Dynamical Systems
  - Navier-Stokes and Euler Equations
  - Infinite-dimensional dynamical systems, Reduced dynamical systems, Numerical analysis of dissipative PDEs
  - Limit behavior of fast and slow dynamics
  - Polymeric flows and non-Newtonian complex fluid

Prof. Shimon Ullman

- Vision, image understanding, brain theory, artificial intelligence.

Department of Mathematics

*Department Head: Prof. Omri Sarig*

The principal research interests of the department lie in the broadly understood areas of analysis, probability, algebra, and geometry.

Topics covered in **Analysis** include operator and matrix theory, spectral theory, linear and nonlinear ordinary and partial differential equations, functional and harmonic analysis, ergodic theory and dynamical systems, control theory in its various manifestations, optimization, game theory, approximation and complexity of functions,
numerical analysis, singularity theory and robotics.

Research in **Probability** theory covers random walks and graphs, motion in random media, percolation, random matrices, Gaussian fields and other probabilistic models in mathematical physics.

Areas of **Geometric** research include the structure of finite and infinite dimensional spaces, analytic, real algebraic and semi-algebraic geometry, typology of foliations and complex vector fields.

The **Algebraic** direction includes some aspects of algebraic geometry, geometric group theory, Lie Theory, representation theory, quantum groups, number theory, automorphic forms, ring theory, statistics of Young diagrams, algebraic combinatorics and enveloping algebras, invariants and crystals.

For the research done at our sister department, the Department of Computer Science and Applied Mathematics, see [here](#).

**Research activities**

**Prof. Avraham Rami Aizenbud**

- Algebraic geometry  
  **Collaboration with:** Nir Avni, Raf Cluckers, Dmitry Gourevitch
  - Algebraic groups
  - Singularity theory
  - Geometric invariant theory
  - Motivic integration
  - Algebraic Stacks
  - Rational points

- Representation theory  
  **Collaboration with:** Nir Avni, Dmitry Gourevitch, Shachar Carmeli, Eitan Sayag.
  - Representation theory of real groups
  - Representation theory of p-adic groups
  - Representation theory of finite groups of Lie type
  - Harmonic analysis on Spherical varieties
  - Gelfand pairs
  - Asymptotic representation theory

- Functional analysis:  
  **Collaboration with:** Dmitry Gourevitch, Shachar Carmeli, Raf Cluckers
  - Distributions and generalized functions
  - Microlocal analysis
  - Topological vector spaces

**Prof. Zvi Artstein**
• Decisions, the impact of evolution.
• Ordinary differential equations, singular perturbations, averaging.
• Control and optimal control, singularly perturbed systems, variational analysis.
• Teaching mathematics in view of evolution

Prof. Itai Benjamini

• Probability and geometry.

Prof. Vladimir Berkovich

• Non-Archimedean analytic geometry.
• Algebraic geometry.
• Number theory.

Prof. Harry Dym

• Classical analysis.
• Operator theory.
  Collaboration with: Damir Z. Arov, Vladimir Derkach
• Inverse problems.
  Collaboration with: Damir Z. Arov

Dr. Ronen Eldan

• High dimensional phenomena in probability and geometry
• Analysis and functional inequalities
• Applications of high dimensional theory to learning theory and optimization

Prof. Ehud Friedgut

• Combinatorics and discrete Fourier analysis.

Prof. Stephen Gelbart

• Complex and p-adic Automorphic forms and L-functions.

Prof. Maria Gorelik

• Representation theory and Lie superalgebras
  Collaboration with: Dimitar Grantcharov, Victor Kac, Vera Serganova.

Dr. Dmitry Gourevitch

• Invariant distributions
Collaboration with: Avraham Aizenbud, Eitan Sayag
• Representation theory of reductive groups over local fields

Collaboration with: Siddhartha Sahi, Avraham Aizenbud, Eitan Sayag,
• Representations of real reductive groups
• Representations of p-adic reductive groups
• Non-commutative harmonic analysis on homogeneous spaces, or Relative representation theory
• Degenerate Whittaker models and Fourier coefficients of automorphic forms
• Multiplicities in induced representations, Gelfand pairs
• Non-commutative harmonic analysis on spherical varieties
• Wave-front sets of distinguished representations
• Fourier coefficients of small automorphic representations

Collaboration with: Henrik P. A. Gustafsson; Axel Kleinschmidt; Daniel Persson; Siddhartha Sahi

Prof. Anthony Joseph

• Lie algebras and enveloping algebras, quantum groups. Invariant theory.

Collaboration with: Yasmine Fittouhi

Prof. Yakar Kannai

• Partial differential equations.
• Mathematical economics

Prof. Victor Katsnelson

• Operator theory
• Harmonic analysis.
• Classical analysis
• Analytic theory of differential equations.
• System representation theory of matrix functions.

Prof. Boaz Klartag

• Analysis
• Convex Geometry
• High-dimensional effects (i.e., when the dimension tends to infinity).

Prof. Gady Kozma

• Harmonic Analysis
• Probability
Prof. Erez Lapid

• Authomorphic forms, representation theory, trace formula

Prof. Dmitry Novikov

• Hilbert 16th problem
• Ordinary differential equations

Prof. Amitai Regev

• Non-commutative ring theory, Algebras satisfying polynomial identities

  Collaboration with: Allan Berele, Doron Zeilberger
• Combinatorics: Symmetric functions, Permutation statistics

Prof. Gideon Schechtman

• Convex geometry
• Functional analysis and geometry of Banach spaces
• Probability

Prof. Sergei Yakovenko

• Analytic theory of ordinary differential equations.
• Singularity theory. Singular foliations, limit cycles, holonomy.

Prof. Yosef Yomdin

• High Order Data Representation, Nonlinear Model Approximation. Taylor Models, High-Order Numerical methods
• Semialgebraic Complexity of functions, Signals Acquisition via non-linear model approximation
• Analytic Theory of Differential Equations, Generalized Moments, Compositions
• Zeroes distribution in Families of Analytic Functions
• Model-based image analysis, representation, compression. Model-based search, capturing, and animation

Prof. Ofer Zeitouni

• Motion in random media
• Random matrices
• Applications in nonlinear filtering, Communication and Information theory
• Logarithmically correlated random fields
The scientific activity of the department is mainly concentrated around the experimental and theoretical research in quantum solid state physics. It includes experimental research of mesoscopic physics, quantum Hall physics, topological states of matter, high temperature superconductors, two and one dimensional superconductors, metal-insulator transition, carbon nanotubes, semiconductor nanowires, and study of material growth. The theoretical efforts concentrate on similar subjects with added work on disordered materials, cold atoms, and quantum optics.

The Braun Center for sub micron research is an integral part of the department. It is a modern and well equipped center, with growth (three MBE's) and characterization systems, which allows to conduct experiments on sub micron semiconductor structures under high magnetic fields, conventional and high temperature superconductors, and nanowires made of carbon nanotubes and semiconductor nanowires.

**Research activities**

**Dr. Haim Beidenkopf**

- Topological electronic phases
- Weyl/Dirac topological semimetals
- Strong/Weak/Crystalline/Higher-order topological insulators
- Topological superconductivity and Majorana modes
- Topological nano-devices
- Scanning tunneling microscopy and spectroscopy
- Molecular beam epitaxy

**Prof. Alexander Finkelstein**

- Effects of the electron-electron interaction in low dimensional and disordered systems.
- Metal-insulator transition in 2D conductors.
- Magnetic fluctuations in high - Tc superconductors.

**Prof. Yuval Gefen**

- Quantum measurements and how to use them for engineering and manipulating quantum states.
- Exotic excitations in the fractional quantum Hall effect and Topological Insulators.
- Edge reconstruction and edge channels in the fractional quantum Hall effect and
Topological Insulators.

Prof. Moty Heiblum

- Exotic quantum states with quantum statistics different from elementary particles
- Non-abelian quantum states (e.g., hosting Majorana particles)
- Interference of electrons and fractional charges in the quantum Hall regime
- Thermal conductance of one-dimensional modes, revealing quantum behavior

Prof. Shahal Ilani

- Imaging Magic angle graphene and other moiré materials
  **Collaboration with:** Prof. Pablo Jarillo-Herrero, MIT
- Electron hydrodynamics
  **Collaboration with:** Prof. Andre Geim, Manchester
- Quantum nano-electron-mechanics
- Imaging experiments of Electron Optics
  **Collaboration with:** Prof. Andre Geim, Manchester
- Scanning Twistorics
- Local measurements of exotic quasiparticles

Prof. Shimon Levit

- Full vector path integrals for light propagation in dielectrics.
- Interaction of Squeezed Light with Atoms and Semiconductor Nanostructures
- Non classical light.
- Resonant scattering off photonic slabs

Prof. Yuval Oreg

- Topological Quantum Materials
  - Superconducting and fractional topological phases theory and applications to quantum topological computers
  - Majorana fermions in superconducting wires and topological superconductors
  - Quantum dots and the Kondo effect and the multi channel Kondo effect
  - Disorder superconductors and normal metal super-conducting junctions
  - Glassy systems
  - Luttinger liquids in one-dimensional systems such as: carbon nano tube, edges of a quantum hall systems, edges of two dimensional topological insulator

Dr. Serge Rosenblum

- Superconducting qubits
- Decoherence and quantum error correction
• Quantum feedback
• Bosonic quantum computing
• Superconducting microwave circuits

**Prof. Dan Shahar**

• Physics of electron’s spin
• Quantum phase transitions: General transport studies and mesoscopics of the metal-insulator, superconductor-insulator and other transitions.
• Scanning tunneling experiments at ultra-low temperatures
• Fractional and integer quantum Hall effect and related phenomena.
• Experiments on materials at ultra low-temperatures.

**Prof. Adi Stern**

• Quantum interference phenomena in the fractional Quantum Hall effect. Electronic transport in strong magnetic fields.
• Non-abelian electronic states - quantum Hall states, topological superconductors and Majorana fermions.
• Fractionalized topological phases - how to construct them, how to measure them, and how to use them for topological quantum computation
• Low density two dimensional electronic systems.
• One dimensional electronic systems - electronic transport in the presence of interactions.

**Prof. Binghai Yan**

• Topological Materials
  • Topological Insulators
  • Dirac and Weyl Semimetals
  • Berry phase
• Transport and optical response in topological systems
  • Light-matter interaction, nonlinear optical response
  • Magneto-transport
  • Spin Hall effect and anomalous Hall effect
• 2D Materials for electronic, spintronic and optical properties
  • Magnetic 2D materials
• Mystery of Chirality
  • DNA-like chiral molecules and the spin polarization
  • Chirality induce nonlinear effects

**Prof. Eli Zeldov**
• Scanning nanoSQUID magnetic microscopy
• Scanning nanoscale thermal imaging
• Imaging of dissipation mechanisms in quantum and topological systems
• Magnetism and dissipation in magic angle twisted bilayer graphene
• Quantum anomalous Hall effect
• Imaging of current and dissipation in the quantum Hall effect
• Magnetic phenomena in topological insulators
• Magnetism at oxide interfaces
• Superconductivity
• Vortex matter and dynamics

Department of Particle Physics and Astrophysics

Department Head: Prof. Yosef Nir

The Department of Particle Physics and Astrophysics is engaged in both experimental
and theoretical research, in various directions. These include elementary particle physics,
field theory, string theory, theoretical astrophysics, observational astrophysics, particle
astrophysics, relativistic heavy ion physics, molecular physics, nuclear physics, plasma
physics, and radiation detection physics.

Research activities

Prof. Ofer Aharony

• Dualities between field theories in various dimensions
  Collaboration with: S. Minwalla, S. Razamat, N. Seiberg, B. Willett, A. Feldman, S.
  Jain, A. Sharon, R. Raghupathy, E. Urbach, T. Solberg
• Conformal bootstrap at large N and quantum gravity
  Collaboration with: F. Alday, A. Bissi, E. Perlmutter
• Non-local deformations of quantum field theories
  Collaboration with: D. Kutasov, A. Giveon, N. Itzhaki, S. Dubovsky, N. Barel, A.
  Feldman, M. Evtikhiev
• Counting black hole microstates using localization and complex gravitational
  solutions
  Collaboration with: F. Benini, O. Mamroud, P. Milan

Prof. Micha Berkooz

• Theoretical high energy physics
  • String theory, Field theory, Gravity
  • Particle Phenomenology
  • Conformal field theory applications in condensed matter systems
• Quantum information and black holes

**Dr. Kfir Blum**

• Theoretical particle physics
• Particle cosmology
• High-energy astrophysics

**Prof. Amos Breskin**

• Noble-liquid neutron and gamma radiography concepts for detection of concealed explosives and nuclear materials (Homeland security)
• Photon imaging detectors
• Noble-liquid detector concepts for Dark-matter searches, neutrino physics and medical diagnostics
• Advanced gas-avalanche electron multipliers
• Particle tracking detectors for future particle and astroparticle experiments
• Methods of Nano-dosimetry for precise evaluation of radiation effects at the DNA level
• Methods for rapid evaluation of core fluids content in oil and gas wells

**Dr. Shikma Bressler**

• ATLAS experiment
  • Data analysis - Searches for physics beyond the standard model
  • Lepton flavour violating decays of the Higgs and Z bosons
  • Asymmetry in electron/muon final states
  • Generic data driven searches
  • Instrumentation - Upgrade of the ATLAS muon spectrometer
  • Production and testing of the sTGC chambers
  • Performance studies
  • Installation in the ATLAS cavern

• Detector physics

**Collaboration with:** RD51 collaboration

• Basic R&D
• The role of resistive materials in gaseous detectors
• Charge and light amplification in Liquid Argon
• Applicative R&D
• Physics applications - future calorimeters in accelerators and neutrino physics experiments
• Civil applications - muon tomography for hazardous material detection, volcanology, medicine and more

**Dr. Ran Budnik**
• Dark Matter detection:
  • The XENON Dark Matter project: Data analysis, physics interpretations, development and construction XENONnT, PMTs, calibration techniques, statistical inference

• Detector physics:
  • Novel effects in LXe detectors
  • Future concepts and technologies for rare event detection - optically measuring single defects in crystals and molecules

• Other:
  • Future concepts for Cosmic Ray precision detection

**Prof. Ehud Duchovni**

• Hardware: the construction of sTGC (stripped Thin Gap Chambers) for the ATLAS new small wheel
• Search for "Physics Beyond the Standard Model" by studying super energetic events with large number of jets
  • Search for micro black holes
  • Search for RPV SUSY
  • Search for RPC SUSY
  • Search for very heavy resonance decaying into jets

**Prof. Yitzhak Frishman**

• Bound States in Non-Abelian Gauge Theories
  **Collaboration with:** Jacob Sonnenschein
• Current quarks, Constituent quarks, and Hadron Masses
  **Collaboration with:** Marek Karliner

**Prof. Avishay Gal-Yam**

• Cosmic explosions
  • Core-collapse supernova explosions: their origins, nature, physics and population statistics
  • Thermonuclear supernova explosions (SNe Ia): their nature and rates
  • Gamma-Ray Bursts: their origin and relation to supernovae
  • New types of cosmic explosions

**Prof. Doron Gepner**

• Rational conformal field theory and solvable lattice models.

**Prof. Eilam Gross**

• Higgs Physics with the ATLAS detector at the LHC
**Collaboration with:** Students: Michael Pitt and Jonathan Shlomi
- Search for Charged Higgs Boson
- Search for Higgs Decay to Charm Quarks
- Charm Tag
- Stratistics in High Energy Physics

**Prof. Shmuel Gurvitz**
- Multi-dimensional tunnelling.
  **Collaboration with:** Xin-Qi Li, D. Sokolovski
  - Two-potential approach to tunneling problems
  - Cluster decay
  - Modified tunneling Hamiltonian
  - Tunneling of the Bose-Einstein Condensate
- Time-dependent quantum transport in mesoscopic system.
  **Collaboration with:** A. Aharony, O. Entin-Wohlman, Xin-Qi Li, Wei-Min Zhang
  - Number and energy resolved master equations for quantum transport
  - Relaxation and dephasing in persistent current
  - Zeno effect and quantum description of classical apparatus

**Prof. Haim Harari**
- Neutrino Physics (Particle Physics, cosmology, astrophysics implications)
- Patterns of quarks and leptons (masses, mixing, substructure)

**Prof. Uri Karshon**
- Heavy quark production at the HERA e-p collider.
  **Collaboration with:** ZEUS Collaboration, DESY, Hamburg
- Gluon density in the proton and partonic structure of the photon.
  **Collaboration with:** ZEUS Collaboration, DESY, Hamburg
- Tests of QCD dynamics in high energy e-p collisions.
  **Collaboration with:** ZEUS Collaboration, DESY, Hamburg

**Dr. Boaz Katz**
- Open questions in theoretical astrophysics including:
  - How do stars explode to produce supernovae? (I think there is an actual chance to finally answer this soon due to accumulating data and new ideas!)
  - The three body problem (surprisingly connected to supernovae)
  - Where do Cosmic Rays come from and how are they accelerated?

**Prof. Michael W. Kirson**
- Theory and systematics of nuclear structure.
• The shell model and interacting boson model for nuclei.

Prof. Zohar Komargodski

• Particle Physics and Quantum Field Theory

Dr. Doron Kushnir

• Problems within the field of high-energy astrophysics and gravitational waves astronomy. Especially supporting the ideas that:
  • Supernova explosions of type Ia are due to direct collisions of white dwarf stars.
  • Core-collapse supernovae are thermonuclear explosions.

Prof. Yitzhak Maron

• Study of High-Energy-Density Plasmas:
  Collaboration with: Cornell Univ., Princeton Univ., Sandia National Laboratories, Naval Research Laboratory, University of Jena in Germany, HZDR Institute-Dresden, Michigan State Univ., Univ. of CA in San Diego, LLNL-NIF facility
  • Experimental platform: Z-pinch systems, with and without externally applied magnetic fields
  • Development of non-invasive spectroscopic diagnostic methods (from visible to x-rays) for investigating matter under extreme conditions.
  • Development of measurements of high spectral, spatial, and temporal resolutions.
  • Design and build up of fast (ns) and ultra-fast (sub ns) spectroscopic systems.
  • Study of Instabilities and turbulence phenomena.
  • Radiation transport in non-equilibrium plasmas.
  • Conversion of electric and magnetic-field energy into particle kinetic energy and radiation.
  • Close collaboration with Universities and National laboratories in the US (Cornell, Sandia National Laboratory, National Ignition Facility, and Naval Research Labs).
  • Line shape computations in hot and dense plasmas
  • Measurements of ion temperature and turbulence in current driven and radiation driven plasmas
  • Measurements of magnetic fields in current driven implosions and in laser-matter interaction experiments

• High-Power-Laser matter interaction:
  Collaboration with: University of Jena and HZDR-Dresden in Germany, LLNL - National Ignition facility, Sandia National Laboratories.
  • Warm dense matter (solid-state density with temperatures of the order of the Fermi energy) formed by intense laser-matter interaction.
  • Intense-laser-beam guiding by plasma channels.
  • Experiments are performed in major European facilities: Jena University and HZDR - Drezden (Germany), École polytechnique - LULI (France).
• Analysis of x-ray data from NIF

Prof. Giora Mikenberg

• Maintenece and construction of the upgrade of the ATLAS-MUON End-Cap MUON System
• Search for Higgs bosons and SUSY particles at LHC.
  **Collaboration with:** E. Duchovni, E. Gross, L. Levinson, D. Lellouch
• Search for the standard-model and SUSY Higgs-bosons at LEP.
  **Collaboration with:** E. Duchovni, E. Gross, L. Levinson, D. Lellouch

Prof. Mordehai Milgrom

• Departure from Newtonian dynamics as an explanation of the dark-matter problem in galactic systems.
• High energy astrophysics: x-ray sources, gamma-ray sources.
• Black holes at the centers of galaxies

Prof. Alexander Milov

• Detector upgrades for ATLAS and PHENIX
• Collective dynamics.
• Heavy boson production and boson-jet correlations
• Global event characterization
• Analysis of the Heavy Ion data from the ATLAS experiment at the LHC

Prof. Yosef Nir

• Particle cosmology
  • Baryogenesis; Leptogenesis; Dark matter
• Higgs physics
• Flavor physics
• CP violation
• Neutrino physics

Prof. Eran Oded Ofek

• Gravitational lensing and microlensing
• Astronomical algorithms and high contrast imaging.
• Design and construction of W-FAST - Two telescopes system to explore the visible-light sky on sub-second time scales and search for Oort cloud objects.
• Transients and supernovae; shock breakout observations and measuring the properties of supernova progenitors; Eruptions prior to supernova explosions and
interaction between the supernova ejecta and its circumstellar matter; Design of the ULTRASAT UV space telescope.

- Search for isolated black holes in the Galaxy via astrometric microlensing.

Prof. Gilad Perez

- What gives masses to the particles? We believe that it is related to electroweak symmetry breaking which raises the hierarchy problem, the huge gap between the weak and Planck scales. The LHC experiments is addressing some of these questions and at the same time rising new ones. Recent cosmological-observation raised additional puzzles: What is the source of dark matter and energy? We explore experimental and theoretical methods to improve our knowledge regarding these issues. We also propose to use optical atomic clock spectroscopy to Search for Higgs-mediated interactions in atoms at table top experiments
    10.1103/PhysRevLett.120.091801.

Dr. Noam Tal Hod

- Physics analysis with the ATLAS experiment at the LHC (CERN)
  **Collaboration with:** NIKHEF, The University of Michigan, University of Wuppertal
  - Direct tests of lepton universality
  - Search for new physics beyond the standard model in dilepton+X final states
    (heavy resonances, contact interactions, clockwork-like signals, lepton flavour violation)
  - Upgrade of the ATLAS muon spectrometer
    **Collaboration with:** Multiple institutions (mostly from Canada, Chile, Russia, China and the USA)
    - Construction and integration of the sTGC detectors in the New Small Wheel of
• LUXE experiment at DESY
  **Collaboration with:** DESY, Albert-Ludwig Universitaet Freiburg, Max-Planck Institute of Structure and Matter, Helmholtz-Zentrum Jena, Friedrich-Schiller Universitaet Jena, Queens University Belfast, University College London, University of Plymouth, Tel Aviv University, Technion
  • Unparalleled tests of strong-field QED in collisions between high-energy electron/photon beam and high-intensity laser pulses. The Schwinger limit is expected to be reached (at the collision centre of mass frame) for the first time in a clean environment.
  • Development of solid-state detectors for tracking and calorimetry
  • Design, simulation and analysis of the entire experimental setup
  • Probing novel beyond the standard model physics which may be enhanced in the presence of strong-fields, e.g. production of axion-like particles which are associated with solution to many of the outstanding problems in particle physics, and which can be furthermore linked to the origin of dark matter.

*Prof. Igal Talmi*

• Theory of nuclear structure
  **Collaboration with:** Shalom Shlomo, Texas A & M University
  • The shell model, its application and its foundations

*Prof. Itzhak Tserruya*

• Electron pair production in relativistic heavy ion collisions: search for quark-gluon plasma and chiral symmetry restoration.
  **Collaboration with:** I. Ravinovich

• R&D, construction and installation of an HBD (Hadron Blind Detector) for the PHENIX experiment at RHIC.
  **Collaboration with:** I. Ravinovich

• Study of ultra-relativistic heavy-ion collisions using the PHENIX detector at RHIC (Relativistic Heavy Ion Collider) at Brookhaven National Laboratory and the CERES detector at CERN
  **Collaboration with:** I. Ravinovich

*Prof. Vladimir Usov*

• Physical processes in relativistic electron-positron plasma.
  **Collaboration with:** G.Z. Machabeli

• The theory of nonthermal radiation from compact astronomical objects (pulsars, white dwarfs, gamma-ray bursters etc.).
  **Collaboration with:** A.K. Harding, D.B. Melrose, M. Milgrom, A.G. Muslimov, A.E. Shabad
• Physical processes in very strong magnetic fields.  
  **Collaboration with:** A.E. Shabad

• Physical processes at the surface and astrophysical appearance of strange-quark-matter stars.  
  **Collaboration with:** K.S. Cheng, T. Harko, M. Milgrom, F. Weber

• Hydrodynamics and high-energy physics of colliding stellar winds in binary systems.  
  **Collaboration with:** N.N. Pilyugin

**Prof. Eli Waxman**

• Theoretical astrophysics  
  **Collaboration with:** Avishay Gal-Yam, Boaz Katz, Doron Kushnir, Eran Ofek  
  • Cosmic explosions (Fast radio bursts, Neutron star mergers, Gamma-ray bursts, Supernovae)  
  • Plasma astrophysics  
  • Neutrino and cosmic-ray astrophysics  

• The ULTRASAT UV satellite project  
  **Collaboration with:** Sagi Ben-Ami, Avishay Gal-Yam, Eran Ofek, Yossi Shvratzvald

**Prof. Daniel Zajfman**

• Atomic and Molecular Physics  
  **Collaboration with:** Oded Heber  
  • Ion trapping, storage rings, photodissociation, photodetachement, cluster physics.

**Department of Physics of Complex Systems**

*Department Head: Prof. Elisha Moses*

The Department of Physics of Complex Systems has research programs in fundamental and applied physics. Research in optics and atomic physics includes nonlinear optics, ultra fast optics and high harmonic generation, quantum optics, slow light, discrete optics, nano optics and nonlinear microscopy, laser cooling and trapping of atoms and ions, studies of Bose Einstein condensation, precision spectroscopy and quantum information processing. Theoretical and experimental research in soft condensed matter is concentrated on equilibrium and non-equilibrium statistical physics, clustering of data, bioinformatics and systems biology, electrokinetics of ions and charged particles in low dielectric liquids, colloids, soft materials and complex fluids. Experimental and theoretical hydrodynamics concentrates on turbulence, spatio-temporal chaos, turbulent Rayleigh-Benard convection, liquids at interfaces, droplet impact, sedimentation and dynamics of single micro-objects, such as polymers, vesicles, capsules and hydrodynamics of their solutions. Turbulence theory is developed in general and in applications to cloud physics. Classical and quantum chaos, statistics of nodal lines in
quantum systems and turbulence are studied theoretically. Mathematical and computational methods for archaeological research are developed. Theoretical physical biology deals with modeling living information systems, their molecular components and the way they evolve. Experimental bio-physics deals with bio-molecules, neural cultures, neurophysics, physics of the brain, physics of bio-systems and decision making in ant colonies.

**Research activities**

**Dr. Hillel Aharoni**

- Geometry and deformation of soft materials
- Topological defects in liquid crystals
- Wrinkling patterns

**Dr. Rotem Arnon-Friedman**

- Quantum cryptography
  - Device-independent quantum cryptography
  - Quantum key distribution
  - Certification protocols
  - Quantum-proof randomness extractors
- Entanglement theory
  - Non-locality
  - Entanglement certification
  - Entanglement as a resource for quantum cryptography

**Prof. Nir Davidson**

- Ultracold atoms
- Quantum degenerated atomic gases
  **Collaboration with:** Roee Ozeri
- Quantum nonlinear dynamics and chaos
- Laser physics
  **Collaboration with:** Asher Friesem
- Slow and stored light
  **Collaboration with:** Ofer Firstenberg
- Atomic optics and interferometry
  **Collaboration with:** Ofer Firstenberg

**Prof. Eytan Domany**

- Computational Physics: equilibrium and non-equilibrium statistical mechanics of spin glasses
Collaboration with: A. P. Young (UCSC)
• Development of tools and algorithms for large scale data analysis. Bioinformatics.
• Analysis of high-throughput biological data (in particular, gene expression data)

Collaboration with: Several research groups at Weizmann, in the USA and in Europe; see below.
• Controlled experiments on cell lines and mice (with D. Givol, V. Rotter, Y. Groner, L. Sachs; D. Gazit (Hadassa))
• Development of antigen chips, applications for autoimmune diseases (with I. Cohen)
• Studies human cancer samples; leukemia (with E. Canaani; G. Rechavi S. Izraeli (Sheba))
• Colorectal cancer; (with D. Notterman (UMDNJ), F. Barany (Cornell), P. Paty (MSK), A. Levine (Princeton))
• Prostate cancer; (with Z. Eshhar, A. Orr (TA Sourasky));
• Glioblastoma; (with M. Hegi, R. Stupp (CHUV))
• Breast and cervical cancer (with J-P Thiery, F. Radvanyi, X. Sastre, C. Rosty (Inst Curie))

Prof. Nirit Dudovich

• Attosecond Physics
• Strong field light matter interactions

Prof. Gregory Falkovich

• Wave turbulence
  Collaboration with: Natalia Vladimirova, Mlchal Shavit, Vladimir Lebedev
• Theory of fluid turbulence. Fundamental aspects and applications.
  Collaboration with: Anna Frishman, Vladimir Lebedev, Natalia Vladimirova, Bjorn Hof.
• Information theory and non-equilibrium statistics
  Collaboration with: Michal Shavit, Natalia Vladimirova
• Viscous Electronics
  Collaboration with: Leonid Levitov, Andrey Shytov, Andre Geim.

Dr. Ofer Feinerman

• Collective behavior of ants.
• Information sharing in cooperative groups.
• Collective decision making.

Dr. Ofer Firstenberg

• Photon-photon interactions and nonlinear quantum optics using Rydberg atoms
• Atom interferometers
• Atomic sensors
• Quantum memories in hot and cold atoms

Prof. Asher Friesem

• Diffractive Optical Elements and Planar Optics.
• Photonic Devices.
• Novel Laser Configurations.

Prof. Ulf Leonhardt

• Forces of the quantum vacuum
• Analogues of the event horizon
• Geometry and light
• Invisibility cloaking and perfect imaging

Prof. David Mukamel

• Systems with long-range interactions
  **Collaboration with:** S. Ruffo A. Campa
• Collective phenomena in systems far from thermal equilibrium.
  **Collaboration with:** S. Majumdar G. Schehr M. Barma A. Kundu
• Coarsening processes and slow dynamics.
• Systems with long range interactions

Prof. Dan Oron

• sub-diffraction limited imaging
• Quantum dot enabled photovoltaics
• ultrafast dynamics of semiconductor quantum dots
• Optics of biogenic and biomimetic crystals

Prof. Roee Ozeri

• Quantum metrology and precision measurements
• Ultra-cold ions and atoms
• Quantum Computing
• Ultra-cold collisions and interactions

Prof. Adam Schwimmer

• String theory.
• Conformal field theory.
• Dynamics of gauge theory.

Prof. Uzy Smilansky

• Mathematical methods for Archaeological research.
• Semi-classical quantization.
• Chaotic scattering.
• Quantum chaos.

Prof. Joel Stavans

• Statistical Mechanics
• Single-Molecule Biological Physics.
  • RNA interference
  • Homologous recombination
• Genetic Networks and Systems Biology
  • Regulation of gene expression by small RNAs
  • Developmental decision making
  • Noise and adaptation

Prof. Victor Steinberg

• Physical hydrodynamics, hydrodynamics of complex fluids, dynamics of single flexible micro-objects (molecules, membranes, etc) in complex fluid flows

Collaboration with: Prof. G. Falkovich, Prof. V. Lebedev, Prof. Y. Dubief, Prof. H. Stark

• Hydrodynamics of polymer solutions, Elastic turbulence and Turbulent mixing by polymers.
• Hydrodynamics and rheology of complex fluids (vesicle, capsule, worm-like micelle, etc suspensions)
• Dynamics and conformation of single polymer molecule, vesicle, micro-capsule, etc in complex fluid flows.
• Microfluidics: mixing, cell separation, random flows.
• Development of non-invasive local sensors for measurements of stress field in fluid flow
The Department is composed of groups working in mathematics, physics, chemistry, computer science, earth and environmental sciences, life sciences, and science and technology for junior-high school. In all these areas there are extensive research and development projects, aimed at (1) studying science and mathematics learning and teaching and their development, (2) producing and implementing improved and up-to-date learning and teaching materials that integrate the use of modern technologies, and (3) providing professional development for teachers, all over Israel. Work is based on an underlying philosophy that considers curriculum development and implementation, teacher professional development, research and evaluation as an interrelated and continuous long-term activity. Research studies focus on cognitive, socio-cultural and affective aspects of learning, teaching and learning to teach science and mathematics, using various research methodologies: quantitative, qualitative and mixed methods.

The department operates four national centers for science teachers (physics, chemistry, biology and science and technology in junior high school) specializing in; the development of leadership among science teachers and in continuous professional development for science teachers using effective models. Another avenue promoted by the department for professional development of science teachers is carried out through the Rothschild-Weizmann Program for Excellence in Science Teaching, which provides science teachers unique opportunities to expand and update their knowledge in science and in science education. In addition, the department runs numerous Professional Learning Communities of science teachers all over Israel. Projects in the department are funded by the Israel Science Foundation (ISF), the German Israeli Foundation (GIF), the Trump Foundation and the Israeli Ministry of Education through the Amos de-Shalit Israeli Center for Science Teaching (MALAM). In addition, the department is involved in several EU projects aiming at enhancing science education both in the formal as well as in the informal level.

Research activities

Prof. Abraham Arcavi

- Research on cognitive characteristics of non academically oriented math students.
  Collaboration with: Dr. Ronnie Karsenty
- Design of curriculum materials as a research based activity
  Collaboration with: Dr. Sue Magidson
- Long-term design of a new curriculum for grades 10, 11 and 12 for non-academically oriented students.
  Collaboration with: Dr. Nurit Hadas
Prof. Michal Armoni

- Teaching the foundations of computer science to young students
  - Theoretical foundations of computer science
  - Basic concepts in algorithm and program design
- Fundamental ideas in computer science: Identifying the core ideas of the discipline, examining their teaching and learning processes
  - Reductive thinking: Reduction as a tool for problem solving
  - Nondeterminism: a tool for abstraction
  - Reversing
  - Abstraction

Prof. Mordechai Ben-Ari

- Teaching and learning computer science
  
  **Collaboration with:** Francesco Mondada, Ecole Polytechnique Federale de Lausanne
  - Educational robotics
  - Matriculation examinations in mathematics

Prof. Ron Blonder

- Nano scale science and technology education
- Self-efficacy of science teachers

Prof. Ruhama Even

- Mathematics education
  - The relevance of academic mathematics studies to expertise in secondary school mathematics teaching.
  - Using assessment to inform instructional decisions.
  - Examining opportunities for learning mathematics offered by mathematics textbooks.
  - Investigating the interactions among curricula, teachers, and classrooms.
  - Mathematical literacy

Prof. Bat Sheva Eylon

- High school curriculum development
  - Translation and adaptation of selected units from the course "Visual Quantum Mechanics" developed by the Physics Education Research Group in Kansas State University.
  - Preparing texts and materials for elective units for physics majors (lasers, chaos). Using computerized networks (internet and intranet) for distance learning of these courses.
• Development of modules for student activities in Mechanics, Electricity and Magnetism and Optics.
• Development of modules for inquiry learning in the context of "mini-projects".
• Development of a new course on Light and Waves for 10th and 12th grades.
• Development of physics programs for the Arab population.
• Elaboration of the national physics syllabus and the matriculation examinations.
• Preparation of materials for e-learning in mechanics and electricity that can be used in various models that integrate in-class and distance learning of physics.

• Research, evaluation and planning

**Collaboration with:** U. Ganiel

• Research of problem-solving processes in high school physics.
• Study of concept learning and misconceptions in high school physics.
• Study of processes involved in integration of technology in physics learning.
• Formative and summative evaluation of new courses.
• Research and development of various strategies for integration of microcomputers in physics learning processes.
• Investigation of learning processes and teaching methods in teacher training programs.
• Study of long-term professional development of teachers and leader-teachers.

• Application of microcomputers in physics teaching

**Collaboration with:** U. Ganiel

• Development of open environments for promoting physics reasoning and inquiry learning.
• Developing custom made programs for specific learning activities within the physics curriculum.

• Teacher development: National center for physics teachers

**Collaboration with:** E. Bagno, U. Ganiel

• In-service teacher training courses.
• In-school projects for promoting the teaching of physics through the use of computers.
• Long-term didactical courses introducing teachers to current research in physics education and its implications to the learning/teaching process.
• Long-term frameworks for leader teachers: Three-year courses for basic training and forums for acting teacher-leaders.
• Resource materials and frameworks for teacher development.
• An annotated database of selected internet resources relevant to high school physics in Israel (in Hebrew).
• One-day national conference and workshops for physics teachers in Israel.
• A prize for outstanding teachers or teams of teachers (together with the physics department and the Amos de-Shalit fund).

• Preparation of learning materials for 7-9 grade

• Introduction to Science and Technology.
• Vacuum and particles: The particulate model of matter.
• About Fibers
• Interactions, Forces and Motion
• Scientific and Technological Communication.
• Projects as Tools for Learning.
• The Materials' Cycle in Earth's Crust.
• The World of Water.

• Computerized Materials
  • Computerized courses and resources for the teaching the topics of "Energy - a Multidisciplinary View", "Nutrition and Health", "Nature as a Model for Imitation - The Bionic Man".
  • Computer simulations for studying units dealing with "Systems".
  • A Computerized environment for analyzing videotapes of motion.
  • Computer programs accompanying the study of Earth-Sciences in grades 7-9.
  • Computer program accompanying the study of the "cell" as a longitudinal strand (with the Center of Educational Technology).
  • "The Golden Way" - A Navigational Tool for Project Based Learning in Science and Technology (with the Association for the Advancement of Science Education in the Upper Galilee).

• In-service courses in science and technology for junior-high school teachers

  Collaboration with: Z. Scherz, I. Hopfeld, N. Orion, O. Kedem, Y. Ben-Hur
  • Design and implementation of 3-year courses for teachers.
  • Preparation of leading science and technology educators.
  • Conducting regional long term activities in several regional teacher centers.
  • Conducting in-service teacher courses for the Arabic population.
  • A National Teacher Center for Juniour High School Teachers (in collaboration with Tel Aviv University).

• Research and Evaluation

  Collaboration with: Z. Scherz, N. Orion, S. Rosenfeld, U. Ganiel
  • Research on teacher and teacher-leader development in science and technology.
  • Investigation of various instructional strategies for understanding central concepts in the science and technology syllabus for junior-high school, and development of learning and thinking skills.
  • Investigation of project based learning (PBL) focusing on learning styles and the integrated development of concepts and skills.
  • Investigation of longitudinal development of conceptual frameworks and learning capabilities.
  • Investigation of learning through the course "systematic inventive thinking".

Prof. David Fortus

• The Role of Hormones in Shaping Adolescents' Motivation to Engage with Science

  Collaboration with: Yoni Yeshayahu, Head of Pediatrics and Juvenile Endocrinology, Samson Assuta Hospital
  • Hormones
• Parents & Peers
• Science Teaching Practices
• Curriculum
• Assessment
• School Culture & Philosophy
• Policy Implementation

• Systems, Transfer & Fields - A Novel Approach to Energy Instruction
  **Collaboration with:** Joe Krajcik - Michigan State University Knut Neumann - Leibniz Institute for Science and Mathematics Education (IPN), Germany Jeff Nordine - Leibniz Institute for Science and Mathematics Education (IPN), Germany
  • energy
  • curriculum
  • assessment
  • preparation for future learning (PFL)
  • NGSS
  • self-efficacy

• Coronavirus Driven Study - Supporting Student Motivation in Hybrid Learning Environments
  • Motivation
  • Self-efficacy
  • Pedagogical Practices

**Prof. Avi Hofstein**

• Research and evaluation
  **Collaboration with:** R. Mamlok
  • Formative and summative of curriculum units that are developed by the chemistry group and the science for all students
  • Teachers' and students' perceptions and attitudes towards science and technology.
  • Non science oriented students' conception of key ideas and concept in chemistry
  • The development of modules for non-science oriented students
  • Analysis of learning difficulties and misconception in chemistry in the Israeli Bagrut
  • Development of argumentation skills in inquiry laboratories
  • Misconception regarding bonding and structure of molecules
  • Assessment of students' perception of the chemistry classroom and laboratory learning environment

• High school chemistry curriculum development and implementation
  **Collaboration with:** Rachel mamlok-Naaman,
  • The development and implementation of text books and teachers' guide
  • Preparation of resources and units for the teaching of Industrial chemistry in Israel.
  • Development of new instructional techniques to teach chemistry in high schools.
  • Inquiry type experiments and
• The use of internet for instruction.
• Development of CAI (computer Assisst Instruction)
• Development of introductory (basic) modules for a new syllabus in high school chemistry.
• Development of modules for non-science oriented students in high schools

Prof. Nir Orion

• Earth and environmental sciences education: research, development and implementation from K-12.
• The outdoor as a learning environment

Prof. Anat Yarden

• Promoting the use of authentic scientific texts in secondary schools
  Collaboration with: Prof. Zohar Livnat, Bar-Ilan University
• Using bioinformatics tools and databases for learning biology and biotechnology in high schools
• Developing coherent understanding of molecular genetics and evolution
  Collaboration with: Prof. Ravit Golan Duncan, Rutgers University
• Advancing biology teachers’ professional development
  Collaboration with: Dr. Irit Sadeh, Ministry of Education
• Collective reasoning around texts across disciplines towards deliberative democracy
  Collaboration with: Prof. Baruch Schwarz, Hebrew University; Prof. Boris Koichu, WIS; Prof. Michal Tabach, Tel-Aviv University; Dr. Einat Heyd-Metzuyanim, Technion

Prof. Edit Yerushalmi

• Development implementation and evaluation of a 2-year interdisciplinary program for high school chemistry and physics students on
• Instructional strategies intended to develop reflective problem solving skills in high school physics students
  Collaboration with: C. Singh, E. Cohen, E. Bagno, B. Eylon
• Study of the effects of self-diagnosis tasks on learning from physics problem solving.
• Development, implementation and evaluation of web-based test preparation modules aimed at organizing students’ knowledge and developing awareness of common misconceptions (Mechanics, Electricity and Magnetism).
• Development, implementation and research of long-term professional development frameworks for physics high school teachers
  Collaboration with: R. Safadi, E. Bagno, A. Rozen
• Workshops for Arab high school physics teachers intended to develop reflective problem solving skills in their students through alternative assessment activities. Workshop approach: Collaborative inquiry into students' self diagnostic activities.
• Models for collaborative action research workshops for high school physics teachers.
• Long-term didactical courses introducing pre-service teachers to current research in physics education and its implications to the learning/teaching process.
• University physics faculty perceptions of learning and teaching problem solving. **Collaboration with:** C. Henderson, K. Heller, P. Heller, V. Quo, E. Cohen