

PhD Program in Bioengineering and Robotics

Curriculum Bionanotechnology

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The Bionanotechnology curriculum is related to basic and applied research programs oriented to (i) the comprehension of fundamental biological phenomena mechanisms at the nanoscale, and (ii) the development of novel technologies and methodologies that take advantage of nanoscale phenomena and/or operate at the nanometer scale. Bionanotechnology covers a broad field of applications, namely: from cells-to-chip and chip-to-cells technologies to nanobiosensors, from nanodiagnosics to advanced nanoscale characterization and imaging tools, from intelligent drug delivery to engineered functional nano-addressable surfaces.

Scientific and technological activities related to the PhD course include:

- the exploitation of nanofabricated structures as building blocks for engineered self assembly architectures across multiple length scales, from the molecular level up to the macroscopic world
- the development of new strategies based on micro- and nano-manufacturing to produce new microsystems and scaffolds with dimensions comparable to cells
- the design, development, and use of advanced methodologies and instrumentations within the framework of optical spectroscopy and micro- nano-scopy, scanning force microscopy, oriented to the nanoscale characterization of biological and hybrid materials/specimens
- the development of new strategies for the assembly of nano-particles able to realize nanostructured environments
- the development of architectures for multi-scale and multi-dimensional characterization of materials, both artificial and biological. Scales ranging from single molecules to cells, tissues, organs, up to the human body. Dimensiones from a 2D (x,y) to a 4D (x, y, z, t) space.
- the development of new materials based on polymers to produce smart multifunctional devices easily processable at scalable-low cost, with a wide range of exciting and outstanding applications.
- the development of all-polymer and/or polymer nanocomposites with tailored properties capable to control, among others, surface wettability, mechanical properties, and antibacterial activity.

International applications are encouraged and will receive logistic support with visa issues, relocation, etc.

1. Development and characterization of magnetic polymer composites

Tutors: [Despina Fragouli, Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: Magnetic polymer nanocomposites are smart and functional materials with physical properties that can be instantaneously and reversibly controlled by an external stimulus. They possess a synergistic performance of the embedded particles and the polymer combined together, preserving the properties of the individual components, and exhibiting characteristics that would not be possible otherwise. They have numerous potential applications, such as biotechnology (e.g. magnetic hyperthermia), sensing, actuation, vibration absorbing technology etc.

Applications are invited for a PhD position in the development and characterization of magnetic polymer-based nanocomposites. The objectives of the project will be the development of a fabrication technology for magnetic polymer nanocomposite structures either free standing as individual components or embedded on polymer films. The developed systems will take advantage of the magnetic properties of the nanocomposites in order to be utilized for:

- a. long distant actuation: micro or nano magnetic stirrers for the mixing or characterization of liquids, micro or nano needles for hyperthermia applications or controlled transport of substances, magnetically deflected membranes for the controlled release of substances or for controlled actuation systems.
- b. magnetic collectors or detectors of diverse substances from biological or environmental applications.

The polymers will be of natural or synthetic origin, and the magnetic fillers of diverse physical properties and morphologies will be directly mixed in the polymer solutions or in the prepolymers. The combined processes of polymer curing and external magnetic fields will give to the final systems the desired characteristics. In fact, the utilization of external stimuli like light, heat, magnetic field during nanocomposite formation will offer to the final system specific surface and physical properties such as magnetic, or mechanical anisotropy, surface morphology and structure. The characterization of the multi-scale structures will be done with various microscopic techniques, together with the characterization of the physical properties such as thermo-mechanical, magnetic, using simple or sophisticated instrumentation the IIT provides.

Requirements: The candidate must have a Bachelor's Degree in one of the following areas: Physics, Materials Science, Chemistry, or Engineering.

background in physics, materials science, chemistry, or engineering. Previous experience on magnetic or polymeric materials will be highly appreciated.

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2. Development of polymeric functional foams and textiles for environmental applications

Tutors: [Despina Fragouli, Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: The increase of the human population and of the quality of life and technology results in the parallel increase of the environmental pollution. Therefore the environmental remediation of air, water, and soil is of great research interest and a significant scientific effort is focused on the development of new materials for the detection and removal of various organic and inorganic pollutants from diverse environments.

The objectives of the project will be the development of simple and easily scalable fabrication technologies for the formation of smart foams and textiles. Such materials should have special surface and bulk properties such as wettability, chemistry and morphology and will be used as detectors and absorbers of organic or inorganic pollutants in water (e.g. oil, nitrates, heavy metal ions) and/or in other specific environments such as polluted air (e.g. acid and solvent fumes) or in soil (e.g. pesticides). The formation of the smart porous structures will be done by simple template techniques, freeze drying, electrospinning, emulsion processes etc. utilizing polymers of synthetic or natural origin, while functional nanoparticles, organic molecules or fillers etc. will offer to the final system the desired characteristics. The full characterization of the final material will be done by investigating the surface and bulk properties in terms of chemistry, morphology and thermomechanical properties while dedicated experimental methods will be developed for the investigation of the ability to detect and entrap the pollutants.

Requirements: We are looking for a motivated young scientist with novel and creative ideas, focused and determined for the development and characterization of functional polymeric foams and textiles for environmental applications such as water, air, or soil remediation and smart detectors. The ideal candidate must have a Bachelor's Degree in one of the following areas: Material Science, Chemistry, Engineering or Physics. Previous experience on composite or polymeric materials and porous structures will be highly appreciated.

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3. Development of Polymer Nanocomposites with in-situ Synthesis of Nanocomposites for Environmental and Biological Applications

Tutors: [Despina Fragouli, Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description:

Applications are invited for a PhD position in the development of polymer nanocomposites, based on the *in-situ* synthesis of nanoparticles (NPs). The synthesis of inorganic NPs by using a polymer matrix as chemical reactor has led to the development of a novel class of nanocomposite materials, where the nucleation, growth and organization of the functional particles of interest is controlled by the polymeric network and by the applied external energy source. A wide variety of NPs can be *in-situ* synthesized, such as gold, silver, platinum, palladium, zinc or iron oxides etc. This class of polymer nanocomposites have attracted a great deal of attention because of their application in gas sensing, biosensors, enzyme reactors, immunoassays and biochemical analysis.

The research activity of the project will be mainly focused on the investigation of the *in-situ* synthesis of NPs within synthetic and natural polymers that include elastomers, acrylates and polysaccharides. Particularly, the chemical-physical mechanism at the basis of the NPs formations will be investigated, and properly controlled in order to create nanocomposites with specific properties. The produced matrix will be employed for the realization of systems of different morphologies such as films, porous structures (foams, membranes) microfibers and microdroplets with advanced functionalities. The characterization of the final structures will be carried out by means of microscopic, mechanical, and chemical analysis. Finally, the novel material will be employed in the realization of devices for the detection and immobilization of antigens, enzymes and other biomolecules in microreactors, or gas detectors and sensors.

Requirements: background in chemistry, materials science, engineering, physics or related disciplines. Attitude for problem solving and previous experience on composite or polymeric materials will be highly appreciated..

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4. Nanofabrication of composite biopolymers for intelligent wound management

Tutor: [Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description:

Applications are invited for a PhD position in the development of composite biopolymers in the form of membranes, nanofibers, or nanoparticles, realized by nanofabrication strategies, for controlled drug delivery to be applied in intelligent wound management.

The project intends to create a new generation of polymer-based hosts that will be able to deliver selective active principles in a controlled way for application in wound management for personalized healthcare. To this aim, natural compounds, such as biodegradable biopolymers and plant extracts, will be used, due to their properties of biocompatibility, low toxicity, biodegradability and environmental sustainability. The project will involve the processing of composite and nanocomposite polymeric materials by techniques including electrospinning, mini-emulsions, flow-focusing microfluidic systems, spray, and chemical synthesis methods. The candidate will gain experience in a range of characterization techniques, including morphological, chemical, thermo-mechanical, and biological analysis. These will include scanning electron microscopy, atomic force microscopy, dynamic light scattering, Infrared and Raman microscopy, antimicrobial and biocompatibility tests. Interaction with collaborating academic groups and industrial partners working in this area can be expected, as well as attendance at international conferences.

Requirements: background in chemistry, biochemistry, biotechnology, bioengineering, materials science, physics or related disciplines. and previous experience on or polymeric materials will be highly appreciated..

Bachelor Degree in one of the following areas: Material Science, Biotechnology, Bioengineering, Chemistry, Physics or a closely related discipline. Attitude for problem solving and previous experience on biopolymer composites, micro- and nano-fabrication procedures, and generation of micro- and nanoparticles will be highly appreciated.

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5. Nano-emulsion Processing of Biopolymers

Tutors: [Ilker S. Bayer, Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: The student is expected to develop new biodegradable polymer composites using emulsion technology. The main focus of this doctoral project will be to produce novel bio-plastic blends from immiscible hydrophobic and hydrophilic polymers that are renewable or natural. Bio-polyesters or similar biodegradable hydrophobic polymers to be dispersed in an oil phase will be emulsified with water soluble natural polymers such as alginates or chitosan. The student is expected to develop an expertise in emulsion preparation and stabilization and producing polymer films from these emulsions. The emulsions will be functionalized with drugs or natural extracts in order to render them bioactive suitable for various biomedical technologies. Detailed characterization experiments including rheology will be conducted in order to assess the properties of the developed bio-polymers. Characterization techniques will include but not limited to microscopy, FTIR, Raman, XRD, mechanical tests, surface wetting and drug release dynamics. Strong collaboration with other research groups within the Smart Materials group at IIT will be necessary.

Requirements: background in polymer science, colloidal science, chemistry, materials science, or chemical engineering. A positive attitude for problem solving and interest in understanding/learning basic polymer chemistry are desirable.

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6. Intelligent Liquid Repellent Nano-composite Surfaces

Tutors: [Ilker S. Bayer, Athanassia Athanassiou](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: Applications are invited for a PhD position in the development of intelligent polymer-based nano-composite surfaces for manipulating liquids. The study will involve development of mechanically robust liquid repellent coatings which can resist many cycles of abrasion damage. After rendering the surfaces mechanically robust, further study will be conducted to induce a degree of smartness. This will be in the form of thermo-responsive effects, pH response, on demand modification of liquid repellency, self-healing as well as tuning lubrication and adhesion characteristics. The student will utilize a mix of hydrophobic polymers with nanoparticles to produce the composites and will characterize the wetting and adhesion properties. Layer-by-layer coating approach will also be implemented. Infusion of oils and ionic liquids into these surfaces will be studied in order to produce self-cleaning surfaces against many organic liquids. The candidate will gain experience in a range of characterization techniques, including morphological, chemical, thermo-mechanical, and tribology and adhesion. These will include scanning electron microscopy, atomic force microscopy, dynamic light scattering, and Infrared and Raman microscopy, lubrication and wetting. Interaction with collaborating academic groups and industrial partners working in this area can be expected, as well as attendance at international conferences.

Requirements: Bachelor Degree in one of the following areas: Material Science, Physics, Chemistry or polymer science. Previous experience on polymeric materials processing of nanoparticles, and coating technologies will be highly appreciated.

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7. Single Molecule Detection: the ultimate biosensor issue

Tutors: [Andrea Toma](#), [Francesco De Angelis](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: The fabrication of nanostructures for extremely large electric-field enhancement has become increasingly important over the last few years with the aim to detect molecules in highly diluted liquids, and/or to record the Raman spectra of a single molecule. Within this context, the realization of complex 3D plasmonic nanostructures integrated in cutting-edge devices represents a multidisciplinary key activity at the core of most research efforts in nanoscience and technology. PhD activity will demonstrate the possibility to conceive and realize innovative 3D metallic nanostructures, endowed with multi-tips and decoupled from the substrate by means of standing silicon pillars. The proposed architecture can offer new and unconventional properties such as the realization of giant electric field confinement and enhancement in a multi-spots bio-sensing platform. The possibility to increase the device active regions will improve the overall spatial efficiency leading to interesting perspectives not only in SERS but also in hyperspectral Raman imaging. The proposed work is part of a research project devoted to the innovative fabrication and optical characterization of complex plasmonic nanostructures made of noble metals with various shapes and spatial arrangements. The candidate will acquire a good clean room expertise combined with spectroscopic characterization (both in the VIS and IR spectral range), working in a multidisciplinary environment across nanofabrication and nano-optics.

Requirements: Candidates should have a M.D. in Physics, Material Science or Engineering, better if accomplished with a good background in electron beam lithography technique and/or FTIR measurements.

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8. Plasmonic nanostructures for all-optical computing

Tutors: Andrea Toma, Francesco De Angelis

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: Optical computing is a new coming field dealing with data manipulation for ultra-fast communication technology. In the attempt of improving the operational capacity of photonic circuits, plasmonics can offer an elegant way for fastening data-elaboration units without signal dispersion. PhD activity will demonstrate the possibility to conceive and realize innovative plasmon-assisted optical logic gates. Basing on the concepts of bonding/anti-bonding and bright/dark plasmonic modes, it will be possible to design and completely characterize the far-field behavior of such devices paving the way for ultrafast signal manipulation and/or multiplexing.

The candidate will acquire a good clean room expertise combined with spectroscopic characterization (both in the VIS and IR spectral range), working in a multidisciplinary environment across nanofabrication and nano-optics.

Requirements: Candidates should have a M.D. in Physics, Material Science or Engineering, better if accomplished with a good background in electron beam lithography technique and/or FTIR measurements.

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9. Nanostructured surfaces for Neuronal Networks Interfaces

Tutor: [Francesco De Angelis](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: Research on human neuronal signaling is the subject of a very large community, but progresses face a dense multi-scale dynamics involving signaling at the molecular, cellular and large neuronal network levels. Whereas the brain capabilities are most likely emerging from large neuronal networks, available electrophysiological methods limit our access to single cells and typically provides only a fragmented observation, on limited spatial/temporal scales. We propose the development of an innovative electro-plasmonic platform will provide a radically new path for real time neuro-interfacing.

This is achieved by exploiting an innovative nanofabrication method able to realize 3D nanostructures which can work at the same time as nanoelectrodes and as amplifiers for spectroscopic signals. These structures will be integrated on CMOS multi-electrode arrays designed to manage multi-scale measurements from the molecular level up to network level on several thousand of measurement sites.

Requirements: This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Electronic Engineering or similar. Background in Biophysics is strongly appreciated.

Contact: francesco.deangelis@iit.it

10. Driving molecules at the nanoscale

Tutor: [Francesco De Angelis](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: The detection of few molecules from highly diluted solution is of extreme interest in different fields such as biomedicine, safety and eco pollution from rare and dangerous chemicals. Nanosensors cannot directly be used for detecting molecules dissolved in femto/atto molar solutions because of the so called “diffusion limit”. In other words, they are diffusion limited and their detection performance becomes unpractical at those concentrations. To overcome this limitation, molecules of interest, initially dispersed in solution, can be guided toward the active area of the sensors exploiting superhydrophobic and superoleophobic surface. By combining plasmonic nanosensors with hydro/oleo-phobic surface unprecedented sensitivity levels can be reached, and the problem of detection of highly diluted sample can be faced radically.

Requirements: This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Chemistry or similar.

Reference: F. De Angelis et al., Nature Photonics, 2011, 5, 682-687.

E. Miele et al, Advanced Materials, 2014, DOI: 10.1002/adma.201400310.

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11. Novel systems for intracellular nano-delivery

Tutor: [Francesco De Angelis](#)

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

The delivery of molecules (drugs, DNA, RNA, or nanoparticles) into the intracellular compartment is one of the fundamental requirements of the current molecular biology. The main difficulties are related to the impermeability of the plasma membrane that regulates the trafficking in and out of the cell. A large variety of techniques have been developed for introducing foreign material into the cytoplasm. Most common approaches are electroporation, chemical transfection, and virus-mediated transduction which are all capable of transforming large populations of cells in an untargeted manner, whereas microinjection enables single-cell selectivity at the cost of invasiveness and decreased throughput. Despite the general effectiveness of these methods, there are numerous limitations. In this research project we propose to develop an in vitro platform for delivering any molecule into the intracellular compartment with single cell selective control and high parallelization potential. The physical method is based on a combination of concepts and tools coming from different areas of Physics, Biology and Nanotechnology, such as nanofabrication techniques, plasmonics, laser nano-surgery, and microfluidics. The developed platform will be able to manage large ensembles of cells as well as single targeted cells. Single cell technologies can provide new and exciting experimental opportunities for unveiling cell individuality that is hidden in experiments carried out on large ensemble.

Requirements: This research theme strongly relies on nanofabrication advanced techniques and candidates should have a master in Physics, Chemistry or similar. Base knowledge in biochemistry or supramolecular chemistry is a plus.

Contact: francesco.deangelis@iit.it

12. Novel nano-size materials for energy storage

Tutors: Remo Proietti Zaccaria, Claudio Capiglia

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: This interdisciplinary project aims at the development of novel materials specifically designed for energy storage. The candidate will exploit both bottom-up and top-down fabrication techniques for the fulfilment of his/her tasks, together with deep electrochemical characterization.

As important task to improve the electrochemical properties of the fabricated materials, the candidate will be requested to elaborate simple mathematical structural modelling to be verified with experimental data. Prior knowledge of Comsol FEM software will be considered an advantage

Requirements: Applicants should hold a master degree within a relevant discipline. A suitable background would be, physics, chemistry, engineer, material science, electrochemistry or similar. Experience with electrochemistry and programming will be favourable. Publications and any other work the applicant wishes to be taken into account must be enclosed. Joint works will be considered provided that a short summary outlining the applicant's contributions is attached.

The application must include a statement of purpose related to the present call. This statement should be precise and brief, and states the candidate's academic and research interests. The applications must also include a motivation letter, CV, diplomas, and reference letters.

Contacts: remo.proietti@iit.it; claudio.capiglia@iit.it

13. Computational approach for Li-ion battery storage

Tutors: Remo Proietti Zaccaria, Claudio Capiglia

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: This project aims to the development of in-house computational model for the design and modelling of Li-ion batteries. The selected numerical method is based on the Finite Element Methods, this matching with the goal of realizing a device-oriented computational model.

The candidate will strongly interact with colleagues working on the experimental aspects of Li-ion batteries, in order to experimentally validate the theoretical model.

Requirements: Applicants should hold a master degree within a relevant discipline. A suitable background would be, physics, chemistry, engineer, material science, electrochemistry or similar. Experience with programming is mandatory (the knowledge of Comsol will be an advantage), while experience with electrochemistry will be favourable.

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14. Photon Enhanced Thermionic Emission

Tutor: Remo Proietti Zaccaria

Department: Nanophysics (IIT)

<http://www.iit.it/en/research/departments/nanophysics.html>

Description: The present project aims to the theoretical development of devices for energy harvesting based on both photovoltaics and thermionic emission, in short PETE. In particular, three issues will be investigated: i) exciton transport in semiconductors; ii) charge transfer of electrons in a vacuum chamber; iii) electrons absorption at the anode face. In fact, the overall PETE device comprises of three key elements, cathode, vacuum chamber and anode. The cathode plays the role of harvesting photons for the generation of excitons (photovoltaics), the vacuum chamber transfers the thermo-emitted electrons from the cathode to the anode (thermionic emission), while at the anode side the electrons are collected for the generation of current. Considering the different physics involved in a PETE device (i.e. photon-exciton coupling, electrons transport in semiconductors, electrons in a vacuum chamber) a multiphysics modelling based on FEM numerical technique will be developed.

Requirements: Applicants should hold a master degree within a relevant discipline. A suitable background would be, physics, chemistry, engineer, material science, electrochemistry or similar. Experience with programming is mandatory (the knowledge of Comsol will be an advantage).

Publications and any other work which the applicant wishes to be taken into account must be enclosed. Joint works will be considered provided that a short summary outlining the applicant's contributions is attached.

The application must include a statement of purpose related to the present call. This statement should be precise and brief, and states the candidate's academic and research interests.

The applications must also include a motivation letter, CV, diplomas, and reference letters.

Contact: remo.proietti@iit.it

15. Nanostructured hybrid, organic and bio-materials for unconventional computing

Tutor: [Laura Pastorino](#)

Department: DIBRIS (University of Genova)

<http://www.dibris.unige.it>

Description: Living beings analyze information and perform calculations in a very way different with respect to that used by now available computers. Chemical and bio-inspired computers are based on non-linear chemical and electrochemical reactions, such as that take place in living beings. In the case of bio-inspired computers, the basis material can be of different nature: both organic and inorganic. The main feature of such approach is the realization of bio-mimicking elements. The proposed project is focused on interfacing simple living organisms, such as slime mold systems, and colloidal nanoengineered containers with artificially made devices and circuits. It is intended to control the response of such systems with respect to external stimuli in physical, chemical, and biological media. Novel computational techniques and working prototypes of nonlinear element-based computers will be developed.

Requirements: background in bioengineering, chemistry, physics, materials science or related disciplines.

Reference: Nanoengineered polymeric capsules as elements of unconventional computing systems, Erokhina, S, and Pastorino L., *physica status solidi (c)*, 12, 175–180, (2015).

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16. Nanoscale electro-mechanical characterization of muscle cells

Tutor: [Roberto Raiteri](#)

Department: DIBRIS (University of Genova)

<http://www.dibris.unige.it>

Description: The project aims at the development of novel experimental techniques and methodologies to characterize the electro-mechanical properties of single cells in order to explain the molecular mechanisms that are at the basis of cell mechano-transduction and are responsible of several degenerative processes and, eventually, pathologies such as muscular dystrophies.

The candidate will couple different techniques, namely, atomic force microscopy, electro-actuated elastomer films, micro- and nano-electrodes, as well as optical microscopies to directly assay mechano-signaling in single myofibers. The work will be done in collaboration with muscle (both skeletal and cardiac) physiologists. The successful candidate will establish novel techniques that have potential broad applications in biophysics and bioengineering, such as nanoscale (in both X-Y and Z directions) visco-elastic characterization, and nanoscale extra- and intra-cellular electrical measurements.

Requirements: background in bioengineering, biophysics or related disciplines. Attitude for developing experimental setups and for problem solving. Interests in understanding/learning muscle physiology.

References: Khairallah RJ *et al.* "Microtubules underlie dysfunction in Duchenne muscular dystrophy" *Science Signaling*, 5(236):ra56. (2012); Saenz Cogollo J *et al.* "A new integrated system combining atomic force microscopy and micro-electrode array for measuring the mechanical properties of living cardiac myocytes" *Biomed. Microdevices*, 13(4), 613-21 (2011).

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