FACILITIES AND OTHER RESOURCES:

CENTER FOR ADVANCED RESEARCH TECHNOLOGIES (CART)

8 CART shared resource laboratories
43 staff members to support research
415 principal investigator collaborations in 2022
1,622 total publications supported

Leadership: Timothy Bushnell, Ph.D., MBA, Director, Center for Advanced Research Technologies

Resource	Director	Equipment	Website
Biosafety Level 3 (BSL-3)	Martin Pavelka, Ph.D.	• Four class II biohazard hoods • Pass-through autoclave • Stationary air and CO2 incubators, shaking incubator • Centrifuge with micro-, low-speed, and high-speed rotors • Electroporator • Visible light spectrophotometer • Tissue homogenizer • Sonicator • Inverted microscope • -80 freezer and liquid nitrogen storage unit • Cell lysis equipment	https://www.urmc.rochester.edu/research/bsl3-core/instrumentation.aspx
Center for Advanced Microscopy & Nanoscopy (CALMN)	V. Kaye Thomas, Ph.D.	• Abberior STED • Nikon A1R HD with TIRF • Leica DMi8 • Olympus FVMPE-RS with 2 lasers • Olympus FV1000 LSM • Zeiss Palm MicroBeam Laser Microdissection • Keyence BZ-X800 Epifluorescence Microscopes • Imaris and Amira/Avizo for Image Analysis • Luxendo MuVi SPIM LS	https://www.urmc.rochester.edu/research/center-advanced-light-microscopy-nanoscopy.aspx
Cold Storage Core (CSC)	Christopher Lane	• -80C/-20C/+4C Storage Units • Resident Storage Units • Long-Term Partial Storage Units • Controlled Access Area • Alarm Point / Emergecny Power	https://www.urmc.rochester.edu/research/cold-storage-core.aspx
Electron Microscopy Resource (EMR)	Karen Bentley, M.S.	• Hitachi 7650 III Analytical Scanning/Transmission Electron Microscope • Thermo Scientific Cryo-EM Microscope Talos L120C • Scanning Electron Microscope Zeiss Supra 40VP Field Emission	https://www.urmc.rochester.edu/research/electron-microscope.aspx

		• Leica EM-GP2 Plunge Freezer • Leica UC7 Ultramicrotome • RMC PowerTome Ultramicrotome • Olympus stereo photo microscope • 2 Olympus double-headed light microscopes • Pelco Easi-glow	
Flow Cytometry Resource (FCR)	Matthew Cochran, M.S.	• BD C6+ • BD LSRII • BD LSR-Fortessa • BD Symphony A1 • Cytek Aurora • Fluidigm Helios • BioRad Bioplex200 • Luminex Image Stream • Nexcelom Celigo S • Malvern NS300 • Agilent Seahorse • BD FACSAria II • BioRad S3e • Amnis ImageStreamX Mark II	https://www.urmc.rochester.edu/research/flow-core/services/instruments/analysis.aspx
Genomics Research Center (GRC)	John M. Ashton, Ph.D., MBA	• Illumina NextSeq 2000 • Illumina NovaSeq 6000 high-throughput DNA sequencer • Illumina NextSeq550 DNA Sequencer • Illumina MiSeq DNA sequencer (x2) • C1 Single-Cell Auto Prep System • 10X Genomics Chromium Controller (x2) • Sage Science Pippin DNA size fractionation system (x2) • QX100 Droplet Digital PCR System • ABI QuantStudio 12K Flex Real-Time PCR System with autoloader and microfluidic card module • ABI 9700 PCR machine (x2) • BioRad DNA Engine PCR machine (x2) • BioRad C1000 Thermocycler (x6) • Perkin Elmer SciClone liquid handling robot for NGS library construction • Eppendorf 5070 liquid handling robot for qPCR setup	https://www.urmc.rochester.edu/research/rochester-genomics-center.aspx

		• Eppendorf 5075 liquid handling robot for library construction automation • Covaris E220 sonication system • Agilent 2200 TapeStation System • Agilent 2100 Bioanalyzer (x2) • one Agilent Fragment Analyzer • BioRad gel documentation system • Qubit fluorometer • Multiple NanoDrop ND-1000 spectrophotometers.	
Mass Spectrometry Resource (MSRL)	Sina Ghaemmaghami, Ph.D.	• Fusion Lumos Tribrid Orbitrap • Q Exactive Plus Hybrid Quadrupole-Orbitrap	https://www.urmc.rochester.edu/research/mass-spectrometry.aspx
Metabolomics Resource (MRB)	Bradley Smith, Ph.D.	• Orbitrap Exploris 240 • Vanquish Flex UPHLC	

Overview and environment: The University of Rochester School of Medicine and Dentistry (URSMD) is committed to providing and supporting Shared Research Laboratories (SRL) and Shared Research Resources (SRR) to support the research mission of the URSMD investigators in basic, translation and clinical research. These facilities cut across all departments and centers, and in 2012 were brought together as the Center for Advanced Research Technologies (CART) under central leadership and administration. Over the last 8 years, the SRL and SRR have been a key component of the URSMD strategic plans. This can be highlighted by the continued subsidized support of the operation of these facilities, (~$1.5 million for FY2022), as well as a major commitment to support the acquisition of new instrumentation and resources, highlighted by over $5M commitment of new resources and renovation of lab space from over the last five years.

New equipment and research enhancements: In the past several years, using a combination of institutional commitment and grant support, the Center for Advanced Research Technologies have seen significant improvements and enhancements of the tools available to support the research mission. These recent enhancements include:

2018 - Genomics Research Center increases sequencing capacity with purchase of a new Illumina NovaSeq 6000 DNA sequencer
2018 – Acquisition of the Illumina Novaseq6000 with internal funds to enhance the Genomics Research Center.
2018 – NIH S10 grant (PI: Yule) for the acquisition of an Abberior STED microscope for the Center for Light Microscopy and Nanoscopy
2018 – NIH S10 grant (PI: Ghaemmaghami) for the acquisition of a ThermoFisher Fusion Lumos Tribrid Mass Spectrometer for the Mass Spectrometry Resource.
2018 - Acquisition of a Bio-Rad S3e cell sorter for the Flow Cytometry Resource with funds from the Wilmot Cancer Institute
2019 – Acquisition of the Agilent Seahorse XFe96 Analyzer for the Flow Cytometry Resource with funds from the Environmental Health Sciences Center.
2019 – Institutional support for the acquisition of a FEI 120kV cryoEM system for the Electron Microscopy Resource. Installed May, 2020.
2019 – Institutional support for the acquisition of a Cytek Aurora Spectral Analyzer for the Flow Cytometry Resource. Installed January, 2020.
2019 – New York State Grant (PI: Land) for the acquisition of a Nikon A1R scanning confocal microscope with TIRF for the Center for Light Microscopy and Nanoscopy.
2019 - New York State Grant (PI: Land) for the acquisition of a 10x Genomics Chromium Controller, a Covaris E220 focused ultrasonicator and an Illumina NextSeq 550 sequencing system for the Genomics Research Center
2019 - Genomics Research Center sunsets its Illumina HiSeq2500T DNA sequencer and purchases a new Illumina NextSeq550 DNA Sequencer as its replacement to add flexibility and quicker turnaround time.
2019 - Genomics Research Center increases single-cell genomics capacity and capability with purchase of a full 10X Genomics Chromium Controller
2019 - Genomics Research Center increases NGS library construction capacity with purchase of a Perkin Elmer SciClone liquid handler for automated library construction
2020 – Flow Cytometry Resource upgrades to the Helios mass cytometer with institutional funds. Installed January 2021
2021 –The Shared Resource Laboratories are consolidated into the Center for Advanced Research Technologies.
2021 – Electron Microscopy Resource installs a new Leica ultramicrotome with institutional funds.
2021 – Flow Cytometry Resource acquires the BD Bioscience Symphony A1 flow cytometer with institutional funds.
2021 – Center for Light Microscopy and Nanoscopy acquires a Leica Stellaris confocal microscope with white light laser using institutional funds. Installed March 2022
2021 – Flow Cytometry Resource acquires a 5-laser Cytek Aurora Spectral Analyzer via a New York State Grant.

2021 - Genomics Research Center upgrades nucleic acid QA/QC technologies with acquisition of a new Agilent TapeStation 4200 system
2021 - Genomics Research Center diversifies spatial transcriptomics service offering with purchase of a NanoString GeoMx spatial profiler platform
2022 - Genomics Research Center upgrades high-performance computing infrastructure with purchase of 57 state-of-the-art compute nodes
2022 – Genomics Research Center launches burst capable Cloud computing infrastructure (AWS, AZURE) in partnership with CIRC to significantly reduce data analysis time and explore AI/ML methodology for advanced bioinformatic analyses
2022 - NIH S10 grant (PI: Thomas) for the acquisition of the Luxendo MuVi Light Sheet Microscope for the Center for Advanced Light Microscopy and Nanoscopy. Installation planned March, 2023
2022 – Flow Cytometry Resource acquires the Luminex Amnis ImagestreamX Gen2 with NYFirst grant and institutional funds
2022 – Flow Cytometry Resource acquires the BD Biosciences FACSymphony A1 with institutional funds
2022 – Genomics Research Center acquires NextSeq2000 with institutional funds.

Shared Resource Laboratories (part of the Center for Advanced Research Technologies)

The UR Medical Center has a number of successful core research facilities that provide services to all researchers at the Medical Center as outlined above. More details on each facility are below:

- **Biosafety Level 3 (BSL-3) Facility.** *Director: Martin Pavelka, Ph.D.* The Biosafety level three facility (BSL-3) is available for the use of any researcher at the university whose work requires manipulation of biological agents which may cause serious or potentially lethal disease as a result of exposure by the inhalation route (such as TB). The BSL-3 Core laboratory is a fully self-contained facility and includes 4 biosafety cabinets, several incubators as well as -80 freezers and a liquid nitrogen storage tank. Additional equipment includes a tabletop centrifuge with high and low speed rotors, an inverted microscope (Olympus CK40), a plate reader, a fluorescent imaging system, a sonifier, visible light spectrophotometer, electroporator, and cell lysis equipment.
- **Center for Advanced Light Microscopy and Nanoscopy.** *Director: V. Kaye Thomas, Ph.D.* This resource provides UR researchers the ability to obtain high quality imaging data using state-of-the-art microscopy instruments. It also serves as one of the information hubs for UR resources centering around imaging and image processing and as a conduit for communication between imaging researchers on campus. Substantial one-on-one guidance is provided for obtaining and assessing high quality, quantifiable image-based data for each instrument. Staff also is continuously available for updating and discussing results in real time.

  Specialized instrumentation includes Confocal:
  - Three Laser Scanning Confocal Microscopes (LSCM):
    - Leica Stellaris 5 with WLL and live cell imaging chamber is equipped with both Galvano and Resonant scanners for rapid imaging of live samples
    - The Nikon A1R HD LSCM is equipped with 6 laser lines and both Galvano and Resonant scanners for rapid imaging of live samples. The Nikon is also equipped for TIRF and single molecule imaging.
    - The Olympus FV1000 LSCM which is configured with 6 lasers and a SIM scanner provides the additional capability for synchronized continuous imaging during photo-manipulation experiments.
  - STED Microscope:
    - The Abberior Instruments easy3d STED system offers variable 2D to 3D STED imaging. Our system is equipped with the RESCue STED, DyMIN STED and MINFIELD STED modules for light dose management to reduce photobleaching and phototoxicity.
  - Multiphoton Microscope:
    - *Olympus FVMPE-RS Twin Lasers Imaging System* with a MaiTai HP DeepSee Ti:Sa laser and an Insight X3 laser is equipped with a high-speed resonant scanner and a galvanometer scanner for both structural and dynamic imaging.
    - Supports animal intravital imaging and physiology studies by providing surgical stations, Isoflurane Vaporizers for animal anesthesia, Laser Doppler Flow Meters for blood flow measurements, Pressure Monitor for blood pressure monitoring, and Blood Gas Analyzer for blood gas and pH measurements.
  - Epifluorescence and Color Imaging
    - Keyence BZ-X800 equipped with high quality objectives and up to 4-channel imaging. Can also be used for color imaging of histological samples.
  - Laser Capture Microdissection:
    - A Palmbeam (Zeiss) laser-capture microdissection microscope equipped with multiple long working distance objectives and both brightfield and immunofluorescence capabilities is available.
  - Image analysis workstation with software including:
    - Bitplane Imaris
    - Amira
    - NIS-Elements with Deconvolution

- MatLab
- Prism
- FIJI/ImageJ
- SVI Huygens Essential

- **Cold Storage Core (CSC).** *Director: Christopher Lane.* The CSC provides a discrete controlled access area where investigators can maintain freezers for long-term storage of research materials. Each unit can be alarmed via data line to a central monitoring system (APOGEE), all units are power protected by emergency backup generators. Each unit receives semi-annual preventive maintenance, and CSC staff record daily temperatures. There are also spare units (4ºC, -20ºC, -80ºC, and -140 ºC) available to all URMC investigators in case of emergencies. A new service has been established offering long term -80 ^{0}C storage of partial unit quantities (i.e. individual racks) for investigators who do not require a full sized unit. Please note that this space is limited.

  Electron Microscopy Resource. *Director: Karen Bentley, M.S.; Technical Director: Chad Galloway, Ph.D*. The principal mission of the Electron Microscopy Resource Laboratory is to provide University of Rochester researchers support in high magnification (**700 to 600,000x** range) for ultrastructural analysis of cells, tissue, virus, and nanostructures. The EM Core's main lab wet bench space occupies 670 sq.ft.; the Hitachi TEM suite occupies 470 sq.ft.; and the FEI Cryo TEM suite occupies 400 sq.ft.

The EM-SRL Equipment:

- Hitachi 7650 III (2008) Analytical Scanning/Transmission Electron Microscope (S/TEM) with a side mount Gatan Erlangshen 11 megapixel digital camera, attached electron dispersive x-ray spectrometer (EDAX), Gatan Digiscan II undermount camera for STEM mode imaging (brightfield and darkfield with fine probe elemental analysis).
- Thermo Scientific Cryo-Electron Microscope (2019) Talos L120C with an Elsa 698 Cryo-transfer holder and CETA16 CMOS detector for 3-D image reconstruction of proteins, and macromolecular complexes. Beam blocker and selective area aperture for diffraction.
- Scanning Electron Microscope: the EMR utilizes the Zeiss Auriga field emission SEM/STEM (2008) housed in the Hajim Engineering School.
- Leica EM-GP2 Plunge Freezer (2019)
- Leica UC7 ultramicrotome (2022)
- RMC PowerTome ultramicrotome (2010)
- Olympus stereo photo microscope (2022)
- 2 Olympus double headed light microscopes (1988 & 2005)
- Pelco Easi-glow (2022) ~~for~~ to glow discharge carbon coated grids,
- Tousimis 931 (2013) automated critical point dryer (for SEM specimens),
- Leica (2008) glass knife breaker
- 5 Diatome diamond knives (2015-2021)

- **Flow Cytometry Resource.** *Director: Timothy Bushnell, Ph.D., MBA; Technical Director: Matthew Cochran, M.S.* The mission of URMC Flow Cytometry Resource Laboratory (FCR) is to provide investigators with state-of-the-art instrumentation along with the technical expertise to support all that is possible now, while pushing the limits of what can be done with flow cytometry. The FCR currently has traditional analytical tools including an Accuri C6+ (4-colors) and 6 LSR/Symphony instruments (one 16-color and five 18-color instruments) from BD Biosciences. The FCR also added two spectral flow cytometers Cytek Auroras recently. There is both a 4 laser (2020) and a 5 laser (2022) full spectrum cytometer capable of identifying 30-40 fluorochromes simultaneously in combinations not previously possible. We have three cell sorters available including a 17 and an 18 color FACSAria-II and a 4 color BioRad S3e. In addition, we have several non-traditional analytical cytometers. The Amnis ImageStream GenX allows for imaging flow cytometry and the detection of up to 10 fluorescent parameters with cellular localization information. The Helios Mass Cytometer, upgraded from the original CyTOF in Jan 2021, uses lanthanide metal mass spectrometry as opposed to traditional fluorescent tags, allowing the analysis of upwards of thirty parameters to be studied simultaneously. The FCR also added the Nanosight NS3000 in 2015 for the detection of nano-sized particles. The Nanosight is capable of measuring the size distribution and concentration of particles as small as 10 nanometers by using light scatter and

capturing the Brownian motion of the particles. In July 2022 the resource also added a BioRad BioPlex200 for multiplex bead array assays measuring a wide range of biomarkers in solution. Two other instruments available in the resource are the Celigo, a microwell plate-based imaging cytometer, and the Seahorse XFe96 for measuring metabolic function. Instrumentation is only part of what we offer. We also offer comprehensive training for staff, consultation for maximizing the effectiveness and cost of experiments, as well as an environment that fosters success in both existing methods and crossing the boundaries into new frontiers.

- **Genomics Research Center.** *Director: John M. Ashton, Ph.D., MBA.* The UR Genomics Research Center (GRC) provides collaborative assistance with experimental design, execution, and data analysis for investigators using high-throughput next generation sequencing (NGS), genotyping and gene expression in their research programs. The GRC addresses rigor and reproducibility by incorporating several key quality assessment and quality control (QA/QC) points throughout standard operating procedures to ensure utmost quality performance. In addition, mycoplasma and cell line authentication analysis are available. Services include RNA-Seq, single-cell genomics applications, loss of function screening (RNAi or CRISPR), Bar-seq, CHiP-Seq, ATAC-seq, epigenomics (RRBS, WGBS, MeDiP, Methyl-seq), small RNA-Seq, repertoire sequencing, RIP-Seq, targeted and whole exome sequencing, whole genome sequencing, 16S rRNA microbiome sequencing, metatranscriptomics, metagenomics, sanger sequencing, qRT-PCR, Affymetrix microarrays, purification of RNA/DNA, nucleic acid amplification, as well as custom applications and approaches. In addition, GRC staff lead collaborative projects with URMC investigators to develop new methodologies and incorporate emerging genomic technologies into faculty research programs and the GRC workflow. Dedicated computational support for hardware, data analysis and storage of high-throughput sequence data is provided by the Center for Integrated Research Computing (CIRC). The following major equipment is located in the GRC: one Illumina NovaSeq 6000 high-throughput DNA sequencer, one Illumina NextSeq550 DNA Sequencer, two Illumina MiSeq DNA sequencers, one C1 Single-Cell Auto Prep System, two 10X Genomics Chromium Controller, two Sage Science Pippin DNA size fractionation system, one QX100 Droplet Digital PCR System, one ABI QuantStudio 12K Flex Real-Time PCR System with autoloader and microfluidic card module, two ABI 9700 PCR machines, two BioRad DNA Engine PCR machines, six BioRad C1000 Thermocyclers, one Perkin Elmer SciClone liquid handling robot for NGS library construction, one Eppendorf 5070 liquid handling robot for qPCR setup, one Eppendorf 5075 liquid handling robot for library construction automation, one Covaris E220 sonication system, one Agilent 2200 TapeStation System, two Agilent 2100 Bioanalyzers, one Agilent Fragment Analyzer, one BioRad gel documentation system, one Qubit flourometer and multiple NanoDrop ND-1000 spectrophotometers.

  Mass Spectrometry Resource Laboratory *Director: Sina Ghaemmaghami, Ph.D.; Technical Director: Kevin Welle***.** The Mass Spectrometry Resource Laboratory (MSRL) provides instrumentation and technical expertise to UR researchers seeking to conduct MS-based protein or small molecule assays. Technicians within the MSRL provide assistance with project design and planning, proper sample preparation, and interpretation of mass spectrometric data.

  - Primary Instruments:
    - Thermo Q Exactive Plus Hybrid Quadrupole-Orbitrap mass spectrometer
    - Fusion Lumos Tribrid mass spectrometer
  - Services provided:
    - Qualitative and quantitative discovery-based proteomics
    - Identification of unknown proteins
    - Characterization of protein complexes and binding interactions
    - Relative and quantification of protein levels
    - Mapping of post-translational modification within proteins
    - Targeted quantitation of small molecules and metabolites

Other Research Resources

- **Animal Resource – Division of Comparative Medicine and the Vivarium**
  - Three NYS licensed, ACLAM board certified laboratory animal veterinarians.
  - Six NYS licensed veterinary technicians
  - One vivarium director of operations (MBA, CMAR), one assistant director of vivarium operations (LATg), fifty vivarium staff (many AALAS certified) provide animal acquisition, husbandry and cage wash services.
  - Division of Comparative Medicine Services: Colony health (zebrafish, mouse, rat, rabbit, nonhuman primate, frogs, canaries, parakeets, degu, African spiny mice, naked mole rats) monitoring, quarantine services, animal acquisition from other research facilities, surgical support/anesthetic services, 24/7 on-call veterinary emergency services, clinical management of any cases of spontaneous or experimental disease, necropsy and histopathology services, training in specialized techniques (e.g. manual & chemical restraint, blood collection, aseptic surgical technique) and rodent breeding colony management.
  - Vivarium Services: Daily husbandry practices, daily observations for health problems, special request services (special diets, water, fasting), provision of federally mandated social housing and enrichment to animals directed by a full-time behaviorist (LAT, MS), and cage wash, autoclave and room sanitation services
  - Major equipment includes HEPA filtered ventilated cages & hoods for barrier maintenance of SPF mice, gnotobiotic mouse flexible film isolator units, dedicated BSL2 mouse housing & procedural space, inhalation anesthesia machines for rodents and large animals, diagnostic, digital, X-ray machine, autoclave for surgery packs, Intensive Care Unit, CO2 euthanasia stations, MRI capabilities and a Gammacell 40 Exactor Low Dose-rate Research Irradiator for irradiation of small animals within the resource.
  - Large animal (sheep, cattle, llamas, alpacas, horses) long term experimental and post-operative housing at an AAALAC accredited sister institution located 35 minutes from the university

  The Animal Resource is a centralized resource facility with staff and programs that support the research and educational uses of laboratory animals. These facilities are fully accredited by AAALAC, International, assured by NIH, registered with USDA APHIS, licensed by NYS and in compliance with state law, federal statute and NIH policy. Support is provided for research with all major animal species from zebrafish to nonhuman primates. Additional contact information and charges for services may be found at https://www.urmc.rochester.edu/animal-resource.aspx . *Director: Jeff Wyatt, DVM, MPH*

- **Center for Advanced Brain Imaging and Neurophysiology (CABIN):**

  The University of Rochester Center for Advanced Brain Imaging & Neurophysiology (UR CABIN) is a 6,000-square-foot state-of-the-art facility for conducting magnetic resonance imaging (MRI) research. The heart of the CABIN is a Siemens MAGNETOM Prisma 3T whole-body scanner which includes:
  - A gradient system of maximum amplitude of XR 80 mT/m @ 200 T/m/s, and high order shim
  - 64-channel and 20-channel head and neck coils (capable of parallel imaging using SENSE/GRAPPA), with dedicated brain pulse sequences allowing many types of research applications.
  - Simultaneous multiple slice (SMS) techniques for acquisition of BOLD and DTI results in time saving, higher spatial/temporal resolution, and/or combinations of each.
  - Spine Dot Engine provides optimized cervical, thoracic, and lumbar spine imaging.
  - Full assortment of other coils including extremity and body coils as well as small animal custom coils, which allow a wide range of other applications, such as musculoskeletal, cardiac, liver and animal imaging.
  - A research agreement with Siemens Healthineers to provide access to pulse sequence programming platform, access to on-going work-in-progress (WIP) software packages, and exchange agreements with researchers in other institutes.

- Computer interfaced with the scanner for synchronization, video display (in room BoldScreen 32, Cambridge Research Systems, with refresh rate up to 120Hz), audio equipment (SereneSound audio system, Resonance Technology Inc. 30dB gradient noise attenuation, 40Hz to 40kHz frequency response, active noise cancellation patient microphone), microphone and response boxes (fORP 904 Subject Response Package, Cambridge Research Systems) to present stimuli and record subject responses
- Standard software packages for stimulus display and response recording (e.g., Presentation, E-Prime, Psychophysics Toolbox and MATLAB).
- FIRMM, NOUS Imaging Inc. system provides real-time monitoring and biofeedback technology that addresses the problem of patient motion during brain MR.
- BIOPAC system (BIOPAC Systems, Inc.) for recording of physiological signals in the MRI environment such as: Electrocardiogram (ECG), Temperature, Respiration, Pulse Wave, ETCO2 and O2 Gas Recording and Analysis, Pulse Oximeter (SpO2). The accompanying AcqKnowledge software allows physiological data viewing, measuring, transformation, and analysis.
- A mock scanner is also available in room adjacent to the 3T Siemens scanner to be used to train research subjects The setup mirrors that of the Prisma as closely as possible, with an audio-visual presentation system and a surround sound system that reproduces scanner noises.
- High-performance computing facilities to support data storage and analysis. MRI data are transferred to a Dell Isilon disk system located at the University data center with back up to another off-site data center. The UR CABIN computer network is kept secure through a variety of means including a perimeter and department firewall as well as Intrusion Detection Systems and Vulnerability Scans.
- Technical staff available for consultation on all aspects of MRI research design, implementation, and analysis, including optimal protocol designs, pulse sequence programming, coil design and construction, design, operation of stimulus presentation and behavioral recording equipment, data processing and analysis, and information technology support.
  Director: John Foxe, Ph.D.; Associate Director: Madalina Tivarus, Ph.D.

- **Center for Integrated Research Computing (CIRC):** The University of Rochester established the Center for Integrated Research Computing (CIRC) to provide researchers across its Medical Center and River Campus with resources necessary to utilize computing and data analysis technology in all areas of scholarship. CIRC currently maintains systems with an aggregated computational performance of approximately 1.5 petaFLOPS, 72 terabytes of memory, and 5.2 petabytes of disk storage, and a variety of scientific software applications and tools, supporting over 1,000 users from diverse departments and research centers. Resources that ensure access to the technology and knowledge for effective computational and analytics research include: computer systems, software, storage, 8 FTE expert staff, part-time student assistants, information sharing, collaboration tools, and an education and training program. Monthly research symposia and regular workshops help investigators use computation and data science technologies and allow over 200 faculty research groups across the University to participate in discussions and collaborative opportunities centered on the application of computing technology to research. CIRC is uniquely positioned to collaborate with faculty and students in computational research design and implementation, software implementation and lifecycle management, application porting and tuning, data visualization and analysis techniques, and development of new computational technologies, methods and instruction.
    - CIRC's Linux compute cluster (known as "BlueHive") consists of 435 nodes of Lenovo and Dell high-performance computing servers with a high-speed, low-latency, InfiniBand interconnect. The SLURM resource scheduler and queuing system is used to optimize usage and support multiple users of the BlueHive Linux cluster environment. In total, there are more than 12,000 cores available with 68 TB of total RAM in the BlueHive cluster. Each compute node has 2 CPUs and up to 64 cores per server. Node memory ranges from 128 to 256 GB and up to 3 TB in a special "high memory" partition. 64 nodes of the BlueHive cluster contain one or more GPUs and include Nvidia Kepler K80 GPUs, Nvidia Volta V100 GPUs, and Nvidia Ampere A100 GPUs. The

approximate computational performance of BlueHive is 1.5 petaFLOPS (FP64). The entire BlueHive cluster has an InfiniBand-attached Lenovo DSS 240 storage system that provides approximately 4 PB of configurable storage. With a parallel file system running IBM's Spectrum Scale enterprise GPFS (General Parallel File System) software on a declustered array of disks, 3 PB is allocated to high performance scratch, and 1 PB has been made available for storage and archiving of files. 500 TB is allocated for archive space, and geographic redundancy is provided at a secure secondary location over 30 miles from the primary storage site. Access controls and limitations are provided by file system ACLs (access control lists) to ensure appropriate security and authorized access to data. The BlueHive network consists of 6 100 Gb/s EDR InfiniBand core switches with 21 InfiniBand leaf switches. The BlueHive cluster also has the ability to burst compute resources into Amazon's AWS cloud. Users can request specific type of configurations for EC2 compute node images directly from the BlueHive system. This functionality allows researchers who need short bursts of infrequent computation access to unique or specialized computing resources.

- There are over 1,100 different software packages, libraries, and applications currently supported in the BlueHive environment. This includes languages such as C/C++ and Fortran (GNU, Intel, and Clang/LLVM), as well as Julia, Python, Java, JavaScript, Go, Rust, and Ruby. Parallel communication libraries are provided by Open MPI, MPICH, and Intel MPI libraries. In addition, CIRC hosts numerous cross-domain scientific computing applications such as R, SAS, Stata, MATLAB, Jupyter, Mathematica, and Amira as well as a variety of database systems. Additional machine learning and statistics software are provided by various Python modules including TensorFlow and PyTorch. Supported developer tools in the BlueHive environment include C/C++ and Fortran compilers from Intel and GNU and math libraries from Intel (i.e. MKL). GPU acceleration libraries (CUDA, cuDNN, etc.) are provided by Nvidia. Visualization software (e.g. scientific imaging software or rendering tools) is accessible remotely via FastX and graphics acceleration is provided by GPUs.
- All CIRC infrastructure is maintained in a state-of-the-art facility dedicated to research computing equipment. Known as the Research Data Center (RDC), this 676 square-foot facility was recently constructed to house advanced computing and storage infrastructure for CIRC. Access to the data center building and the raised computing floor is strictly controlled by authorized individual access building controls. The RDC is co-located with the University's Primary Data Center and therefore benefits from a shared, common data center infrastructure including security, monitoring, and 24-hour staffing. CIRC maintains a disaster recovery document to ensure the resumption of operation of the Center's resources in the event of a system failure or other disaster. All non-volatile data (i.e. in home directories and in partitions for software) are backed up to the University's CommVault system with Simpana software and is managed by information technology staff in the University's enterprise-level Primary Data Center.
- Every winter and summer, CIRC provides a six-week long program in training for computational and data science. This boot camp program is open to all University of Rochester faculty and students and provides hands-on, workshop-style training on a variety of techniques and programming languages useful for developing tools and exploring research data. Past modules of the summer school include: Using Linux, Programming Python, Using Databases, Using MATLAB, and Data Analysis with STATA, SAS, and R. *Director: Brendan Mort*

- **Health Sciences Center for Computational Innovation (HSCCI).** Beginning in 2008 the UR created the HSCCI, a world-class center for the advancement of health-related research supported by high-performance computational (HPC) resources.
  - The mission of the HSCCI is to facilitate collaboration among research faculty, computational biologists, programmers, and software developers to advance biomedical research. The Center will provide pilot funding for both research staff and HPC computational resources
  - Computational resources are provided to HSCCI by the BlueHive Linux cluster, which is housed in the University's state-of-the-art, high-reliability, **Research Data Center (RDC)** and managed

by the CIRC (see CIRC listing). HSCCI research domains include projects concentrated in the following areas:

- Modeling Complex Biological Systems and Integration of Big Data: Vertical integration of multiple high-dimensional data sets from different levels of a complex biological system-incorporates genomics, microbiomics, proteomics, and organ-level data.
- Biomedical Imaging: Improved computational methods for analyzing images collected by a variety of technologies including MRI, ultrasound, and multiphoton microscopy. Includes development of analytical tools and computational methods for four-dimensional (3D over time) data.
- Molecular and Fluid Dynamics: Structural simulation and prediction of RNA, protein, and intermolecular interactions; fluid dynamics related to medical diagnostics and biological processes (eg. microfluidic devices and blood or air flow).
- Biomedical Informatics: Personalized medicine, mining Electronic Medical Records, perform virtual clinical trials

  - The HSCCI also led development of a state-of-the-art data visualization research lab – the Visualization-Innovation-Science-Technology-Application (VISTA) Collaboratory – now available to researchers. The mission of the VISTA is to provide collaborative space to house technology, research, and education in the data visualization sciences. Our approach is to bring together expertise in computer science, software, vision research, brain and cognitive sciences, statistics, and mathematics to work with experts in imaging, medicine, and biology to use, develop, and teach visualization technologies for large complex data. The VISTA houses an 8' x 20', 50 megapixel HD CineMassive display connected directly to the BlueHive supercomputer through a dedicated high speed, high bandwidth optical cable to the RDC. *Executive Director: David J. Topham M.S., Ph.D.; Associate Director: Benjamin Miller, Ph.D.*

- **Intellectual and Developmental Disabilities Research Center (IDDRC):**
  Services provided:
  - The IDDRC provides access and use of four highly interactive Cores to provide critical infrastructure to support IDD investigators. The IDDRC cores are:
    - Human Phenotyping and Recruitment (HPR)
      - High quality phenotyping and clinical assessment services, along with comprehensive resources for research design consultation, subject recruitment, and investigator training.
    - Translational Neuroimaging & Neurophysiology (TNN)
      - Human and small animal neuroimaging tools (3T and 9.4T MRI)
      - Human and small animal electroencephalography (EEG)
      - Mobile Brain/Body Imaging (MoBI)
    - Cell and Molecular Imaging (CMI)
      - Advanced imaging, analysis, and viral vector-based transduction methods to support in vitro and in vivo study of phenomena at the subcellular, cellular, tissue, and whole animal scale.
    - Animal Behavior and Neurophysiology (ABN).
      - Behavioral and neurophysiological assays in rodent models
      - Access to well established assays that are essential to IDD research,
      - Access to single neuron, multiunit, and population activity measures
  - The IDDRC explores the complexities of the brain's network of nerve cells, how the brain processes external stimuli, and the origins of behavioral disorders. The Center leverages and expands these efforts with the goal of accelerating the translation of scientific discoveries into the

next generation of therapies and interventions that improve the lives of people with IDD. *Director: John Foxe, Ph.D.; Co Director: Jonathan Mink, MD, PhD.*

- **Model Imaging and Tomotherapy Facility:** *Director: Brian Marples, Ph.D.*
    - The Model Imaging and Tomotherapy Facility offers researchers at the University of Rochester access to a Small Animal Radiation Research Platform (SARRP, Xstrahl). This x-ray irradiator uses on-board CT imaging to guide the delivery of radiation treatments using techniques that are directly comparable to those used in current clinical practice. This technology is currently being used to provide clinically-relevant protocols for a range of tumor models (brain, lung, pancreatic, renal, bladder, bone), as well as investigate the development and prevention of post-therapeutic effects in normal tissues that affect cancer survivors, e.g. the bladder (cystitis), lung (pneumonitis and fibrosis), salivary glands (xerostomia), brain (necrosis; cognitive dysfunction), kidney (fibrosis, radiation nephropathy), bladder toxicity and post-therapy bone disease.
    - Radiation therapy protocols can be delivered (either as single dose and/or fractionated) to animal models hosting subcutaneous or orthotopic human tumors, or syngeneic mouse tumors for investigating immunotherapy, and normal tissue toxicity studies.
    - The SARRP is capable of delivering multiple X-ray beams that make use of fixed or variable beam collimators varying from 0.5 mm to 10 cm, with an accuracy of 0.25 mm. Since this platform allows the generation of beams that can be rotated in directions ranging from vertical to 30° below horizontal, with 4-dimensional control over positioning of the model, recognized through the use of a laser-based positioning system, it provides flexibility for irradiating a range of anatomical sized targets and locations.
    - The SARRP includes on-board cone-beam computed tomographic imaging, which is amalgamated with treatment planning and image fusion software. This CT component can be used independently as a small animal imaging device or, in conjunction with the dedicated dose planning system, can be used to generate individual conformal radiotherapy plans for preclinical studies or image fusion with other imaging data sets, including MR (any orientation) PET, etc.
    - To complement the SARRP, a Gammacell 40 Irradiator (barrier housed in the vivarium) and Shepherd Mark I Cesium Irradiator are also available for animal and cell radiation treatment.
    - Dosimetry services are provided that adherence to nationally-recognized dosimetry standards to ensure experimental reproducibly.
- **Molecular Imaging Facility.** *Director: Jermaine Jenkins, Ph.D.*
    - The Molecular Imaging Facility provides researchers at the UR with access to a Typhoon RGB imaging system (acquired in 2017) capable of detecting and quantifying the levels and positions of radio- and fluorescently labeled molecules in a variety of formats including gels, blots and microtiter plates.
    - The Typhoon RGB is housed within the Center for RNA Biology, and handles gel sandwiches, agarose and polyacrylamide gels, membranes, microplates, and microarrays, with the capacity for multiplexed detection of chemiluminescence, fluorescence and ionizing radiation.
- **Small Animal Multispectral Imaging Core**. The Small Animal Multispectral Imaging Core offers state-of-the-art longitudinal multispectral (bioluminescence and fluorescence) imaging capabilities, to compliment and boost the extensive imaging resources available to University of Rochester Medical Center (URMC) researchers engaged in wide ranging areas of biomedical research with emphasis on clinical translation in alignment with the mission of the Clinical and Translational Sciences Institute (CTSI). The Core houses an IVIS® Spectrum system with unique capabilities for sensitively imaging both bioluminescent and fluorescent reporters within the same animal without mixing the multi-spectra. The system performs both epi- and trans-illumination fluorescent imaging and uses high efficiency narrow band-pass filters coupled with spectral unmixing algorithms to differentiate between multiple shallow and deep fluorescent sources. *Director: Hani Awad, Ph.D.*

- **Structural Biology and Biophysics Facility (SBBF):** The SBBF aims to be resource for researchers at the University of Rochester and other upstate NY academic institutions to gain access to our specialized instrumentation that will aid them in biomacromolecular structure determination and biophysical characterization of interactions. The Facility Manager is available to train individuals in the use of core instruments. He can also assist with experimental design, data interpretation, and if requested can perform experiments for clients
    - The facility has a Biacore T200 surface plasmon resonance (SPR) to measure the on- and off-rates and affinities of biomolecular interactions, and a Horiba FluoroMax-4 spectrofluorometer to study macromolecular interactions using fluorescence.
    - To estimate the secondary structure and determine the thermal stability of macromolecular samples a Jasco 1100 circular dichroism spectrophotometer is available.
    - A Wyatt DynaPro Plate Reader II uses dynamic light scattering to determine the hydrodynamic radius (size) and size distribution of polymers and biopolymers in solution.
    - We provide users access to a Cytiva ÄKTA Pure chromatography system for purification of proteins, peptides, nucleic acids or complexes thereof.
    - The facility is also equipped with a SPT Labtech Mosquito® liquid handling robot for setting up 96 well crystallization trays, and a Bruker X8 microfocus X-ray diffractometer that is well suited for rapid screening and diffraction data collection of crystals of all sizes.
    - There are also temperature controlled incubators, a walk-in 4 cold room, cryogenic storage dewars, microscopes for viewing crystal trays, and synchrotron supplies like Uni-pucks & SSRL Cassettes and their accessories.
    - We have recently acquired a Thermo Fisher Vitrobot Mark IV to prepare vitrified biological sample grids for use in cryo-electron microscopy (cryoEM) using the EM-SRL FEI 120kv TEM. A Quorum Technologies GloQube discharge system is also available for the hydrophilization and cleaning of TEM grids before sample application and vitrification on the Vitrobot.
    - We also offer researchers help with cryoEM data analysis and processing of images to obtain a 3D model reconstruction and refinement using computing resources available through CIRC.
    - The facility has purchased a dedicated turn-key cryoEM 4x NVIDIA GPU workstation for use in the cryoEM single particle analysis workflow.
    - *Director: Jermaine Jenkins, Ph.D.*

- **Mouse Genome Editing Resource (through Augusta University Genome Editing Core).** The Mouse Genome Editing Resource Facility provides expertise and assistance in the production of genetically modified mouse models by either DNA microinjection, CRISPR, or gene targeting in embryonic stem (ES) cells. For gene targeting and transgenic projects, the core assists in all phases of the project, including design and construction of DNA constructs, homologous recombination in ES cells, microinjection of DNA/RNA and Cas9 into mouse zygotes and of ES cells into mouse blastocysts in order to generate founder mice, breeding founder mice to germline transmission, and PCR genotyping. Other services include mouse embryo and sperm cryopreservation, re-derivation of mice to obtain Specific Pathogen Free (SPF) status, generation of congenic mice (backcrossing), colony management, and providing mice of common strains (C57BL/6, ICR, Cre, and FLP; regular and pregnant females or litters). The laboratory consists of a barrier facility for procedures involving production and maintenance of genetically modified mouse strains, a tissue culture facility for ES cells, and a molecular laboratory for generating transgene and gene-targeting constructs, and genotyping experiments. *Director: Lin Gan, Ph.D.*

  The Core's facilities and equipment include:

- Two Nikon TE2000-S inverted microinjection microscope setups equipped with Eppendorf FemtoJet 4i electronic microinjectors/Nomarski Optics/Narishige micromanipulators for mouse embryo microinjections.
- Four stations of eight Nikon surgical microscopes for egg and embryo isolation and transfer.
- Sutter P1000 micropipette puller for microinjection pipette preparation
- Biosafety cabinet/CO2 incubator/cell counter/electroporation system for ES cell culture and gene targeting.
- One Bio-Rad QX200™ Droplet Digital PCR machine and four C1000 PCR machines for mouse genotyping analysis.