MASSEY COMPREHENSIVE CANCER CENTER

The Massey Comprehensive Cancer Center (Massey) was established at Virginia Commonwealth University (VCU) in 1974, became a National Cancer Institute (NCI)-designated cancer center in 1975, and has been continuously funded by an NCI Cancer Center Support Grant (CCSG) since that time. Massey's mission is to reduce the state cancer burden for all Virginians by addressing the confluence between biological, social, and policy drivers through high-impact, cutting-edge research; person-centered care across the continuum, from prevention through survivorship; community integration; and training the next generation of community-centric researchers and healthcare professionals.

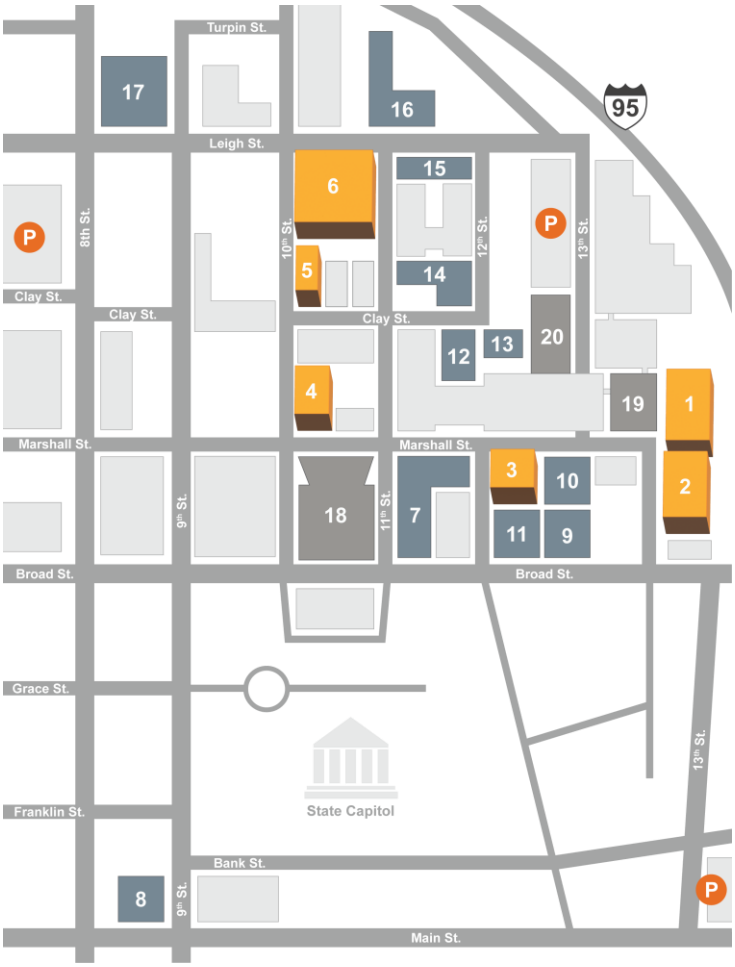
Massey has 147 members representing more than 30 academic departments across seven VCU schools and colleges. Massey members are organized into three research programs. The Cancer Biology (CB) Research Program members unravel the mechanistic underpinnings of tumor pathogenesis and progression and identify key interactions between tumors and their microenvironment that could shed light on the intrinsic and extrinsic mechanisms accounting for cancer progression. The Developmental Therapeutics (DT) Research Program members explore cancer therapeutics, identify molecular targets, assess the molecular genetic profiles of tumors, and translate these findings, along with those from the other two programs, into novel therapeutic strategies for treating cancer. The Cancer Prevention and Control (CPC) Research Program members develop basic and applied research programs in behavioral, social, and population sciences to create or enhance interventions that reduce cancer risk, incidence, morbidity, and mortality and enhance quality of life.

Massey provides support for a variety of shared resources, including six that are CCSG-supported: Biostatistics Shared Resource (BSSR), Flow Cytometry Shared Resource (FCSR), Lipidomics and Metabolomics Shared Resource (LMSR), Microscopy Shared Resource (MSR), Tissue and Data Analysis and Acquisition Core/Shared Resource (TDAAC), and the Transgenic/Knockout Shared Resource (TGKO). Additionally, Massey has a comprehensive Clinical Trials Office (CTO) that provides administrative, regulatory, and nursing support for clinical trials conducted at the center; an Office of Community Outreach and Engagement; and an Office of Cancer Research Training and Education Coordination.

RESEARCH FACILITIES SUPPORTING THE MAJORITY OF MASSEY RESEARCH ACTIVITIES

The Massey Director has overall responsibility for laboratory, clinical, and administrative spaces in six buildings on the VCU Health Medical Center Campus (**Figure 1**).

Figure 1: The VCU Health Medical Center Campus



Massey-Controlled Space

1. Massey Comprehensive Cancer Center Building* (2 members; SRs: BSSR, TDAAC)
2. Goodwin Research Laboratory Building (29 members)
3. McGlothlin Medical Education Center - 2.5 floors (7 members; CTO)
4. Virginia Mechanics Institute* (1 member)
5. Leigh House*
6. Adult Outpatient Pavilion - 5 floors of cancer clinical space (6 members)

Massey Member-Occupied Facilities

7. Sanger Hall (32 members; SRs: LMSR, MSR, TDAAC)
8. One Capitol Square (23 members; SR: BSSR)
9. Molecular Medicine Research Building (9 members; SRs: FCSR, TGKO)
10. Kontos Medical Sciences Building (3 members; SR: FCSR)
11. West Hospital (3 members)
12. Robert Blackwell Smith Building (4 members)
13. White House (1 member)
14. McGuire Hall and Annex (2 members)
15. W. Baxter Perkinson Jr. Building (6 members)
16. Sadie Heath Cabaniss Hall - School of Nursing (1 member)
17. Virginia BioTech Research Park (3 members)

Other Clinical Facilities with Dedicated Cancer Space

18. Children's Hospital of Richmond (4 members)
19. North Hospital
20. Critical Care Hospital

**Includes Massey Administration space. Note 11 Massey members reside in buildings on the Monroe Park Campus, approximately 1.5 miles from the VCU Medical Health Center campus*

Research Space Under the Authority of the Massey Director

Massey Building

The 65,000 (gross) ft^2 Massey building was dedicated in 1983. The ground floor includes offices and conference rooms for Administration. The first floor provides 10,954 ft^2 of assignable laboratory and shared resource space that houses the Massey-supported Cancer Mouse Models Core (CMMC) and the Clinical and Translational Research Laboratory (CTRL) as well as a component of TDAAC (pathology analysis services). The second floor of the building has a 6,061 (gross) ft^2 state-of-the-art barrier rodent facility to serve Massey investigators in the adjacent Goodwin Research Laboratory.

Goodwin Research Laboratory (GRL) Building

The GRL, dedicated in May 2006, is a state-of-the-art, 80,000 (gross) ft^2 research laboratory building under the complete control of the Massey Director. Currently, 29 members from all three Massey research programs have research and office space in GRL, and this building includes the Massey Director's Executive Suite.

McGlothlin Medical Education Center (MMEC)

Built in 2013, the 11th and 12th floors of the MMEC house the Massey CTO staff of over 100 individuals (14,802 ft^2) and the Office of Community Outreach and Engagement (489 ft^2). The 11th floor houses seven clinical investigators from the Division of Hematology, Oncology and Palliative Care, the Division of Neuro-Oncology and the Division of Gynecological-Oncology. These two floors are under the complete control of the Massey Director.

Research Space Not Under the Authority of the Massey Director

Sanger Hall

Sanger Hall is an 11-story laboratory research building located one block from Massey. This building has 486,495 (gross) ft^2. Thirty-two Massey members occupy research and/or office space in Sanger Hall as does the LMSR and the biorepository portion of TDAAC.

Molecular Medicine Research Building (MMRB)

The 125,000 (gross) ft2 MMRB was dedicated in 2009. Thirty percent of the space in this building is designated for nine Massey members in the CB and DT Research Programs and the TGKO and FCSR.

One Capital Square Building

Twenty-three Massey members representing both the CPC Research Program and the BSSR are located in this building, which is a five-minute walk from the Massey Building and GRL.

Massey Clinical Facilities Under the Authority of the Massey Director

VCU Health Campus

The majority of inpatient and outpatient cancer care within VCU Health is carried out in VCU's new Adult Outpatient Pavilion and the Critical Care and North Hospitals on the downtown VCU Health Medical Center Campus. Clinical cancer spaces for adult oncology services (inpatient and outpatient) are under the authority of the VCU Health Cancer Service Line (CSL), which is led by the Massey Director, **Robert A. Winn**, **MD**. These spaces include:

- A new single point of care, 17-story facility (**Figure 2**), called the VCU Health Adult Outpatient Pavilion (opened December 2021) has 169,821ft^2 (five floors) dedicated to clinical cancer outpatient services. The Pavilion features medical, surgical, and radiation oncology clinics (including MRI-guided radiotherapy). It increases Massey's outpatient clinical capacity from 24 to 48 oncology infusion bays and includes 47 exam rooms.
- A state-of-the-art Critical Care Hospital with all private rooms includes a dedicated 28-bed inpatient unit for medical oncology patients on the second floor.
- A newly renovated 21-bed inpatient unit with level II air filtration and an outpatient clinic and day hospital space for allogeneic and autologous stem cell transplantation in the North Hospital (16,594 ft^2). This serves as the largest comprehensive bone marrow transplant program in Virginia, which currently ranks in the top 20 nationally by volume and quality measures.

Figure 2: VCU Health Adult Outpatient Pavilion

The following main campus clinical spaces are not included in the CSL and are not under the authority of the Massey Director. However, they are very much an integral part of Massey's clinical care operations:

- An 11-bed palliative care unit in North Hospital, which serves as the inpatient component of the Massey Thomas Palliative Care Program.
- A Clinical Research Support Unit operated by the Wright Center for Clinical and Translational Research. This unit, located in the North Hospital, has seven outpatient beds with overnight capacity, three clinical rooms, and a metabolic chamber, and is used by Massey investigators to support more complex, time-intensive clinical trials.
- A ~4,600 ft^2 state-of-the-art pediatric oncology clinic in the VCU Children's Hospital of Richmond outpatient facility.

Massey at Stony Point (included in the CSL)

This multidisciplinary adult oncology outpatient care facility with 5,692 (assignable) ft^2 of space is located approximately ten miles west of the VCU Health Medical Center Campus to better serve suburban and nearby communities. This state-of-the-art clinical facility houses outpatient services in medical oncology, surgical oncology, radiation therapy, chemotherapy, and breast imaging. Clinical trials are also offered at this site.

Massey at Hanover Medical Park (included in the CSL)
Full-service radiation oncology is provided at this multispecialty clinic with 7,200 (assignable) ft^2 located ten miles northeast of Massey. Access to clinical trials is also offered.

VCU Health Community Memorial Hospital (CMH – not currently included in the CSL)
Located 90 miles south of Richmond on I-85, VCU Health CMH has 11,610 (assignable) ft^2 and is a community-owned nonprofit hospital in South Hill, Virginia that serves the south-central region of Virginia and portions of North Carolina. This medical center provides health care for a large geographic region encompassing a predominantly underserved rural population that includes a high percentage of Black/African Americans. VCU/Massey partners with the hospital to provide its medical oncology and radiation oncology care, which is provided by Massey medical and radiation oncologists. Additionally, Massey clinical trials are available at this site through its Minority-Underserved NCI Community Oncology Research Program.

VCU Health Tappahannock Hospital (not currently included in the CSL)
Located 45 miles northeast of Richmond, VCU Health Tappahannock Hospital has 5,958 (assignable) ft^2 and serves the Tappahannock area, including Essex, King and Queen, and King William counties, and the Northern Neck counties of Richmond, Westmoreland, Northumberland, and Lancaster. The partnership provides area residents access to VCU medical specialists and technology. Massey partners to provide physician services for medical oncology and hematology.

MASSEY SHARED RESOURCES

The Massey Director named **Paul Fawcett, PhD** the Associate Director for Shared Resources in 2010 to ensure that Massey's shared resource facilities operate efficiently, evolve effectively to serve cancer center members, and offer access to cutting-edge, relevant technologies to drive Massey member science. Fawcett is charged with overseeing a centralized management structure to monitor, optimize, and forecast needs. He is extremely adept in this role as he also serves as VCU's Executive Director for Research Infrastructure, making him ideally positioned for leading CCSG Shared Resource Management efforts.

Biostatistics Shared Resource

The Biostatistics Shared Resource (BSSR) is a Massey and CCSG-supported resource directed by **Nolan Wages, PhD**, a Professor in the Department of Biostatistics of the School of Population Health with expertise in adaptive clinical trial design, longitudinal and repeated measure data analysis, and Bayesian statistical methodologies. The BSSR assists Massey investigators by aligning specific faculty biostatisticians with each Massey research program. Support is provided by two MS-level and six PhD-level biostatisticians who have biostatistical experience and expertise using cutting-edge biostatistical methods such as adaptive study designs for randomized clinical trials, Bayesian and hierarchical modeling, longitudinal data analysis, biomedical imaging data analysis, survival analysis, latent variable modeling, and diagnostic test evaluation. BSSR's emphasis on collaboration contributes substantially to member research by ensuring that appropriate biostatistical expertise is available for project development in the basic sciences and design of clinical trials. In addition to offering collaboration at all levels of research projects, clinical trials, and grant applications, BSSR faculty contribute to cancer-related methodological research directly applicable to Massey's programmatic priorities. They also train investigators through seminars and individual sessions and contribute to the education of postdoctoral scientists and clinical fellows through the clinical research and biostatistics graduate degree concentration. The BSSR biostatisticians are located in the One Capitol Square building, and the BSSR operates a satellite office located in the Massey Building, staffed Mondays, Tuesdays, and Fridays, and upon request.

Flow Cytometry Shared Resource

The Flow Cytometry Shared Resource (FCSR) is a Massey and CCSG-supported resource directed by **Rebecca K. Martin, PhD**, an Assistant Professor in the Department of Microbiology and Immunology. She is supported by two FTEs. The FCSR provides Massey investigators with the equipment and expertise required for quantitative cell analysis, cell sorting, advanced cell analysis coupled to imaging, and surface plasmon resonance. The FCSR currently maintains a comprehensive suite of instrumentation for cell analysis, cell sorting, and image cytometry (**Table 1**). In addition, the FCSR provides services that include training, cell sorting and analysis, data acquisition, and preparation of flow data for publication. The FCSR has undergone continuous evolution of its instrumentation since its foundation, with current plans that include acquiring a new spectral sorter to accompany the newly acquired spectral analyzer. The FCSR is located on the fourth floor of MMRB with a

satellite location on the third floor of the connecting Kontos Medical Science Building. The FCSR occupies ~1,500 ft^2 of total space and is within easy walking distance of most all Massey investigators.

Table 1: Major FCSR Instruments/Equipment	
FCSR Instrument	**Description**
Cytek Aurora Spectral Cytometer with Automated Sample Loader	Has five lasers (355 nm: 20 mW; 405 nm: 100 mW; 488 nm: 50 mW; 561 nm: 50 mW; 640 nm: 80 mW), three scattering channels, and 64 fluorescence channels. This instrument provides excellent sensitivity and resolution, distinguishing particles from the background at 100 nm without fluorescence using flat-top laser beam profiles with narrow vertical beam height. This system enables autofluorescence extraction to improve data clarity. This instrument uses Spectroflo acquisition software and is capable of deep immunophenotyping with 40 colors at a rate of 35,000 events per second. The sample loader has three throughput modes optimized for 40-tube racks as well as multiple types of 96-well plates.
BD FACSAria Fusion SORP High-Speed Cell Sorter	Equipped with five lasers (355 nm, 405nm, 488 nm, 561 nm, 640 nm) allowing the use of 18-color simultaneous detection. Capabilities include various sort nozzle sizes, four-way sorting and single-cell sorting into plates. It is equipped with the temperature control option for sorting sample and collection vials and the BD Aerosol Management System for sorting potentially biohazardous samples. The system is contained inside a BD hood for sorting potentially biohazardous samples. The sorter uses FACSDIVA software for acquisition.
BD LSRFortessa X-20 Analyzer	Equipped with five lasers (355 nm: 15 mW; 405 nm: 50 mW; 488 nm: 50 mW; 561 nm: 50 mW; 640 nm: 40 mW), it detects up to 20 parameters simultaneously. The system is pressure-driven with hydrodynamic focusing. The flow cell design includes fixed alignment and gel-coupling to optics to reduce startup time, improve experiment reproducibility, and capture the maximum amount of light emission from the sample stream. This instrument uses FACSDIVA software for acquisition, has three adjustable flow rates, and can acquire 40,000 events per second.
Reichert SR7500DC Dual Channel SPR	A powerful two-channel surface plasmon resonance instrument. The Reichert SR7500DC uses TraceDrawer data analysis software. The flexible, component-based platform is ideal for analyzing lower molecular weight compounds and offers high precision in determining kinetics and affinities for a variety of biomolecular interactions, including those between proteins, nucleic acids, lipids, carbohydrates, small molecules, whole cells, bacteria, viruses, and polymers.
Amnis ImageStreamX Mark II Analyzer	This imaging flow cytometer combines the speed, sensitivity, and phenotyping abilities of flow cytometry with the detailed imagery and functional insights of microscopy utilizing the same dyes and markers employed in microscopy and flow cytometry. This unique combination enables a broad range of applications that would be impossible using either technique alone. The Amnis ImageStreamX Mark II produces multiple high-resolution images of every cell directly in flow, including brightfield and darkfield (SSC), and is equipped with four lasers (405 nm, 488 nm, 561 nm, 642 nm) allowing up to five-color simultaneous detection.
BD FACSCanto II Analyzer	Has two lasers (488 nm and 633 nm) and detects up to nine parameters simultaneously. The system uses FACSDIVA software for acquisition. The BD FACSCanto II is equipped with a carousel loader for automated sample acquisition.
BD FACSAria II High-Speed Cell Sorter	Equipped with three lasers (405 nm, 488 nm, 633 nm) allowing nine-color simultaneous detection and sorting. Capabilities include various sort nozzle sizes, four-way sorting and single-cell sorting into plates. It is equipped with the temperature control option for the sort sample and collection vials, and the BD Aerosol Management System for additional containment. The system is contained inside a Baker BioProtect Hood for sorting potentially biohazardous samples. The sorter uses FACSDIVA software for acquisition.
Cytek Aurora CS Spectral Sorter (new in 2022)	The sorter has five lasers (355 nm: 20 mW; 405 nm: 100 mW; 488 nm: 50 mW; 561 nm: 50 mW; 640 nm: 80 mW), three scattering channels, and 67 fluorescence channels. Like the Cytek Aurora, this instrument provides autofluorescence extraction to improve data clarity as well as excellent sensitivity and resolution of small particles. This instrument additionally provides high-end sorting capabilities with six-way sorting into 1.5 mL tubes, four-way sorting into 5 mL tubes, and single-cell sorting into plates. This sorter is equipped with primary aerosol evacuation integrated into the instrument with user-replaceable HEPA filters and a Biosafety Class 2 Type A2 cabinet. This instrument uses Spectroflo CS software and is capable of deep immune sorting with 40 colors at a rate of 25,000 events per second.

Lipidomics and Metabolomics Shared Resource

The Lipidomics and Metabolomics Shared Resource (LMSR) is a Massey and CCSG-supported resource directed by **L. Ashley Cowart, PhD**, a Professor in the Department of Biochemistry. She is supported by two additional FTEs. The goal of the LMSR is to provide Massey investigators with access to state-of-the-art mass

spectrometry services focused on high-throughput analysis of small molecules – both lipids and water-soluble metabolites – to support their basic, translational, and clinical research activities. Historically, the LMSR has primarily focused on analyses of bioactive lipids including, but not limited to, sphingolipids and eicosanoids. These analyses have been established using AB SCIEX 4000 QTRAP, AB SCIEX 5500 QTRAP, and AB SCIEX 6500 QTRAP mass spectrometers (major LMSR instruments are listed in **Table 2**). Significantly, the acquisition of a ThermoFisher Q-Exactive HF orbitrap has brought an expanded capability to the shared resource. Indeed, as the NCI has emphasized the potential of metabolomics for advances in cancer detection, prevention, treatment, and prognostication, the LMSR is poised to facilitate developments in precision medicine. While characterization of sample lipid profiles will remain a key driver of science for the Massey groups focused on lipid signaling, untargeted metabolomics is opening new doors for Massey investigators beyond the lipidome. The LMSR occupies approximately 2,000 ft^2 of space in Sanger Hall.

Table 2: Major LMSR Instruments/Equipment

LMSR Instrument	Description
SCIEX 6500 QTRAP Mass Spectrometer	A hybrid triple quadrupole/linear ion-trap mass spectrometer with a mass range of 5 to 2000 Da and enhanced signal response in negative ion mode. Coupled to a Shimadzu ultra-performance liquid chromatography (UPLC) system with custom-built 2D UPLC system and a photodiode array detector for orthogonal data acquisition. Ion trap allows structural determination via MS3 product ion spectra. Due to increased orifice diameter, the system has LOQs of 50 fmol or lower on many lipid classes. The 6500 boasts 5-msec polarity switching in MRM mode, which allows simultaneous acquisition of positive and negative species.
SCIEX 5500 QTRAP Mass Spectrometer	A hybrid triple quadrupole/linear ion-trap mass spectrometer with a mass range of 5 to 1750 Da is coupled to a Shimadzu UPLC system with a SIL-30AMP autosampler, which is capable of queueing 384 samples for increased sample throughput. The 5500 QTRAP has over six orders of magnitude of linear range. With a Turbo-V ion source, this mass spectrometer can accommodate up to 1 mL/min of organic LC flow, which enables a wide range of LC gradient options.
SCIEX 4000 Mass Spectrometers (2x)	Hybrid triple quadrupole/linear ion-trap mass spectrometers with a mass range of 5 to 3000 Da, mass accuracy of 0.1 Da, a scan speed of 24000 Da/sec, and a polarity switching time of 700 msec. The 4000 QTRAP is capable of handling complex samples while still maintaining a robust five-orders-of-magnitude dynamic range.
ThermoFisher Q-Exactive HF Mass Spectrometer	A high-mass accuracy instrument with a mass range of 50 to 6000 Da, <1 ppm mass accuracy, and a 1-sec full cycle time (at 35,000 resolution). Coupled to a Vanquish Horizon UHPLC, it is ideal for untargeted lipidomics/metabolomics and is integrated with the “LIPIDSEARCH” database for identification and semi-quantitative analysis of over 5,000 lipid species and the “COMPOUND DISCOVERER” database for identification and semi-quantitative analysis of 40,000+ water-soluble metabolites.
Agilent Seahorse XFe24	Measures the oxygen consumption rate and extracellular acidification rate (ECAR) of live cells in a 24-well plate format. The wells can accommodate 500 to 1000 µL assays and function in a range of 10000 to 1000000 cells/well.

Microscopy Shared Resource

The Microscopy Shared Resource (MSR) is a Massey and CCSG-supported resource directed by **Tytus Bernas, PhD**, an Assistant Professor in the Department of Anatomy and Neurobiology. He is supported by two full-time technicians and a highly experienced hourly technician. The MSR provides Massey investigators with access to high-end imaging instrumentation and analytical techniques, as well as consultative expertise in microscopic imaging. The MSR maintains a suite of fluorescence, transmitted, and backscattered light imaging systems including multiphoton, total internal reflection fluorescence, super-resolution (structured illumination and localization), and wide-field microscopes (major MSR instruments are listed in **Table 3**). Furthermore, the MSR houses transmitted (TEM) and scanning (SEM) electron microscopes capable of correlative light-electron operation. The MSR supports multidimensional (3D, time-lapse) and multiparametric (intensity, spectrum, lifetime, and anisotropy) imaging of cells and tissues, using multiple fluorescent labels. MSR services include sample preparation, imaging, training, consultation, experiment design, and data analysis. In addition to equipment for live-cell/tissue imaging, the MSR provides computer workstations and software for multidimensional image analysis, processing, and visualization. The MSR is located on the ninth floor of Sanger Hall in a suite of rooms (3,000 ft^2 of wet lab and office space) conveniently located for Massey users. Major instruments are housed in separate rooms to facilitate access management and control experimental conditions.

Table 3: Major MSR Instruments/Equipment	
MSR Instrument	**Description**
Zeiss ELYRA 7 Lattice SIM System (new in 2022)	Based on the motorized AxioObserver Z1, configured with three diode lasers (405, 489, and 633 nm), and a diode-pumped solid-state (561 nm) laser. The system is fully motorized, equipped with hardware autofocus, a heated enclosure, and stage microincubator for live-cell imaging. Two sCMOS cameras (2048x2048 pixels, PCO) can be used for simultaneous two-channel fluorescence imaging in 3D super-resolution mode (with piezo stage) or fast time-lapse image acquisition (255 fps).
Zeiss LSM880 Confocal Laser Scanning Microscope (2019)	Configured around the Inverted AxioObserver Z1, fully motorized stand and equipped with temperature enclosure and stage microincubator for live-cell imaging. The system features blue diode (405 nm and 440 nm), multi-line Argon (458, 488, 514 nm), DPSS (561 nm), and red diode (594 and 633 nm) lasers. The microscope has two internal single-band PMTs and HyD spectral detector. Furthermore, the microscope is equipped with an external HyD image scanning array (Airy detector) used to increase the resolution of imaging in the lateral (xy) direction. The system offers hardware autofocus and a choice between fast piezo or standard mechanical z-drive (long movement range) in 3D-image acquisition.
Zeiss LSM710 Confocal Laser Scanning Microscope (2013)	Configured around the Inverted AxioObserver Z1, fully motorized stand and equipped with stage microincubator for live-cell imaging. The system is equipped with pulsed diode (405 nm and 440 nm), multi-line Argon (458, 488, 514 nm), diode-pumped solid-state (561 nm), and red HeNe (633 nm) lasers. The microscope has three internal PMT detectors (two single-band and a spectral) and two external hybrid detectors (HyD) with time-correlated photon counting capability (TCSPC), controlled by Becker and Hickl acquisition module and used for fluorescence lifetime imaging.
JEOL JEM-1400Plus 120keV Transmission Electron Microscope (2018)	With a maximum accelerating voltage of 120keV, the system is equipped with a fully motorized stage (xyz) with tilling capability. The system can produce magnifications ranging from 10x to 1200000x (resolution up to 0.2 nm) and register images with a water-cooled direct detection sCMOS camera (Gatan, 4000x4000 pixels).
Olympus 488 nm and 561 nm CELLTIRF Laser and Optics Upgrade (upgraded 2018)	Based on the IX 71 inverted stand. The system is equipped with 405, 488, and 561 diode lasers (100 mW each) and a sCMOS camera (2048x2048 pixels, BSI) with image splitter for simultaneous two-channel acquisition. The microscope can be configured for wide-field (transmitted light and fluorescence) and localization microscopy (PALM/STORM) operation. The system offers hardware autofocus and a stage incubator for live-cell imaging.
Zeiss Spinning Disc Confocal Microscope (2015)	Based on the motorized AxioObserver Z1 and the double incubator (same as in the LSM880). The system is equipped with blue diode (405 nm), multi-line Argon (458, 488, 514 nm), DPSS (561 nm) and red diode (and 634 nm) lasers. The microscope uses a Yokogawa X1 disc head and two EMCCD cameras (512x512 pixels, Photometrics), offering two-channel, parallel image acquisition. An additional CCD camera (1300x1030 pixels, Zeiss) is installed on the other side port for wide-field (fluorescence, phase contrast, DIC) imaging. The system is equipped with a temperature-controlled enclosure and stage microincubator, compatible with multi-well plates, Petri dishes, and slides.
Zeiss LSM510 META NLO Confocal/Multiphoton Laser Scanning Microscope (2005)	Configured around an Axioskop2 stand, set on a Luigs & Neumann 380FM workstation, and equipped for electrophysiological recording. This system has three visible lasers a pulsed infrared Ti:sapphire tunable laser for multiphoton imaging. The microscope is equipped with photomultiplier (PMT) detectors: two internal descanned single-band, external spectral detector, and two external non-descanned (used in multiphoton mode). It is anticipated that the system will be decommissioned in 2022.
JEOL 1400 TEM (2018)	With a maximum accelerating voltage of 120keV, this TEM is equipped with a fully motorized stage (xyz) with tilling capability. The system can produce magnifications ranging from 10x to 1200000x (resolution up to 0.2 nm) and register images with a water-cooled direct detection sCMOS camera (Gatan, 4000x4000 pixels).
Zeiss EVO 50 XVP SEM	This SEM can operate at full or variable pressure (up to 750 Pa). In the former mode, the system uses backscattered (BSE) and secondary (SE) electron detectors whereas in the latter a dedicated BSE detector is used. The system is fully motorized and equipped with Deben coolstage and a water vapor introduction kit.

Tissue and Data Acquisition and Analysis Core/Shared Resource

The Tissue and Data Analysis and Acquisition Core/Shared Resource (TDAAC) is a Massey and CCSG-supported resource co-directed by **Michael O. Idowu, MD** and **Jennifer E. Koblinski, PhD**, Professor and Associate Professor in the Department of Pathology, respectively. They are supported by 8.75 FTEs. TDAAC serves as the primary source of high-quality, well-annotated, patient-derived cancer specimens and the gateway through which Massey investigators conducting Investigator-initiated Trials (IITs) acquire the human tissue

samples required to support their research.

An Institutional Review Board (IRB)-approved protocol governing TDAAC operations allows for the collection and banking of residual specimens arising from standard-of-care diagnostic and therapeutic procedures. The TDAAC ensures that residual sample acquisition during patient care is performed to preserve the molecular integrity of the specimens. All banked fresh-frozen tissue specimens have a corresponding formalin-fixed, paraffin-embedded (FFPE) counterpart. The TDAAC also assists investigators with specific IRB protocols to acquire tissues specifically for research.

TDAAC effectively assists Massey investigators by providing the following services: 1) acquiring fresh-frozen and FFPE tissue for banking; 2) acquiring and processing hematopoietic specimens that require primary cell culture; 3) acquiring fresh tissue for patient-derived xenografts (PDXs); 4) offering well-annotated patient-derived cancer specimens for IRB-approved translational research and clinical trials; 5) extracting and quantifying macromolecules, including RNA and DNA; 6) offering pathology services including grossing, embedding, sectioning, and H&E staining; 7) developing tissue microarrays (TMAs); and 8) providing automated immunohistochemistry (IHC), multiplex immunofluorescence (mIF), and multiplex *in situ* hybridization (mISH), and automated quantitative pathology imaging and analysis. In addition, TDAAC provides consultative services for experimental design and educates users on the use of biospecimens and histological applications. Major TDAAC instruments are listed in **Table 4** below. TDAAC has recently deployed a rotary microtome to provide unstained FFPE slides. In 2020, the TDAAC acquired a state-of-the-art tissue microarrayer (Thermofisher TMA Grand Master system) to make TMAs of various tumors with corresponding clinical follow-up and outcome information readily available. The construction of TMAs significantly enhances TDAAC's ability to support intra- and inter-institutional research and provides a cost-effective tool for reliable assessment of biomarkers in FFPE tumor samples. TDAAC leverages a number of informatics relationships within VCU and works in close collaboration with Massey's informatics team to obtain clinical data for patients whose samples are banked. TDAAC occupies a 1,400 ft^2 laboratory space located in Sanger Hall (biorepository) and 799 ft^2 in the Massey Building (pathology analysis services).

Table 4: Major TDAAC Instruments/Equipment

TDAAC Instrument	Description
TMA Grand Master with PCR	Fully automated high-throughput tissue microarrayer with the highest-capacity available on the market.
Leica BOND RX Automated H&E Staining System	Quantitative pathology imaging system with inForm software. The Vectra Polaris performs automated high-speed digital whole-slide scanning with 10x, 20x, or 40x in brightfield or fluorescence. The multispectral range is from 440-780nm. This allows for imaging over up to eight multiple overlapping biomarkers plus DAPI (nucleus) without interference of autofluorescence. The supportive inFrom and Phenoptr software allows for biomarker quantification and spatial analysis.
Leica Bond RX	This instrument performs automated staining of up to 30 slides for immunohistochemistry, in situ hybridization, and multiplex staining for both. The system allows for completely customized protocols and performs these experiments in less time and more accurately and reproducible than manual staining.
DakoCoverStainer by Aligent	This instrument performs complete automated H&E staining including baking, dewaxing, staining, dehydration, and coverslipping. The automation provides consistent staining quality and reduces turnaround time for staining.
Sakura Tissue-Tek VIP Automated Tissue Processor	The tissue processor allows for up to ten different processing programs and up to 300 specimens to be processed at one time. It can be programmed for up to 14-stage processing cycle.
Sakura Tissue-Tek Tissue Embedding Center	This system has a modular tissue embedding station that has two separate components: a heated embedding module and a cold plate.
Agilent 2100 Bioanalyzer	Automated electrophoresis system to check the quality of nucleic acids. In less than 30 minutes for 12 samples, sizing, quantitation, integrity, and purity is provided in a visual display.
MagMAX Express	Uses magnetic bead-based kits for automated nucleic acid extraction and purification. The results are superior and very quick; 24 samples in each 15-minute run.
Applied Biosystems Thermal Cycler 2720	Personal, 96-well thermocycler, which works well for basic and cycling protocols.

Table 4: Major TDAAC Instruments/Equipment	
TDAAC Instrument	**Description**
Thermo Scientific NanoDrop 8000	Multi-sample, microvolume UV-Vis spectrophotometer, which quickly measures quantity and quality of nucleic acid samples.
Leica CM1850 Cryostat	Designed for rapid freezing and sectioning of frozen tissue samples at -20°C.
Microm HM-310 Rotary Microtome	Efficient and precise sectioning of paraffin-embedded tissue
Thermo Scientific Revco PLUS Ultra-Low Temperature Freezers (multiple)	-80°C storage.
Thermo Scientific Locator 4 PLUS Cryobiological Storage Vessels	Cryogenic storage use.
Beckman, Z2 Coulter	Cell and particle counter.

Transgenic/Knockout Mouse Shared Resource

The Transgenic/Knockout Mouse Shared Resource (TGKO) is a Massey and CCSG-supported resource directed by **Jolene J. Windle**, **PhD**, a Professor in the Department of Human and Molecular Genetics. She is supported by three FTEs. The TGKO provides Massey investigators with access to the efficient and cost-effective production of genetically engineered mouse models (GEMMs), including transgenic, knockout, conditional knockout, and knock-in mice along with a wide array of support services that facilitate their use. TGKO services offered include 1) production of transgenic mice by standard transgenesis technology, as well as gene-targeted mouse models, including KO, conditional KO, and knock-in models. Since 2016, CRISPR/Cas9 technology has been used exclusively for the production of gene-targeted models; 2) breeding colony management, including establishment and expansion of colonies, mating, weaning, tail clipping, genotyping, and transfer of experimental animals to the investigator; 3) support services including mouse line rederivation and both sperm and embryo cryopreservation and cryorecovery; 4) production of mouse embryo fibroblast cell lines; 5) management of an IVIS Spectrum optical imager located in the barrier vivarium used by TGKO; and 6) consultation on all aspects of GEMM planning, production, and use. Major TGKO instruments are listed in **Table 5**. The TGKO has restricted-access laboratory space and dedicated animal holding space (~1,900 ft^2) in the 8th floor barrier vivarium in MMRB, as well as laboratory space on the floor below.

Table 5: Major TGKO Instruments/Equipment	
TGKO Instrument	**Description**
BioCool III Freezer	Embryo cryopreservation.
Eppendorf FemtoJet 4i Microinjector	Reproducibly injects small volumes into adherent cells and suspension cells.
TransferMan 4r Micromanipulators	For manipulation of oocytes and early embryos, transfer of stem cells and microparticles, and a wide range of applications in non-human reproductive biology.
NEPA21 Embryo Electroporator	For introduction of CRISPR reagents into mouse eggs.
Olympus SZX-7 Microscope with EP-50 Camera	For documenting sperm motility.
Minitube Multicoder Printer	For labeling of individual cryostraws.
LN_2 Holding Dewar	LN_2 holding dewar.
PerkinElmer IVIS Spectrum II T Imager	Uses leading optical technology for preclinical imaging research and development ideal for non-invasive longitudinal monitoring of disease progression, cell trafficking and gene expression patterns in living animals.

<u>Cancer Mouse Models Core</u>

The Cancer Mouse Models Core (CMMC) facilitates in vivo preclinical/translational research by supporting investigators with the development of several different types of mouse models: syngeneic models, genetically engineered mice, and xenograft models. The CMMC also supports in vivo drug administration and testing services, as well as small animal imaging for monitoring tumor progression. The CMMC's founding Director is

Koblinski. With over 25 years of experience performing xenograft and syngeneic studies in various cancer models, Koblinski is well qualified to lead this shared resource and is supported by five experienced staff members. Staff members are experienced in designing and performing experiments using syngeneic, xenograft (including patient-derived xenograft), and GEMMs of primary and metastatic cancer. CMMC staff members provide experiment consultation and train researchers in specific animal procedures. The CMMC includes animal holding space (~533 ft^2) in the second-floor barrier vivarium in the GRL Building. Major instruments include an IVIS Lumina X5 (satellite location in Sanger Hall), an IVIS Lumina S5 (in the ultrabarrier section of the Massey GRL barrier facility for severely immunocompromised mouse models), an IVIS Spectrum in the general Massey GRL barrier facility, and an IVIS 200 (adjacent to Massey Goodwin barrier facility, for imaging animals that may not reenter the barrier).

Massey Clinical and Translational Research Laboratory

The Massey Clinical and Translational Research Laboratory (CTRL) provides general instrumentation and services for clinical investigators without their own laboratories for molecular and cellular biology correlative studies in support of Massey IITs. Services include: serum and plasma processing, white blood cells isolation, ELISA, immunohistochemistry, RT-PCR, droplet digital PCR, Western blot analysis, and assistance with accessing flow cytometry services. The laboratory occupies 2,500 ft^2 in the Massey building. The laboratory is equipped with instruments and equipment to perform a wide range of research activities in molecular and cellular biology, protein analysis, microbiology, and image analysis. The CTRL general equipment includes a chemical fume hood, two Class 3 biosafety cabinets, autoclave, centrifuges, water bath, refrigerator, chromatography refrigerator, -20^{o}C and -80^{o}C freezers, two CO2 incubators, a CO2/O2 incubator, and several tabletop and floor model centrifuges. Molecular biology equipment includes an Eppendorf thermal cycler, a five-color Applied Biosystems StepOnePlus real-time PCR system, electrophoresis and Western blotting apparatus, a transilluminator, and standard and NanoDrop spectrophotometers. A LiCor fluorescence reader for Western blots enables simultaneously high-sensitivity detection of up to two fluorophores. Biomarker analysis capabilities rely on the use of a PerkinElmer Multimode plate reader with absorbance and luminescence capabilities. There is a Zeiss Axio Imager M1m fluorescent microscope with monochrome and color CCD cameras along with Zeiss software for image analysis. The CTRL also houses a dedicated dielectrophoresis-based ApoStream instrument for the isolation of rare and circulating tumor cells from peripheral blood and other biological fluids obtained from patients entered into early phase trials. The CTRL is equipped with instruments to perform the following analytical methods and supporting techniques: fluorescent and light microscopy, ELISA for various analytes (absorbance, fluorescence, luminescence), Western blotting, quantitative and standard PCR, mammalian cell culture, isolation of circulating tumor cells, cell-based assays, and peripheral blood mononuclear cell isolation.

Massey Clinical Trials Office

The Clinical Trials Office (CTO), one of the original SRs established by Massey, was created to support the development and conduct of cancer clinical research and, in particular, clinical trials at the institution. The CTO provides the following services to all Massey members conducting cancer clinical trials: regulatory affairs and compliance, feasibility and scientific review, study activation, subject recruitment, coordination of protocol treatment and other study requirements, data capture/submission, collection/submission of biospecimens and other materials, expedited reporting of protocol-specified events, quality assurance, information dissemination, and reporting clinical trial activity including clinicaltrials.gov. In addition, the CTO provides project management, development, and support for Massey IITs. The CTO includes clinical research nurses (CRNs), clinical research coordinators (CRCs), clinical data managers, regulatory coordinators/specialists. Additionally, Massey administrative staff members provide clinical trial management and CTO operation support. The offices of the clinical research staff are located in the MMEC, which are within two blocks of the Adult Outpatient Pavilion. Each office/work station is equipped with computer and phone and is in a secure location to maintain privacy of participant records. CRNs and CRCs have access to the electronic medical records through a secure portal. Storage cabinets for regulatory files and copies of source documents are locked.

Bioinformatics Shared Resource

The Bioinformatics Shared Resource (BISR) was established in November 2020 with the recruitment of founding Director **Jinze Liu, PhD**, a Professor of Biostatistics with expertise in cancer genomics, bioinformatics, and machine learning. She has over 15 years' experience providing bioinformatics support to cancer researchers. The BISR advances basic and translational cancer research by facilitating the interpretation of complex and large-scale biological datasets to provide robust, cost-efficient, and timely support in data management, data access, data analysis and integration. In addition to 50% of Liu's effort, the BISR is supported by 2.5 MS-level FTEs with experience in bioinformatic data analysis and pipeline development. Initial development of the BISR

is focused on providing services in high demand by Massey members. These include analysis of high-throughput sequencing data (whole exome/genome sequencing, RNA-seq, and single-cell RNA-seq), pathway analysis, assistance accessing and mining public cancer datasets, and support for grant applications by generating preliminary data and developing data analysis strategies. The BISR is also actively developing analysis pipelines in support of metabolomics and proteomics in collaboration with those resources. Additionally, BISR staff provide regular training and consulting for trainees and clinical scientists on routine bioinformatic data analyses.

Proteomics Mass Spectrometry Shared Resource

The Proteomics Mass Spectrometry Shared Resource (PMSR) was founded in 2019. Launching the resource with an older ThermoFisher LCQ Deca LC-MS/MS system, in 2020, Massey procured a ThermoFisher Q-Exactive HF mass spectrometry system as the primary instrument. Mass spectrometry expert Adam Hawkridge, PhD, an Associate Professor in the Department of Pharmaceutics, is the PMSR Director. The PMSR now offers services for protein identification (e.g., gel bands, protein binding partners), molecular weight determination for peptides and proteins, protein post-translational modifications (e.g., methylation, acetylation, phosphorylation), and relative quantification (e.g., label free quantification, TMT).

Table 6: Major PMSR Instruments/Equipment

PSR Instrument	Description
Thermo Exploris 480 w/Vanquish Neo UHPLC & UV-vis	The instrument is the most advanced Q Exactive Orbitrap platform available with analytical figures of merit that provide outstanding proteome coverage. The high-pressure UHPLC system supports extended length nanoflow analytical columns that enable the identification of >5,000 proteins from a standard cell lysate sample in a single run. Additional capabilities include relative protein quantification (label free, SILAC, and TMT), post-translational modification analysis (phospho, methyl, etc.), and targeted absolution quantification (parallel reaction monitoring).
Thermo Q Exactive HF-X w/Easy nLC 1200	The high-pressure UHPLC system of this instrument supports heated nanoflow analytical columns that enable the identification of >4000 proteins from a standard cell lysate sample in a single run. Additional capabilities include relative protein quantification (label free, SILAC, and TMT), post-translational modification analysis (phospho, methyl, etc.), and targeted absolution quantification (parallel reaction monitoring).
Thermo Fusion Lumos ETD w/ Easy nLC 1200	This instrument is a hybrid Orbitrap platform that includes CID, HCD, ETD, and EThCD dissociation techniques and MSn capabilities. These unique technical features are complementary to the QE HFX and 480 Exploris in that they enable a higher degree of peptide/protein structural characterization. This becomes particularly important for site localization of amino acid modifications (e.g., PTMs), complex PTM characterization (e.g., glycosylation), and chemical cross-linked peptides.