Capabilities Statement
Laboratory of Renewable Resources Engineering (LORRE)
http://www.purdue.engineering/LORRE
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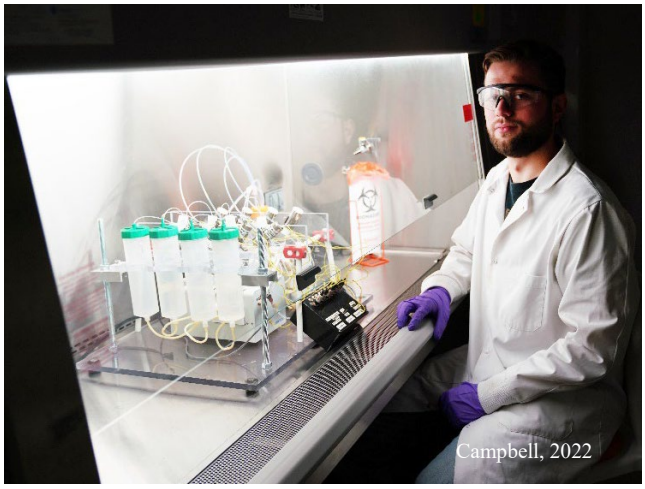
The Laboratory of Renewable Resources Engineering (LORRE) has moved into a new facility designed to accommodate core research areas in renewable energy (transportation fuels), bioproducts, and health. The LORRE labs, located on the 4th floor of the new Agricultural and Biological Engineering Building, consist of areas that house specific functions given in Table 1. The open laboratory blocks (4107 and 4118) facilitate general biological, biochemical, and microbiological research; training of students, industrial collaborators and post-doctoral researchers; assembly / testing / translation of prototype devices; scale-up of enzyme reactions, microbial fermentations, and biocatalytic reactions. Fundamental mechanistic studies of biological systems result in measurements and data for computational modeling purposes.

LORRE and its facilities serve Purdue's Colleges of Agriculture, Engineering and College of Science through sharing of its expertise and protocols that address a range of research topics in bioprocess and bioreaction engineering, bionanotechnology, bioseparations, biorecovery, renewable energy, bioproducts, and pathogen detection. The laboratory's capabilities are enhanced through cooperative research projects and via shared facilities such as Discovery Park that enables access to instrumentation and equipment for analytical characterization and imaging. Imaging capabilities include multiphoton laser scanning confocal microscopy of proteins and cellular systems.



The BSL-2 laboratory in LORRE carries out research on detection of food and other pathogens. Imaging instruments facilitate monitoring and validation of binding of labeled markers with microbial targets, proteins and peptides, and particulate structures of various sizes. Doppler imaging (Physics, laboratory of David Nolte) facilitates research on interactions between pathogens and immortalized mammalian cells. LORRE collaborates with its counterparts at Indiana University, Bloomington, and its association with FDA FERN, on food safety.

The laboratory environment of LORRE aims to facilitate multidisciplinary research in the context of graduate and undergraduate student education. A student office suite, embedded within the LORRE laboratory, co-locates a diverse pool of graduate and undergraduate students near their experiments. Separately, the LORRE office area houses visiting scholars, industrial partners, and research collaborators to initiate new projects, address industrial research and

development needs and to carry out continuing education of visiting scientists, engineers, and post-doctoral scholars for translating public research results to application and publication.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Separately, LORRE has the facilities, equipment, and / or access to expertise and instruments (including mass spectrometry) for protein characterization, enzyme formulation and development. Omics including proteomics, secretomics, and whole genome sequencing are employed to characterize industrially relevant microorganisms and identify pathogens. NREL Laboratory Analytical Procedures (LAP's) are the basis for compositional analysis: glucan, xylan, arabinan, acetyl, lignin, ash, and extractives for soybean and corn products, corn fiber (DDGS), soybean hulls; agricultural (lignocellulosic) residues, wood, and sugar cane bagasse.

These analyses are important for assessing the chemical make-up of plant lignocellulosic biomass and for determining material balances around biochemical and thermochemical processing of plant biomass. The laboratory generates sufficient low carbon footprint bioproducts and ligno-cellulose co-products to facilitate analysis, characterization and testing. Capabilities include lab-scale thermochemical reactions in packed beds, and batch and flow-through reactors. Liquid hot water and dilute acid pretreatments of lignocellulosic biomass at temperatures up to 260°C is attainable with a daily throughput of up to 100 g of biomass (dry).

LORRE also performs liquid-phase thermochemical reactions of biologically-derived molecules (sugars, alcohols, etc.) over solid catalysts or in homogeneous reaction solutions at temperatures up to 260°C. The HPLC and GC analytical capabilities support measurement of product yields, rates, reaction selectivity, activation energy, and other engineering parameters necessary for reactor and /or catalyst design and scale-up. Most pretreatment, enzyme mimetic research, and thermochemical reactions are done in a temperature-controlled sandbathes in 45 mL stainless steel tubular reactors. Instrument capabilities include liquid chromatographs for sugar, protein, and fermentation product analysis.


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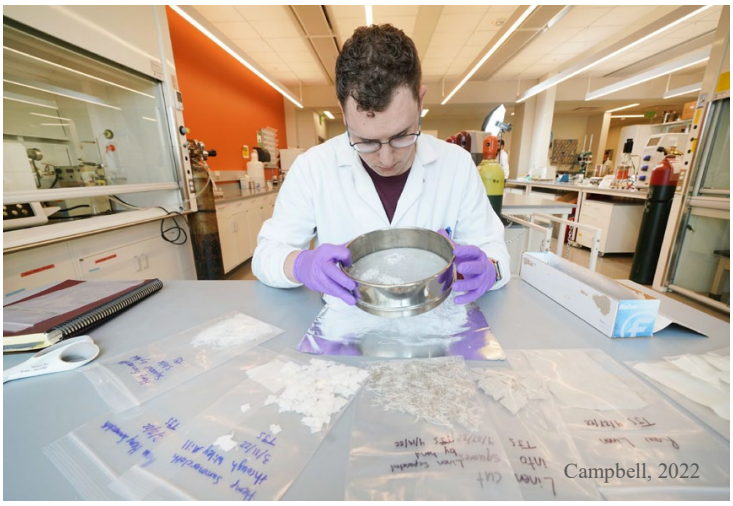
Facilities for and expertise in carrying out lab-scale enzymatic reactions from the microtiter plate scale to 1L reactor scale at temperatures ranging from 4°C to 80°C for

Table 1. Summary of LORRE Facilities

Room	Laboratory	Function
4107	Bioreactors Laboratory Block	Fermentation, enzyme reactions, biomass, processing, value-added products, extraction, compositional analysis, product recovery, corn, soybean, lignocellulose.
4107A	BSL-2 Pathogen Laboratory restricted access, self-closing door	Detection / characterization of pathogens; Rapid concentration; testing of food samples; methods research. BSL-2 Facility
4107B	Volatile Fuel	Preparation, characterization of drop-in and sustainable aviation biofuels.
4117C	Tissue and mammalian cell culture (restricted access)	Propagation of immortalized cells and tissue culture for research purposes.
4118	Bioproduct and Bioseparations Laboratory Block	Bioproduct preparation / characterization protein, sugar, polysaccharide liquid chromatography, protein characterization.
4118A	Bioseparations Laboratory	Chromatography, fractionation, and tangential flow filtration (TFF) of therapeutic proteins, microorganisms, nucleic acids, nanoparticles
4118B	Biophysical Characterization	*In vitro* systems for measuring diffusion and aggregation of proteins, nucleic acids, and nanoparticles within biological matrices (HA, collagen, simulated SQ tissue environments).
4118C	Yeast and fungal microbiology	Fermentation of wild-type and transformed yeast and fungi (including cellulolytic fungi, enzyme, protein, and bioproduct expression).
4090	Imaging / Microscopy Laboratory	Microscopes for imaging fluorescent labeled proteins and microorganisms in microfluidic devices.

both homogeneous and heterogeneous reaction systems. The available HPLC and spectrophotometric analytical capabilities support measurement of parameters form which different bioprocess defining variables may be determined including product yields, enzyme and microbial kinetics, determination of enzyme inhibition and deactivation, and activation energy (i.e., rate, titer, yield). In conjunction with the preparative-scale bioseparations capabilities, the



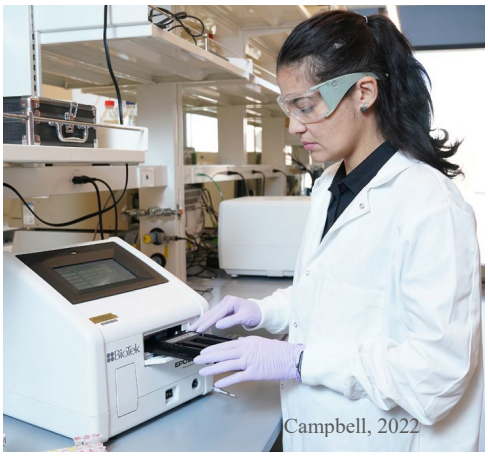
laboratory has the ability to separate and purify enzymes and their reaction products, respectively, for testing.

The LORRE Recharge Center performs quantitative chemical analyses of liquid samples by HPLC. The Center has capabilities to quantify carbohydrates, organic acids, alcohols, and protein, including analysis of liquid samples from fermentations (both aerobic and anaerobic), enzyme reactions, aqueous phase thermochemical reactions, anaerobic digesters, distillation condensates, and plant extracts. In addition to standard analyses, the laboratory has capabilities to develop new HPLC analytical methods using ion exclusion, reverse phase, size exclusion and ion exchange chromatography to identify and quantify biomolecules of interest.

LORRE has the facilities, equipment - or access to equipment and expertise - to conduct molecular biology research, including cloning, developing gene knock-outs, gene expression profiling, intracellular enzyme expression assays, metabolic engineering and classical strain development for bacteria and yeast. Coupled with fermentation facilities and analysis capabilities,

LORRE is able to perform aerobic, microaerobic, and anaerobic fermentations using bacteria, yeast, and fungi, as well as propagation of host cells and bioproduct expression. The necessary facilities are available to conduct these fermentations and analyze the products from microwell plates, shake flasks, instrumented 1L fermenters, up to a 20 L scale. When combined with the analytical and bioseparations capabilities, the fermentation capabilities allow LORRE to conduct fermentations, analyze the output, purify the product, and develop process models around the production of proteins and biochemical. LORRE is positioned to carry out strain development, including synthetic biology, followed by process integration and assessment of protein or bioproduct expression.

LORRE partners with multiple investigators and facilities from Agricultural and Biological Engineering, Weldon School of Biomedical Engineering, Department of Chemistry, Civil Engineering, Mechanical Engineering, Food Science, Chemical Engineering, and Discovery Park to access a range of instrument capabilities and imaging systems. Omics are carried through the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DP core (mass spectrometry), while whole genome sequencing capabilities have been carried out in collaboration with the State Chemists Office. The laboratory has access to other instruments and equipment with collaborators in Bindley Biosciences, Food Science, Materials Science and Engineering Departments, and the Weldon School of Biomedical Engineering, respectively.

Access to advanced instrumental capabilities include multiphoton laser scanning confocal microscopy, flow cytometry, florescence microscopy, and electron microscopy. Food science has provided expertise in plasmon residence while MSE is an excellent resource for measuring and modeling rheology of liquefied concentrated biomass and biopolymer slurries. Access to shop capabilities in the Agricultural and Biological Engineering Department facilitates fabrication of systems and skid-mounted units up to an approximate volume of 50 gallons. The shop is fully capable of welding different types of stainless steels, and vessels. For micro-fabrication, biopharmaceutical and bioseparations prototype construction, researchers in LORRE work with the prototyping facility and shop in the Weldon School of Biomedical Engineering.

Laboratory safety, record keeping (notebooks), data security, and technical training for specific instruments or equipment is required before researchers work in LORRE facilities. This is provided by staff using materials from Purdue REM, with completion certified by laboratory management before research begins. Mandatory safety training includes personal protection, chemical safety, and data security. Depending on research area, safety training for microbiological work and handling pathogens and mammalian cells may also be required.

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Inputs from: Fernanda da Cunha, Abigail Engelberth, Nathan Mosier, Shweta Singh, visiting scholars, graduate students and undergraduate researchers

Keywords: energy, health, bioproducts (LORRE's mission).
agricultural (value-added) products
bioreactors, bioprocess engineering, mammalian cell culture,
biomass (lignocellulose), thermochemical reactions, high pressure reactions
biopharmaceuticals,
bioseparations:
liquid chromatography, tangential flow filtration (microfiltration, ultrafiltration)
computer modeling: mechanistic – first principles, systems modeling for circular economics, technoeconomic and life cycle analysis of bioprocesses
enzyme catalysis, enzyme bioreactors,
microbiology, molecular biology, fermentation,
pathogens.
protein characterization

Appendix:
Listing of Facilities and Equipment for Laboratory of Renewable Resources Engineering

Bioreactors and Fermenters

1 L bioreactor Bioflo 120 (Eppendorf, Enfield, CT): the bench-scale bioreactor/fermenter system is equipped with different sets of interchangeable impellers for the 1L vessel with a removable heat-blanketed to perform microbial fermentation. A high-precision expanded range thermal mass flow controller is available providing the capability for low flow mammalian cell culture through hi gh-demand microbial processes on a single controller.

1 L bioreactor: The BioFlo 110 (Hamburg, Germany) is a modular fermentation system for microbial and cell fermentation, equipped with 2 rotors. It automates procedures to ensure the accuracy and reliability of results. Operators can set points for both pH and dissolved oxygen.

15 L bioreactor: BioFlo 115 (New Brunswick BioFlo/CelliGen, Enfield, CT): this fermenter and bioreactor of 14L capacity can be used as a microbial fermenter or mammalian cell culture bioreactor. It is equipped with built-in pumps, gas flow controllers, and pH/DO foam/level controllers, suitable for fermentation and cell culture operating modes.

40 L Bioreactor Bioflo -5000, Mobile Pilot Plant Fermentor - New Brunswick BioFlo-5000 (Edison, NJ) - BioFlo 500 mobile pilot plant fermentor can be used for process development and small-scale production up to 40 L. The fermentor has the capacity to handle diverse organisms and it is capable of supporting aerobic and anerobic fermentations. The bioreactor also makes it possible to monitor and control cultivation parameters. The system controller sets temperature, stirring and the rate of air input to the reactor vessel. pH and dissolved oxygen (DO) can be monitored with electrodes. The pH of the medium can be held within tight limits by means of built-in acid and base pumps.

Shaker incubator series - (2 units) New Brunswick Scientific, Edison, New Jersey. Model: INNOVA 44). Capacity for flasks up to 5 L in volume, the space-saving glide up door, multistep programming, the reliable Innova triple-eccentric drive.

Biopolymer, DNA, RNA, Protein, Microorganism, Cell Culture, Micro / Nanoparticle Characterization / Research

Biosafety cabinets class II, type A2: total of 7 units (NEJAIRE, Plymouth Mn .Model No. NU-540-600): these are equipped with power outlets, and are connected to vacuum lines, configured to meet the needs of most clinical and research applications, offering containment that meets the NSF/ANSI 49 standard that is followed in most of the Americas. Additional 2 items. 1 Thermo Scientific 1300 A2, and 1 Thermo Scientific HERA Safe KS.

Microorganisms

Fungal strains: wild fungi strains of Aspergillus and Trichoderma species: *A. niger* A12 and *A. niger* 3T5B8, both from Embrapa Food Technology collection (Rio de Janeiro, Brazil), and *T. reesei* Rut-C30 purchased from the Centre for Agricultural Bioscience International (CABI) culture collection in the United Kingdom (IMI number: 345108).

Bacteria: *Salmonella Enteritidis*; *Escherichia coli* O157 B6-914 (expressing a green fluorescent protein) with both Shiga-toxin genes deleted; *Listeria innocua* and *Listeria monocytogenes*. The recombinant microorganism is an E. coli O-157-GFP strain obtained from Dr. Amanda Deering's laboratory in the Food Science Department at Purdue University. The detailed information for its construction can be found in the Material and Methods section of "Construction and identification of bioluminescent E. coli strains" from Fratamico et al., 1997 (Journal of Food Protection, 60 (10): 1163-1177), and in the Material and Methods section 2.1 from Deering et al. 2011 (Food Research International 45 (2): 1037-1043).

Access to other microbial collections: USDA ARS Culture Collection, which contains about 100,000 strains of bacteria and fungi, ATCC (American Type Culture Collection) global biological resource center and standards organization, which includes a collection of more than **18,000 strains** of bacteria, as well as 3,000 different types of animal viruses and 1,000 plant viruses, among others.

Cell culture (1 dedicated room / laboratory)

3D cell culture bioreactors: rotary cell culture system (RCCS, Synthecon INC., Houston, TX), compatible with High Aspect Ratio Vessels (HARVs). Each disposable vessel is individually packaged and gamma sterilized, in sizes of 10 and 50 mL. Ability to co-culture multiple cell types in a 3D spheroid morphology; can be used with or without scaffolds to generate 3d cell models; low shear force in the rotating vessel (low turbulence) allows spheroid growth. Applications in cancer modeling/ tumor spheroid culture, cancer cell invasion studies, tissue engineering, spheroid formation and culture, recellularization, decellularization, explant culture, organoid culture, host-pathogen studies.

CO_2 incubator: MYTEMP mini CO_2 (Benchmark, Edison, NJ). Equipped with Digital control of temperature and CO_2, Dual beam, infrared sensor, and accepts bottles and flasks up to 2L**.** **Capabilities:** ideal for cell cultures and other applications requiring CO_2 gas control.

Freeze Drier: Lyovaper L-200 pro freeze drier (BUCHI, India). It can gently dry frozen preparations by sublimating water in vacuum.

Supporting Instruments: Biopolymer, Protein, DNA, RNA, nanoparticle research

Agilent BioTek Epoch 2 Model: EPOCH2TS (Winooski, Vermont) microplate reader. Spectrophotometer for UV-Vis absorbance measurements, performed in 6- to 384-well microplates, cuvettes, and in microvolume samples with the available Take3 microvolume plate. Broad wavelength range enables applications from nucleic acid and protein quantification at low UV to microbial growth assays higher wavelengths.

Ettan DALT six Electrophoresis unit - Modular system for large format and medium throughput 2-D electrophoresis. (GE healthcare & Biosciences AB, Uppsala, Sweden) (Model: 80-6485-08)

Gel Doc EZ Imager – Compact automated gel imaging instrument. It can be used for DNA gels and fluorescence imaging, Coomassie, copper, silver, and zinc stains, nucleic acid applications with SYBR stains, stain-free imaging with Bio-Rad stain-free gels. (BIORAD Laboratories Inc., Hercules, CA) (Model: GelDoc EZ)

GelDoc Go Imaging system - It has an intuitive Image Lab Touch Software onboard, with capabilities such as auto image capture, auto analysis, user preferences. It can be used for DNA gels and fluorescence imaging, Coomassie, copper, silver, and zinc stains, nucleic acid applications with SYBR stains, stain-free imaging with Bio-Rad stain-free gels. (BIORAD Laboratories Inc., Hercules, CA) (Model: GelDoc Go)

Mini Protean Cell - The Mini-PROTEAN 2-D electrophoresis cell performs both tube gel IEF and vertical electrophoresis applications. (BIORAD Laboratories Inc., Hercules, CA) (Model: Mini-PROTEAN II Cell)

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Multimode microplate reader: Biotek Synergy H1 (Agilent, Santa Clara, CA). modular multimode microplate reader, with monochromator-based optics and filter-based optics. Equipped with continuously variable bandwidth monochromators for fluorescence excitation and emission wavelength selection. Fluorescence bandwidth can be set between 9 and 50 nm, in 1 nm increments, allowing users to optimize reader setting. **Capabilities:** Microvolume analysis with Take3 plate measures up to 16 or 48 samples in one run. Gen5 software has customizable protocols for ssDNA, dsDNA, RNA, and protein quantification for fast setup.

Sonicator FB120 (Fisher Scientific, Pittsburgh, PA). Ultrasonic energy disrupts or agitates particles in liquids for size reduction, cell disruption, and dispersion of nanoparticles.

Thermal Cycler for nucleic acid Amplification - BIO-RAD Laboratories Inc. Model MyCycler, equipped with 96 well alpha block, and program protocols with as many as 9 cycles with 9 steps each, and repeats up to 99 times per cycle. Temperature ranges from 4 – 100 C. Capabilities: Ideal for PCR and other cycling techniques.

Viscometer: Rheosense microVisc (RheoSense Inc. San Ramon, CA) equipped with temperature control (HVROC-L, HVROC-T), shear rate range 1.7 – 5,800 s^{-1} and viscosity range 0.2 – 20,000 mPa.s (cP). Chips A05 and A20 available. **Capability:** measure viscosity of high concentrated protein solutions, in the range of range 0.2 – 20,000 mPa.s (cP).

Osmometer: Precision systems Inc, 5010 Osmette III, automatic osmometer.

Other standard instruments include melting point apparatus, automated pipettors, pH meters, water purification units, laboratory glassware, plastic disposables, dishwasher.

Bioseparations:

Ultrafiltration, Gas Chromatography and Liquid Chromatography

Microfiltration and Ultrafiltration:

Continuous cell concentration and recovery device (C3D): The C3D uses cross-flow microfiltration in a hollow fiber module containing a polyether sulphone membrane with 0.2 µm pore size. A C3D with four separate hollow fiber modules was developed at LORRE, and calibrated to further increase efficiency. Capability: To concentrates environmental and pathogenic bacteria that may be present in a water sample to a detectable level. Overall, this process has the potential to decrease the time needed for the sample to reach a detectable level from up to 72 hours down to just 6-8 h.

Hollow Filtration equipment: equipped with hollow fibers with a wide range of surface areas, sample holder, Masterflex peristaltic pump (Masterflex easy -load II L/S, 77201-60), pump tubing (Cole-Parmer Instrument Company LLC), special high-pressure tubing (Masterflex, MFLX96241-14) to allow operation at 60 psi, and Mettler Toledo scale (Mettler Toledo, PL60001E). Currently in use hollow fibers of 190 cm^2 (Repligen Corporation, D02-S500-05-N) and 390 cm^2 (Repligen Corporation, D04-S010-05-N), and adaptable to a wide range of hollow fiber dimensions. Capabilities: bioseparation and concentration of biomolecules, cells, or particles from liquid suspensions.

Stirred Ultrafiltration Cells: Amicon 400 mL (MilliporeSigma, Burlington, MA) Model 402, for 76 mm diameter filters, max pressure 75 psi. Capability: concentrating, purifying, and fractionating macromolecules and particles from liquid solutions.

Tangential Flow Filtration (TFF): for flat-sheet membrane ultrafiltration (MilliporeSigma, Burlington, MA) - Pellicon® 3 88 cm^2 cassette filter holder (MilliporeSigma), equipped with Pellicon® 3 Cassettes with Ultracel® 30 kDa Membrane, D screen, 88 cm^2 (MilliporeSigma, P3C030D00). TFF set-up is equipped with Masterflex peristaltic pumps, Special high-pressure tubing (Masterflex, MFLX96241-14), PendoTECH inline pressure sensors (PendoTECH, PREPS-N-000P), and conductivity sensor (PendoTECH, CONDS-N-012). Data is acquired by the PendoTECH PMAT4A monitor and transmitter and downloaded to a laptop through an RS-232 interface with PC (PendoTECH, PMATP-GUI software). **Capabilities:** protein and other biomolecules, nanoparticles; concentration, purification, and buffer exchange.

Liquid Chromatography

Centrifugal partition chromatography: CPC unit complete with a CherryOne periphery control unit. The CPC control unit is equipped with 5 independent pump heads with the ability to vary the flow rate to the CPC from 1 to 15 mL/min. The CPC unit has both an ELSD and a UV detector to account for a wide variety of compounds. A fraction collector is located at the instrument outlet to collect fractions by time or volume to either collect fractions for further analysis or accumulate fractions of a compound of interest.

Liquid chromatography (3 systems): Model 1 Waters e2695 separations module (made in Singapore), Waters 2414 Refractive Index Detector (made in US), Waters 2489 UV/visible Detector (made in Singapore), Waters 2475 Multi λ Fluorescence Detector (made in US), and two Waters column heater module (made in MA, US). This system can perform liquid chromatography. Consists of Model 2 Waters 2695 separations module (made in Singapore), Waters 2414 Refractive Index Detector (made in US), Waters 996 Photodiode Array Detector (made in US), and WAT038040 column heater module (made in MA, US). **Capabilities:** Currently in use for analysis of proteins, sugars, organic acids, and ethanol.

HPLC Pump: Model 515 HPLC – Waters. For preparative and inverse chromatography systems that test stationary phase properties using pre-selected molecular probes.

Gas Chromatograph Agilent 7820A equipped for either liquid (7693A autosampler) or gas samples (7697A Headspace) and outfitted with both TCD and FID detectors. GC-MS:

Metering Pump Model F200X, brand Chemyx from USA, designed to deliver accurate and precise amounts of fluids for a multitude of applications.

Specialized Computational Resources

Server: Brown cluster providing 96 GB of RAM. Additional Windows-based SINCS server with an enhanced NVIDIA GPU-enabled i7 processor inserted with an additional total of 96GB RAM.

Process simulation software (Aspen and SuperPro) and performs heavy computation for data-driven research involving optimization and Machine Learning.

The laboratory also utilizes Purdue ITAP and Engineering Computing Network (ECN) resources.

Laboratory Block General Equipment

Autoclave: Primus Sterilizer Company (Integrated solutions, Kansas, USA, model PEB24RSS-208) for sterilization of glassware, culture media, instruments and waste.

Balances: Total of 15 units, several brands, and precision specifications.

Bench-scale centrifuges: (Eppendorf, Germany, 5415D) is used to separate solid and liquid by high-speed rotation. Maximum capacity 24 * 3.75g or 24* 1.5 ml microcentrifuge tubes, up to 13200 rpm, rotor F-45-24-11.

Digital & magnetic stirring heating Mantles (98-111-B) are capable of providing steady heat and stirring for 2L solutions.

Floor Centrifuges (3 units)

Centrifuge Beckman Coulter Avanti J-20XP (Brea, California, United States); up to 26,000 rpm and 82,000 x g; equipped with different rotors for sample capacities from 15 to 100ml.

Centrifuge Avanti J-30I (Brea, California, United States) has a maximum speed of 30,000 rpm and is compatible with most Beckman J series rotors. It also accommodates both swinging bucket and fixed-angle rotors. It is equipped to fit different rotors for samples with capacities from 15ml to 100ml.

Centrifuge Beckman Coulter Avanti J-E (Brea, California, United States) is a high-speed centrifuge with a 4-liter capacity and a maximum speed of 21,000 RPM. The centrifuge is capable of accommodating a variety of sample sizes and types, and it supports various rotor options, enabling a wide range of applications.

Fume hoods (12 units)

Sentry air (Lab crafters, Ronkonkoma, NY): Operating average face velocity range of 50 FPM – 125 FPM. Capabilities: designed for high performance projects to provide the highest levels of safety, energy efficiency and performance. Complies with UL 1805, SEFA 1, NFPA 45, ANSI/AIHA Z9.5.

Heating Block

Standard Heating block: (Avantor, USA): Heats to 150°C (302°F). Fits 20 microtubes of 1.5 mL each. Capability: Multi-purpose units are ideal for incubation and activation of cultures, enzyme reactions, immunoassays, melting/boiling points, and a variety of other laboratory procedures.

Imaging / Microscopes in LORRE facilities (advanced imaging in Bindley Core user facility)

Nikon Eclipse E600FN microscope: for patch clamp experiments; specimen clearance angle of 45 degrees and is equipped with the CFI60 infinity optical system, which provides clear images.

Nikon Eclipse Fluorescent TE2000U fluorescence inverted microscope for slides or short-term live cell work. Set up for Brightfield with Phase Contrast and Fluorescence studies. includes a manual Nikon XY stage with inserts, a digital camera (Cool Snap ES), and four objective lenses (X4, X10, X40, and X100). Uses a three-step process to eliminate stray light.

Zeiss Primo Star microscope equipped with high-quality optics for detailed imaging of microbiological structures. Includes brightfield illumination for observing stained samples on standard glass slides.

Micro-centrifuges (2 units)

Microcentrifuge bench-top with maximum 21,130 x g, digital timer for run times of up to 30 minutes. Maximum capacity for the rotor is 18 to 24 samples of 1.5ml, varying on each model. Models **Eppendorf 5415 D** (Hamburg, Germany), **Eppendorf 5424** (Hamburg, Germany), and **Eppendorf 5418 R** (Hamburg, Germany). Microcentrifuge Eppendorf 5418 R is a 18-place microcentrifuge designed for low to medium capacity with 1.5/2.0 mL tubes and Microtainer®. The force of up to 16,873 × g allows for standard molecular biology applications.

Refrigerators / Freezers (connected to back-up generator electrical source)

Ultrafreezer - 80 C degrees - Stores samples at -80 degree Celsius. Built for to attain the most critical sample storage and challenging lab environments, with outstanding energy efficiency. (Thermoscientific, Waltham, MA) (Model: TSX60086A).

Ultrafreezer -86 C degrees - Stores samples at -80 degree Celsius. Temperature range: -86° to -50°C, with control in 1° increments. Designed for convenient storage on or under the lab bench or stacked two high. (Fisher scientific, Waltham, MA) (Model: U101-86) .

Freezers (6 units): Storing samples at -20 Celsius. Models: Sears Roebuck and Co., Chicago, IL, MOD: 253.21111104; Electrolux Home products, Augusta,GA, Model: FFU21M7HWJ; Crosley, Winston-Salem, NC, Model: WCV20/W3; Sears Roebuck and Co., Chicago, IL) (MOD: 253.28042807).

Refrigerators: 8 units. Storing samples at 4 Celsius. Models: W.C Wood Co. Ltd., Guelph, Canada, Model: WR17-ZW/E; Amana, Amana, Iowa, Model: TX21VW; Sears Roebuck and Co., Chicago, IL, MOD: 253.60722000; Thermo Fisher Scientific, Asheville, NC, Model: VCR430A21; LABRepCo, Horsham, Pennsylvania, Model: LHU-36-HG; GS Laboratory Equipment, Asheville, NC, Model: U2020FA14.

Rotavapor R-200 (BUCHI) and **Heating Bath B-490 (BUCHI)** connected to an external cooling to accelerate evaporation by increasing heat removal surface during rotation. The heating unit can provide heat up to 180°C.

Sample Prep for Foods

Seward Stomacher® 400: lab blender allows for easy and effective sample preparation while delivering reliable, consistent results. Programmable process times and paddle speeds for consistent results. Suitable for volume sample sizes from 80ml – 400ml

Sandbaths (80 to 400 C) and Waterbaths (up to 85 C)

Sand Baths: total of 5 units, equipped with either 2 or 3 heaters, high and medium settings with 1-10 level energy dial, 900W, 120V, 50/60Hz, 10.5A. Capable of heating items to high temperatures more safely than oil baths, requires external controller.

Sand Bath Controllers Techne TC-8D (F937F) - 3 units, Duxford (Cambridge, England). External PID controller with K-type thermocouples for setting temperatures

Techne SBS-4 (Burlington, NJ): equipped with 2 heaters, high and medium settings with 1-10 level energy dial, 900W, 120V, 50/60Hz, 10.5A. Capable of heating items to high temperatures more safely than oil baths, requires external controller

Techne Tecam SBL-1 (Princeton, NJ): equipped with 2 heaters, high and medium settings with 1-10 level energy dial, 117V, 60Hz, 20A. Capable of heating items to high temperatures more safely than oil baths, requires external controller
Techne Tecam SBL-2 (Duxford Cambridge, England): equipped with 3 heaters for increased temperature precision, high, medium and low settings with 1-10 level energy dial, 220-250V, 50/60Hz, 13A.

Sand Bath 5: (Duxford Cambridge, England): equipped with 3 heaters for increased temperature precision, high, medium and low settings with 1-10 level energy dial, 220-250V, 50/60Hz, 13A.

Thermo Fisher sensor controlled 280 Series, water bath, 2.5 L, microprocessor controlled, with temperature range from 0 to 100° C.

Neslab RTE 111 bath/ circulator, water bath, with a digital panel for temperature control for pump flow to an external circulation system.

Soxhlet system: Lab-assembled system that consists of 4 Soxhlet extractors with cooling water flow , 4 separate heating mantles and controllers for temperatures up to 100 °C. System supports 4 samples running at the same time. Soxhlet extractor retains solvent sample during evaporation and condensation to completely extract desired component over long periods of time.

Ovens (8 units)

Fisher Scientific Isotemp Oven, 737G (2 units) for drying samples.

Fisher Scientific Isotemp Oven 2 (model 637G). Equipped with dial for temperature control. 120V, 60Hz,11A.for glassware and sample drying.

High Temperature Box Furnace NC BF51794C-1 (Lindberg, Asheville,): Max temp 1100C. 3.5kW, 208/240V, 50/60Hz, 15A, 1 phase. High temperatures to measure biomass ash content.

Hybridization Oven: Hybrid, model H-9360: Features rotisserie speed control from 2-15rpm, fits ten 35mm bottles of at least 150mm in length and a drip tray. Continuous mixing, temperatures up to 99.9°C, digital readout, removable bottom tray.

Mechanical Oven Model MO1490A-1. Lindberg, Asheville, NC. Temperature range from 40-260 C. 1.6kW, 120V, 50/60Hz, 13.5A, 1 phase. Range of temperatures for drying..

Mechanical Oven Model MO1420A-1 (Lindberg, Asheville, NC.): temperature range of 40-260C. 1.6kW, 120V, 50/60Hz, 13.5A, 1 phase.

Vacuum Oven model 1415M Sheldon Manufacturing, Cornelius, OR: 110-120V, 50/60Hz, 6.5A. Vacuum oven for drying temperature sensitive samples.