SECOND ANNUAL

ART IN RESEARCH EXPOSITION

September 9, 2022
To push our students to their creative capacity while showcasing their research, the Weldon School is proud to host our second annual Art in Research exhibition.

Our graduate and postdoctoral students were invited to submit their images (photography, micrographs, illustrations, visualizations, and renderings) that depicted their research, along with a description on how the image was created and how it represents the importance of research in their field.

This exhibition captures the creative and innovative submissions from our talented biomedical engineering students, who are always persistently pursuing the next giant leap in healthcare.
**Composition with Red, Blue and Grayscale of a murine cardiac left ventricle**

Submitted by: Katherine Leyba  
Contributors: Pierre Sicard; Craig Goergen  
Creation: This work was created using Adobe Express from images acquired by the VisualSonics Vevo LAZR-X photo acoustic system by FUJIFILM. The concept was inspired by Piet Mondrian’s Composition with Red, Blue, and Yellow.

Caption: The following depicts a combined ultrasound (grayscale) and photo acoustic longitudinal cross-section image of a murine cardiac left ventricle. Regions of oxygenated hemoglobin (red) and deoxygenated hemoglobin (blue) are shown. These types of images are used to quantify left ventricular function and composition in mice undergoing cardiac stress such as myocardial infarction. With this information, we believe these non-invasive imaging modalities have the potential to be clinically translated for treatment and intervention of cardiovascular diseases.

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**Cartilage – The Shimmering Substance**

Submitted by: Arthit Chatanuvong  
Contributor: Deva Chan  
Creation: This image was taken as a z-stack in an upright confocal microscope (Zeiss-LSM 800) at the Weldon School of Biomedical Engineering. The maximum projection image was extracted from the z-stacks using Zen Blue software.

Caption: The image shows a micrograph of cartilage explant extracted from Bovine ankle. Live-dead staining is performed on the tissue and the green represents live cells while the red shows dead cells. Higher proportion of green represents tissue viability under culture conditions.

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**Zebrafish Embryo RNAscope for bmp2b, chd, sizzled mRNA**

Submitted by: Linlin Li  
Creation: Ziess Confocal microscope 800

Caption: Zebrafish Embryo RNAscope for bmp2b, chd, sizzled mRNA at 5.7 hours post fertilization

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**The One Ring of Yeast**

Submitted by: Cheng Bi  
Contributor: Donghan Ma  
Creation: This two-color super-res image is about a fission yeast cell, in which the two motor proteins, Myo2p and Myp2p, expressing mEGFP and mCherry were labeled with anti-GFP and anti-RFP nanobody respectively. Each nanobody also conjugated with a super-res suitable organic dye by radiometric detection of spectrally overlapped fluorescence tags, Alexa Fluor 647 and CF660C, we obtained two-color super-res images of nanobody labeled Myo2p and Myp2p with minimized wavelength induced misalignment. The instrument is a custom bi-plane imaging system with HIL illumination; image reconstruction was done using Matlab.

Caption: Motor protein protein motor of cytokinesis, the contractile ring that separates one cell into two daughter cells. In fission yeast, there are two types of myosin-II working together to conduct cytokinesis. And this image shows the first time two types of myosin-II proteins distributed in contractile ring simultaneously with nanoscale resolution.
Interferometric Metrology in Spatially Quasi-Incoherent Light: Birch Wood Sample Analysis
Submitted by: Yacouba Dembele
Contributors: Joel Wahl; Mikael Sjodahl; Kerstin Ramser
Creation: The optical system is constructed around an imaging Michelson-type interferometer set-up in which the interference term is isolated through the temporal phase stepping method. A semi-transparent Birch wood sample deposited on a PMMA polymer is used as object with a thickness of 1.8mm. The object was moved a distance of 1 mm and images were acquired in steps of 5µ.

Cardiac Strain Pop Art
Submitted by: Conner Earl
Creation: The 3D left ventricle images were created in a custom MATLAB graphical user interface from 4D cardiac magnetic resonance images taken in a patient with Duchenne muscular dystrophy. Each quadrant represents a different colorized strain map superimposed on the heart during peak systole. Caption: Each quadrant in this image depicts a 3D colorized strain map of the left ventricle. Each quadrant in this image depicts a 3D colorized strain map of the left ventricle in the heart of a patient with Duchenne muscular dystrophy. Each quadrant represents a different colorized strain map superimposed on the heart during peak systole.

Axons Under Super Resolution Microscope
Submitted by: Peiya Zhang
Contributor: Xi Cheng
Creation: The image was taken with Single Molecule Localization Microscopy (SMLM), which is a super resolution technique that can resolve structures below the diffraction limit of light. Caption: This image depicts axons of interneurons at primary visual cortex in mouse brain section. This image shows the 3D structures of axons, where the structure variations in the 3rd dimension are indicated by the color of differences. The structure of interest is labeled with fluorophores that can blink under laser illumination. Each raw camera frame detects a subset of fluorophores labeled on the structure of interest. The final image was obtained by pin-pointing the 3D coordinate of each individual fluorophore, then rendering with these 3D coordinates. The reconstruction process is performed using INSPR software.

Microtubule Network - from Diffraction to Super Resolution
Submitted by: Hao-Cheng Gao
Creation: The raw dataset was acquired by 4Pi microscopic system. The super-resolution reconstruction was processed through SMLM algorithm and rendered by using Matlab, while the diffraction image was rendered from raw data by using Matlab. The final image was overlapped diffraction image with super-resolution image by Photoshop. Caption: The microtubule network was imaged within COS7 cell T0020 labeled by Alexa488 by using 4Pi microscope, which enables resolving ultrastructure in a nanometer-level. Here, we demonstrate that hollow structures of tubule with a diameter ~70nm can be revealed in the super-resolution reconstruction (color image in the right side pseudo-colored based on localized Z position). To visualize the resolution improvement, the diffraction image (gray scale image in the left side pseudo-colored based on fluorescent intensity) of same target was overlapped on top for comparison. Moreover, we, by good luck, revealed a heart of microtubule network.
Neurons Through a Microelectrode Array

Submitted by: Daniel Gonzales
Contributors: Hammad Khan; Saumitra Yadav
Creation: Two photon imaging through a transparent electrode array on the surface of the mouse brain. Electrical recordings were simultaneously captured. Matlab was used to analyze data, ImageJ was used to curate the two photon images, and Adobe Illustrator was used to compile into one image.

Caption: We used specialized techniques to fabricate miniscule microelectrodes on a flexible neural interface. We place this microelectrode array on the surface of the mouse brain for electrical recordings in awake animals. Simultaneously, we use a specialized microscope, called a two-photon microscope, to image the activity of many individual neurons under the microelectrode array.

MRS: Technical Innovations & Clinical Applications

Submitted by: Antonia Susnjar
Creation: The image was created in combination with an actual human MRI and MRS scan. Anatomical MRI images were opened in a dicom viewer (Horos) to illustrate a region of interest from which biochemical composition was obtained. That data was initially processed through Osprey, first all-in-one software for MRS analysis, and then quantified and fitted using LCModel. Illustrations of the brain metabolites were made using Biorender website.

Caption: Magnetic resonance spectroscopy (MRS) is a noninvasive technique used for measuring biochemical changes in the tissue. MRS can be conducted as a part of routine magnetic resonance imaging (MRI) scan on any commercially available MRI scanners. While MRI identifies the anatomical changes by obtaining contrast images, MRS creates a spectrum arraying the types and quantity of chemicals in the brain or other organs. By excluding the overwhelming signals from water and fat, MRS quantifies clinically relevant biomarkers such as choline which is a cell membrane turnover marker, and its higher levels are associated with demyelination and cancer.

Lighting the Neuron

Submitted by: Shulan Xiao
Creation: The images are taken with a 2 photon fluorescence microscope on a live neuron. The grayscale images are then color-coded base on depth with ImageJ to create the rainbow color.

Caption: This image shows a pyramidal neuron in the mouse cortex. The neuron is filled with the fluorescent dye and captured by a microscope. While it looks like a tree, the neuron receives information from its "branches", and the "trunk" of this neuron "tree" is a critical pathway for information integration. The various neuronal morphology/geometry is not only artistic, but also critical for functionality.

Super Resolution Image of Dendrite Spines in depth of 139 µm of stained mouse-brain tissue

Submitted by: Maryam Mahmoodi
Contributors: Donghan Ma; Fang Huang
Creation: The image is captured by AO-assisted Single Molecule Localization Microscopy (SMLM) and reconstructed our developed In-Situ Point spread function Retrieval (INSPR) toolbox. The AO-assisted SMLM can simultaneously detect a single molecule’s PSF shape and efficiently recompense aberrations-induced distortion. Our results indicate that the corrected PSF of the single molecules located deep into the tissue sample could approach the PSF of those placed on the coverslip surface. It demonstrates that AO technology allows robust 3D fluorescence super-resolution imaging for thick tissues.

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Cerebral Automata
Submitted by: Hammad Khan
Contributors: Om Kohle; Alicia Scott
Creation: Confocal microscopy, ImageJ, PowerPoint, Illustrator
Caption: Devastating diseases manifest from the depths of our brain. Whereby our understanding of its origins is still elusive, current work has continued to investigate the mechanisms of disease spread. The image shows one such way to map disease progression in which damaged cellular structures are labeled, identifying vulnerable areas of the brain during disease states will not only demystify the origins of pathology but what ultimately gives rise to cerebral automata.

Adipose Stem Cell
Submitted by: Sarah Brookes
Creation: Image taken on a Zeiss 880 confocal microscope and processed with Imaris software.
Caption: This is an adipose stem cell stained with fluorescent markers to show mitochondria (red), cytoskeleton (green), and the nucleus (blue).

Brain Biomechanics
Submitted by: Tyler Devine
Contributors: Yunjie Tong; Vitaliy Rayz
Creation: The brain is segmented into 4 quarters, as follows: (Top-Left) T2-weighted FLAIR (3T MRI) Coronal slice of Alzheimer’s patient visualized in ITK Snap; (Top-Right) Cauchy Stress quantified by in-house code and visualized in Paraview; (Bottom-Left) Eulerian Strain quantified by in-house code and visualized in Paraview; (Bottom-Right) White matter fiber bundles quantified and visualized using DSI Studio. With these four images, the graphical effects and construction was done in PowerPoint.
Caption: MRI-based Biomarkers for Alzheimer’s Disease – The graphic is segmented into 4 quarters, as follows: (Top-Left) 3T MRI Brain Scan of Alzheimer’s Disease patient; (Top-Right) Biomechanical stress profiles; (Bottom-Left) Biomechanical strain profile; (Bottom-Right) White matter fiber architecture, which show the "wires" connecting the different parts of the brain. These four quarters each represent a facet of our novel approach to understand the disease progression of neurodegeneration in elderly individuals. It is our hope that the analyses underlying these images will aid in the detection of cognitive decline in mid-life, while symptoms may still be treatable.

The Other Brain Cell
Submitted by: Brock Beauclair
Contributors: Edmond Rogers; Riyi Shi
Creation: Histiotypical neuronal cell cultures were stained using immunocythological techniques. Fluorescence was captured using a Zeiss 880 AryScan Confocal Microscope and Zen Black Software. Minor editing and image construction was done using PowerPoint.
Caption: This image shows neurons (green), microglial cells (red), and cell nuclei (blue). Microglia play an important role as the resident immune cell of the brain but in popular culture neurons often comes to mind as The Brain Cell. However more research into how microglia react following sickness or injury is showing that they can play an outsized role in keeping us healthy and thinking.
Simulated Hemodynamic Aortic Spaghettification
Submitted by: Sydney Clark
Contributors: Sam Zhang; Hannah Cebull; Craig Goergen
Creation: SimVascular, ParaView
Caption: This image depicts the hemodynamic stream traces using computational fluid dynamic simulations in an aorta affected by rheumatic heart disease. The systolic aortic model was contoured using vessel segmentation and patient-specific flow velocities were determined from phase-contrast magnetic resonance imaging data. The multiple overlayed lines depict ray-traced streams of particles as they move through the simulated thoracic aorta. The different colors depict different average velocities of particle flow streams, with blue lines depicting lower velocities (<25 cm/s) and red lines depicting higher velocities (>25 cm/s). This combination of multicolored lines results in an eventual visual “spaghettification” of the aorta.

The Color Spectrum of the Brain
Submitted by: Megan Lipton
Contributor: Maria Dadarlat
Creation: The image of the mouse brain surface was captured with a 2-photon microscope using Scanbox software (Neurolabware). The colored squares were created and overlaid onto the brain image using Adobe Illustrator software.
Caption: The brain's intricate capabilities are often represented in research with limited artistic rendering. Representing the brain both scientifically and artistically is important to provide a complete story in neuroscience research. To demonstrate this, I performed 2-photon imaging over the mouse primary somatosensory cortex (S1) to generate a black and white image of the brain surface. The S1 brain region is involved in important functions such as sensing movement, texture, pain, and temperature. To complement this scientific depiction, I overlaid a color spectrum to artistically represent S1 complexity. Together, this combination of science and art provides unique insight into neuroscience research.

Eye of the Storm – Dissecting Aortic Aneurysms
Submitted by: Luke Schepers
Contributor: MacKenzie McIntosh
Creation: Scanning electron microscopy images were acquired on a Tescan Vega 3 SEM imaging station with VegaTC software. Whole vessel images were acquired at low magnification (78x) and clot structures were acquired at high magnification (2kx). The H&E stained histology image was acquired by MacKenzie MacIntosh at 20x magnification with a Leica microscope.
Caption: Here, we dive deep into the false lumen of a dissecting aortic aneurysm to analyze clot structures. Mouse aortas are imaged daily with ultrasound to detect aneurysm development in vivo. Once aneurysms occur, aorta tissue samples are removed for histology and scanning electron microscopy (SEM). Whole vessel SEM (top left) and H&E stained histology slides (bottom left) show the true/original lumen and false lumen/aneurysm. High magnification SEM images (right) show fibrin structures and individual red blood cells that have morphed from biconcave discs to polyhedracytes. SEM provides high magnification/high-resolution images of early clot structure formation after aneurysm occurrence.

Positions of Axons in the Vagus Nerve
Submitted by: Chris Kannmacher
Contributors: Meredith Hedtke; Leif Havton; Natalia Biscola; Terry Powley
Creation: The graphic was creating using MATLAB software and nerve segmentation data to gradually display the positions of axons in the vagus nerve in relation to their diameters. This is overlaid onto an image of a cross section from the nerve.
Caption: The originally-submitted video shows a cross section of the vagus nerve exposing an array of axons. Using MATLAB, axons are gradually plotted correlating to their diameters with the 4 colors identifying various ranges. This video was taken from a software application developed that allows the user to interact with this graphic to identify additional information for experimentation and prediction. The image above is a screen shot from the video.
Flow streamlines provide a key to understanding cerebrospinal fluid movement in the brain

Submitted by: Neal Patel
Contributors: Tyler Diorio; Vitaliy Rayz
Creation: This image shows cerebrospinal fluid flow streamlines based on MRI study using Purdue’s 3T Siemens PRISMA MRI scanners. In this study, we acquired images that show the structure of the brain and cerebroventricular space. We also measure CSF velocities with phase-contrast 4D Flow MRI. We used these data to run subject-specific computational fluid dynamics in the cerebroventricular space using ANSYS Fluent software. Paraview, an open-source software, is used for visualizations.

Caption: Cerebrospinal fluid (CSF) plays a role in cushioning the brain and clearing metabolic wastes. Disregulation of CSF flow is associated with brain disorders ranging from hydrocephalus to Alzheimer's disease. To study CSF flow in vivo, we use Siemens 3T MRI scanner at the Purdue MRI Facility. We acquire images of the cerebral anatomy as well as the flow patterns within the cerebral ventricles. We then use these imaging data to run subject-specific CFD simulations. These streamlines in the image show simulated CSF flow patterns over the cardiac cycle in a healthy subject.

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Submitted by: Lexi Petrucciani
Contributors: Alexis Hoerter; Elsje Pienaar
Creation: The simulation was built with Repast Simphony, run on Brown HPC, and visualization was done using Python. Images were then stitched together in Adobe Illustrator.

Caption: Agent-based modeling was used to represent the interactions between immune cells and bacteria with rules, and simulations were run to match experimental data. The pink spheres represent macrophages, and the white and blue spheres represent T cells. The spherical structure is meant to emulate the tuberculosis granuloma, the pathologic structure formed in infected lungs. The disappearing of the granuloma across the panels and the title of the piece allude to the work being done to end the tuberculosis pandemic that has plagued humans for millennia.

The Mirror Dimension

Submitted by: Eugene Kim
Contributor: Tamara Krivas Ubran
Creation: The image was taken through a confocal laser scanning microscope (CLSM) with 40X magnification. The original image was then processed using the OpenCV library in Python and Adobe Photoshop to generate the patterned image shown here.

Caption: Representation of a rat hippocampal neuron. Protein signaling in neurons is critical for our learning and memory in the brain. Neurons were cultured on a dish for 11 days to observe the dendrites (green), newly synthesized calcium/calmodulin-dependent protein kinase II (CaMKII) (red), and the nucleus (blue). We observe that newly synthesized CaMKII are localized near the nucleus and make their way through the dendrite, which further implicates the protein's role in long-term potentiation.

Pop cARTilage

Submitted by: Cameron Villaranal
Creation: This is a T1 rho scan of the knee. All image processing was done in MATLAB. I generated a mask of the cartilage by hand segmenting a transverse slice containing a portion of the femoral condyles. After segmenting the image I performed a curve fit using the Bloch equations to find the T1 rho time constant for cartilage and visualized the time constant within the hand segmented regions. After this, I applied different color maps. Each of the panels is the same depiction of the hand segmented and curve fit cartilage with a different color map applied (aiming for a Warholian interpretation here).

Caption: A montage of cartilage in the style of Andy Warhol. In image processing one of the key steps is making your image or selecting and separating out a region on which to focus your analysis. It just so happens that this mask also looks like a mask.
**Actin Like A Starry Night**

Submitted by: Claudia Benito Alston

Creation: Human Umbilical Vein Endothelial Cells after DAPI, Phalloidin and a Tunel Stain. Imaged using the Zeiss Confocal at 20x magnification.

Caption: Mechanically stimulated endothelial cells (HUVECs) on the left and untreated (control) cells on the right. The cells were grown to confluence, so until they covered the entire area of a Transwell, which is a mesh cells can be grown on in a well. This model is used to measure drug delivery through a cell monolayer. The colors and focal point were chosen to look like A Starry Night, by Van Gogh. This research is contributing to the understanding of how different types of mechanical loading affect cell dynamics and drug delivery.

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**mHealth For Noninvasive Blood Hemoglobin Testing**

Submitted by: Sang Mok Park

Contributors: YoungJae Kim; Young Kim

Creation: Sang Mok Park and Professor Young Kim initially made a conceptual diagram that can represent the research clearly. Then, YoungJae Kim who is a graphic designer worked on a high-quality image.

Caption: We have developed a mobile health (mHealth) technology for noninvasively measuring blood hemoglobin levels using smartphone photos of peripheral tissue. The inner eyelid is used as an accessible sensing site because of the relatively uniform microvasculature and the absence of skin pigments. The mobile application collects red-green-blue (RGB) information from the eyelid and applies a machine learning algorithm to mathematically reconstruct a spectrum from RGB in the visible wavelength range. The reconstructed spectrum of the eye is then processed to accurately and precisely predict the amount of total blood high content.

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**Regenerated Fluorescent Silk Protein Microparticles**

Submitted by: Jungwoo Leem

Contributor: Young Kim

Creation: Left-up: scanning electron microscopy (FEI Quanta 3D FEG; Oregon, USA), the others: confocal scanning microscopy (Zeiss LSM 880; Carl Zeiss GmbH, Jena, Germany)

Caption: Regenerated fluorescent silk protein microparticles. The transgenic silk is genetically engineered with fluorescent proteins of enhanced cyan fluorescent protein (eCFP), enhanced green fluorescent protein (eGFP), and far-red fluorescent protein mKate2. Silk protein and fluorescent protein serve as edible photonic biomaterials. The fluorescent silk microparticles are used for cryptographic primitives that can play an important role in pharmaceutical and counterfeiting, such as serialization, track and trace, and authentication at the dosage level.

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**The Oxygen Distribution of a Chick Embryo**

Submitted by: Yuhyun Ji

Contributor: Young Kim

Creation: Using a deep learning algorithm, oxygen saturation distribution was predicted from an RGB image of a smartphone. Specifically, an image from a smartphone was transformed into a hyperspectral cube, and oxygen saturation values were predicted from the hyperspectral cube.

Caption: Image of a chick embryo day 8 (the left half) and its oxygen distribution (the right half). The oxygen distribution of a chick embryo was predicted from an RGB image using deep learning. In-vivo measurement of oxygen value using a camera is an easy-access technology, and we can use a smartphone as a detector even. This technology has the potential to diagnose diseases, such as anemia, skin cancer, or sickle cell disease.
Danio rerio in the Tank

Submitted by: Nissa Larson
Contributor: Nathan French
Creation: TÜV SÜD LSM800 Confocal Laser Scanning Microscope, Acrylic
Caption: This piece depicts zebrafish (Danio rerio) embryos in a freshwater tank, appearing as part of the environment. The two embryos of the Tüpfel long-fin wild-type zebrafish are shown in the center of the scene in cyan and gold. These images were taken at the three-hour post fertilization stage with the Zeiss LSM800. Fluorescent stains Alexa Fluor 647 Phalloidin and DAPI (4′,6-diamidino-2-phenylindole) designate the cytoskeletal component F-actin in cyan and the cell nuclei in gold, respectively. The transition from embryo to fish in just days is an incredible process to watch, and I wanted to recognize that in my artwork.