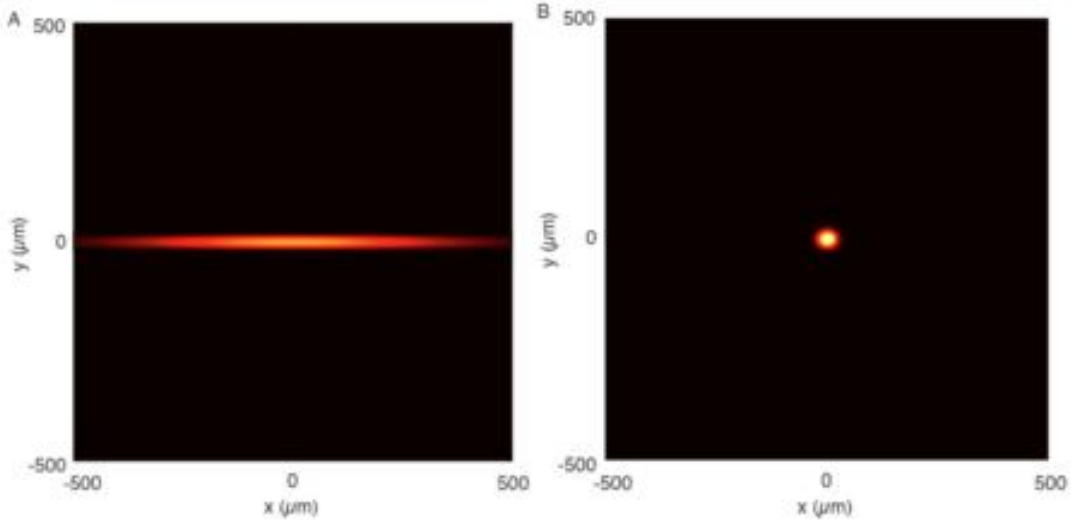
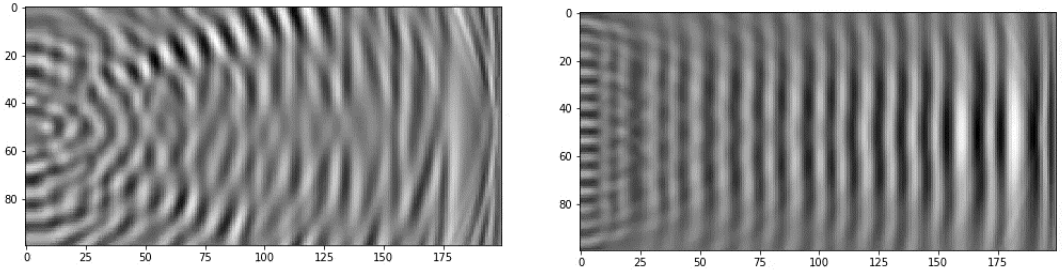
Light Sources - Serving Life and Other Sciences
(a perspective from a physicist in the U.S.)

- Motivations for upgrades of synchrotrons
- Can new capabilities being developed at light sources be useful for life sciences?
- Relevance and Impact
  - Both health and disruptive events
    - Biopreparedness
- …next talk from ALS biologist Greg Hura



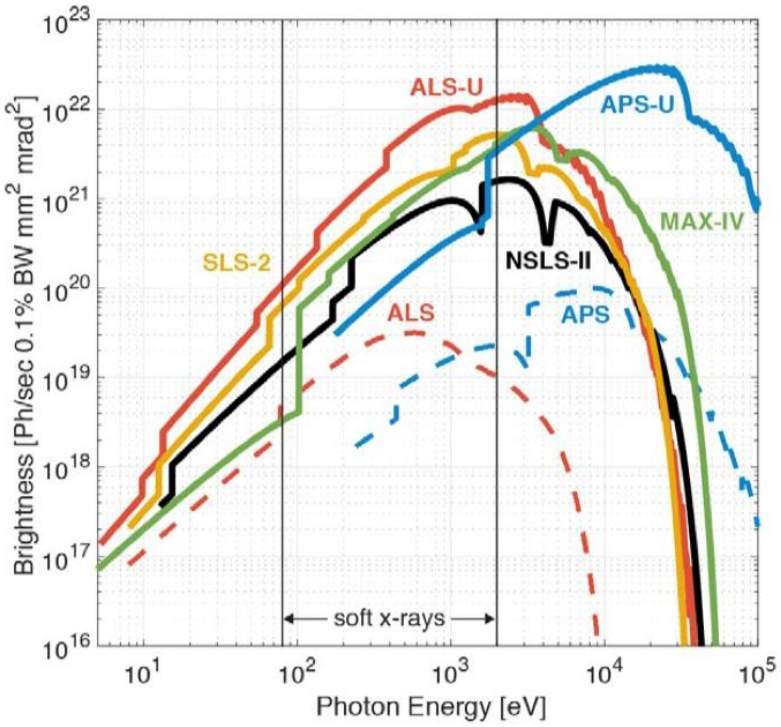


Roger Falcone
University of California, Berkeley
Advanced Light Source, LBNL

High brightness upgrades of 3rd generation synchrotrons

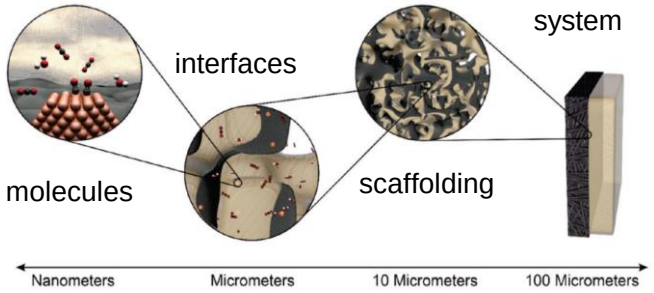
Challenges and **opportunities** for life sciences

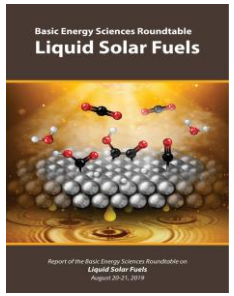
- **Lengthy shutdowns with productivity loss**
- **New capabilities - increased brightness and coherence**
  - Powerful undulator sources, round beams, improved optics
  - Micro-focus, better collimation, use of phase
- **Techniques are evolving**
  - Serial crystallography: developed at XFELS, proven at rings
  - Tender x-rays (for elemental contrast)
  - Time-resolved SAXS (msec time resolution)
  - Ptychography (chemically-resolved dynamics, 3d imaging)
  - New opportunities offered by coherence (beginning to be explored)

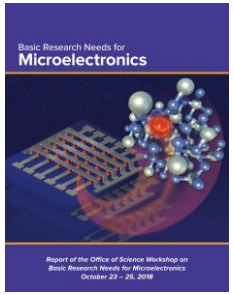


Science needs were developed at workshops and in reports

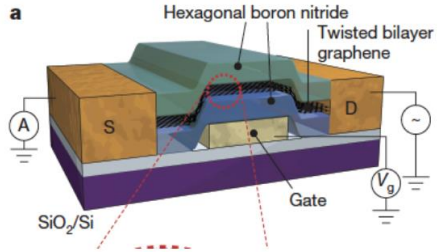
High-performance and selective catalysts



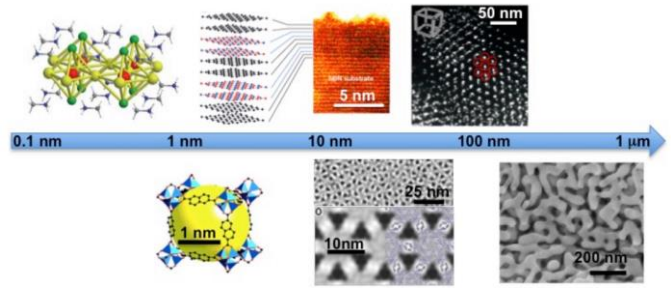


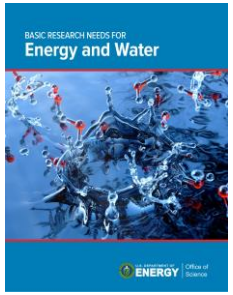


New materials for microelectronics

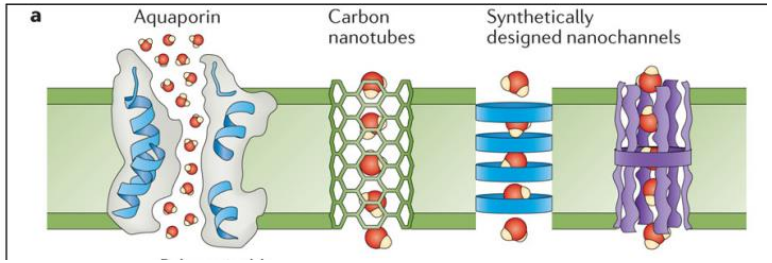


Synthesis of materials with targeted functionality





Customized membranes for water purification

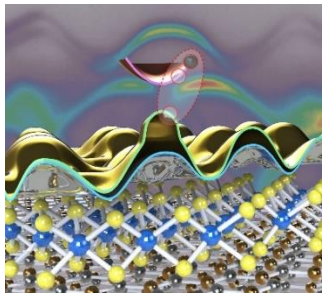


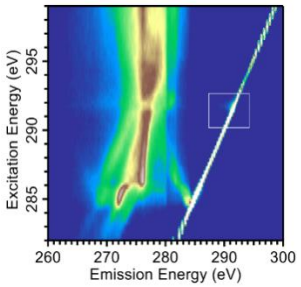
Goals for ALS-U developed to support those science needs

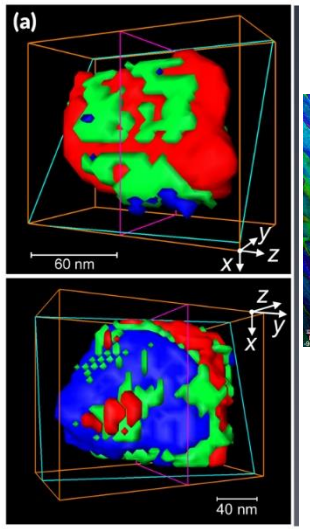
Discover new quantum materials and understand emergent properties of nanoscale electronic phases

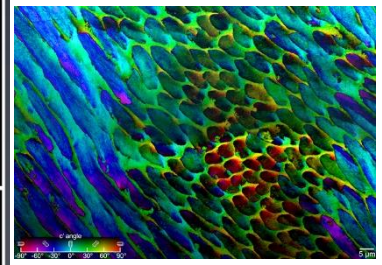
- Develop novel, low power approaches in microelectronics and for quantum information science

ARPES, XPEEM, RXSX, dichroism









Probe chemical and structural heterogeneity of materials such as polymers and biologically inspired materials

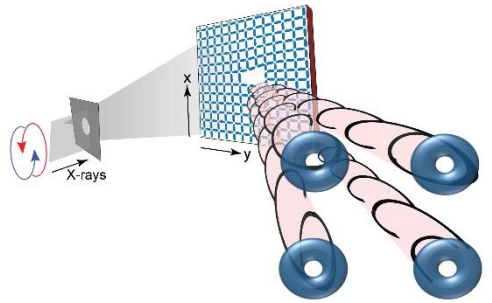
- Achieve improved functionality, lower-cost materials cycles

Nano and micro-probes, ptychography, tomography

Leverage soft x-ray phase coherence

- Improve sensitivity, spectral resolution, and spatial and temporal dynamic range of SXR techniques

XPCS, diffractive imaging

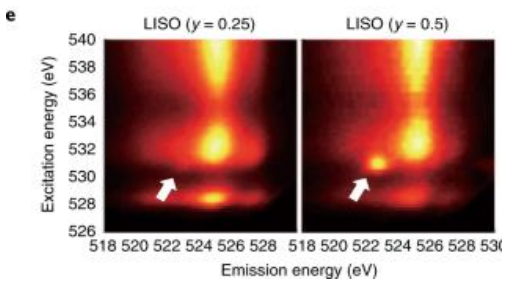


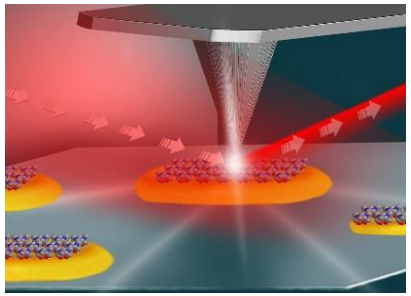
Goals for ALS-U developed to support those science needs

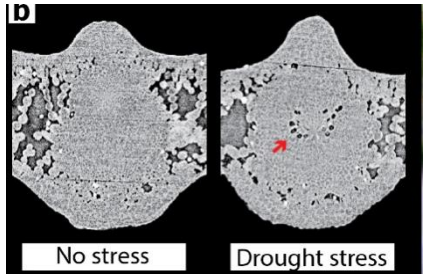
Map electronic, ionic, and chemical pathways in catalysis, energy conversion, and energy storage

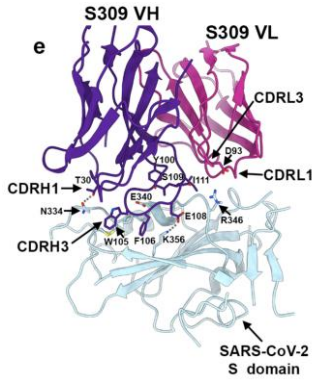
- Support sustainable energy future, low environmental impact

SINS IR, Chemical RIXS, APXPS









Conduct time-resolved and in situ/operando/in vivo studies of geological and biological materials and systems

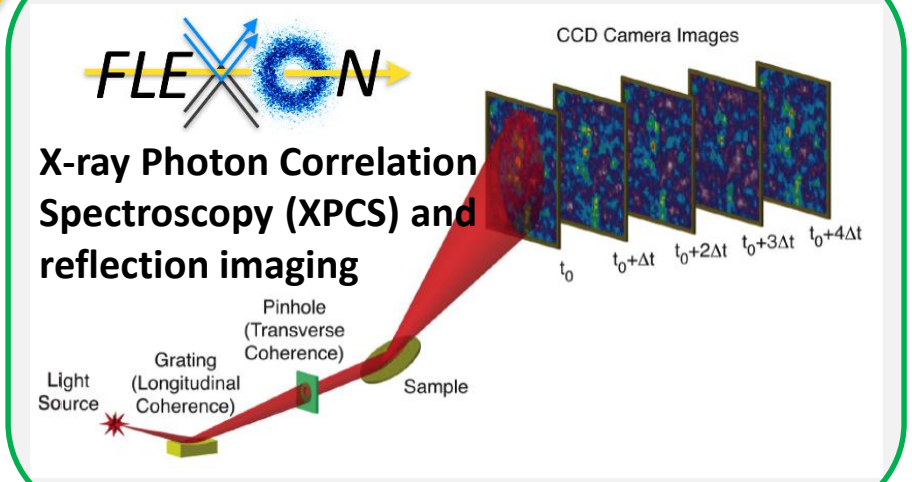
- Develop deep understanding of interactions and mechanisms of biological and environmental systems across large temporal and spatial scales

Diffraction, nano-x-ray probes

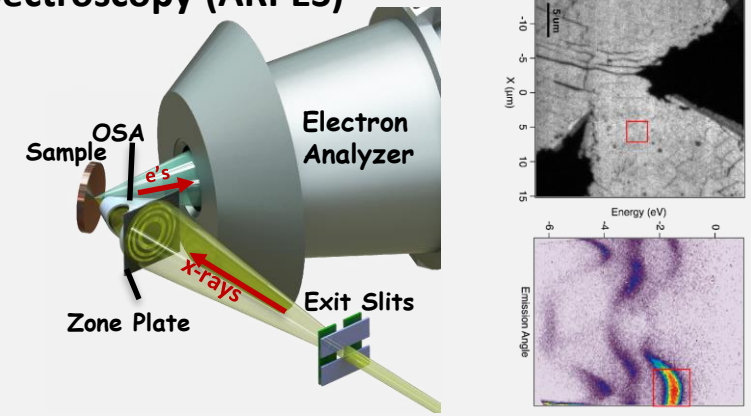
Can these new capabilities also benefit the life sciences?

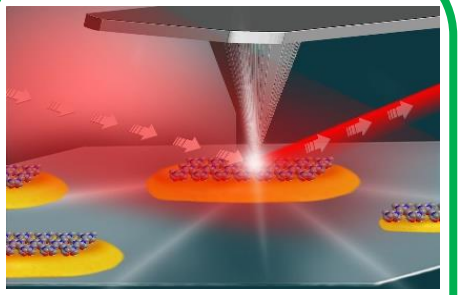
New ALS-U beamlines support those goals

X-ray Photon Correlation Spectroscopy (XPCS) and reflection imaging

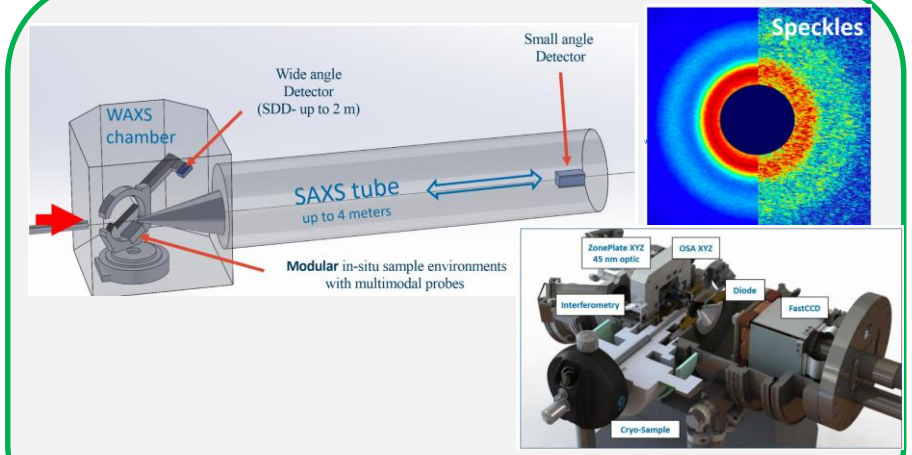


Angle resolved Photoemission Spectroscopy (ARPES)



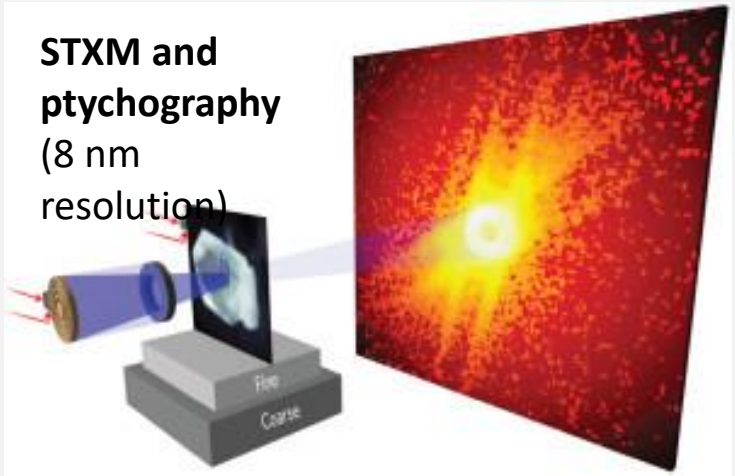


SINS IR
for cell typing
with
1 micron resolution



Tender-nanoprobe and coherent scattering

STXM and ptychography (8 nm resolution)



PEEM,
full-field microscopy,
ambient condition photoemission,
etc.

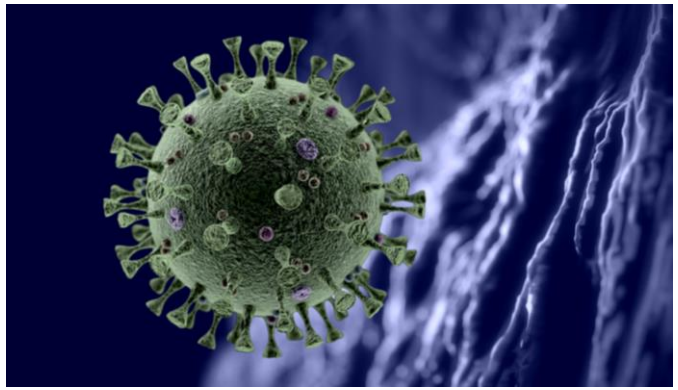
ALS-U
ADVANCED LIGHT SOURCE

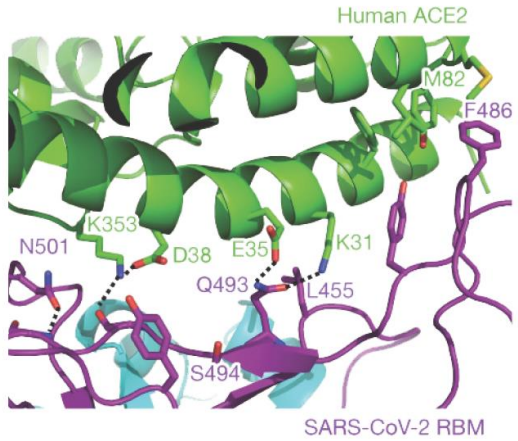
Synchrotron upgrades – explore use for life sciences

- Increased beam stability, higher brightness, round beams
- Multi-bend achromats allows smaller-gap insertion devices for power and shorter wavelengths
- Increased use of coherent imaging techniques
- Evolving use of pump-probe techniques with various triggers, for dynamics
  - “camshaft timing modes” and femtosecond slicing sources eliminated
    - modest time resolution at storage rings
  - At FELs, ultrafast dynamics with two color (e.g., Raman gain, diffraction + spectroscopy)
- Trend to facility operations with set of multimodal capabilities
  - x-ray, electron, optical
  - links to supercomputing centers, applied mathematicians, sample prep, indexing, etc.
- An example interesting problem: chemical-imaging, multiscale scanning of cm^3 of soil

Science for Biopreparedness is increasingly important

- A recent U.S. report was motivated by impact of work on COVID-19
- Collaboration among agencies (DOE ASCR, BES and BER)
  - Build on existing biology infrastructure at user facilities (NIH, HHMI, NSF, industry)
- Identified roles that facilities should play to address future pandemics and related crises
- Develop *Priority Research Opportunities* to support Biopreparedness
  - Prepare for: “natural outbreaks, lab accidents, malevolent acts”

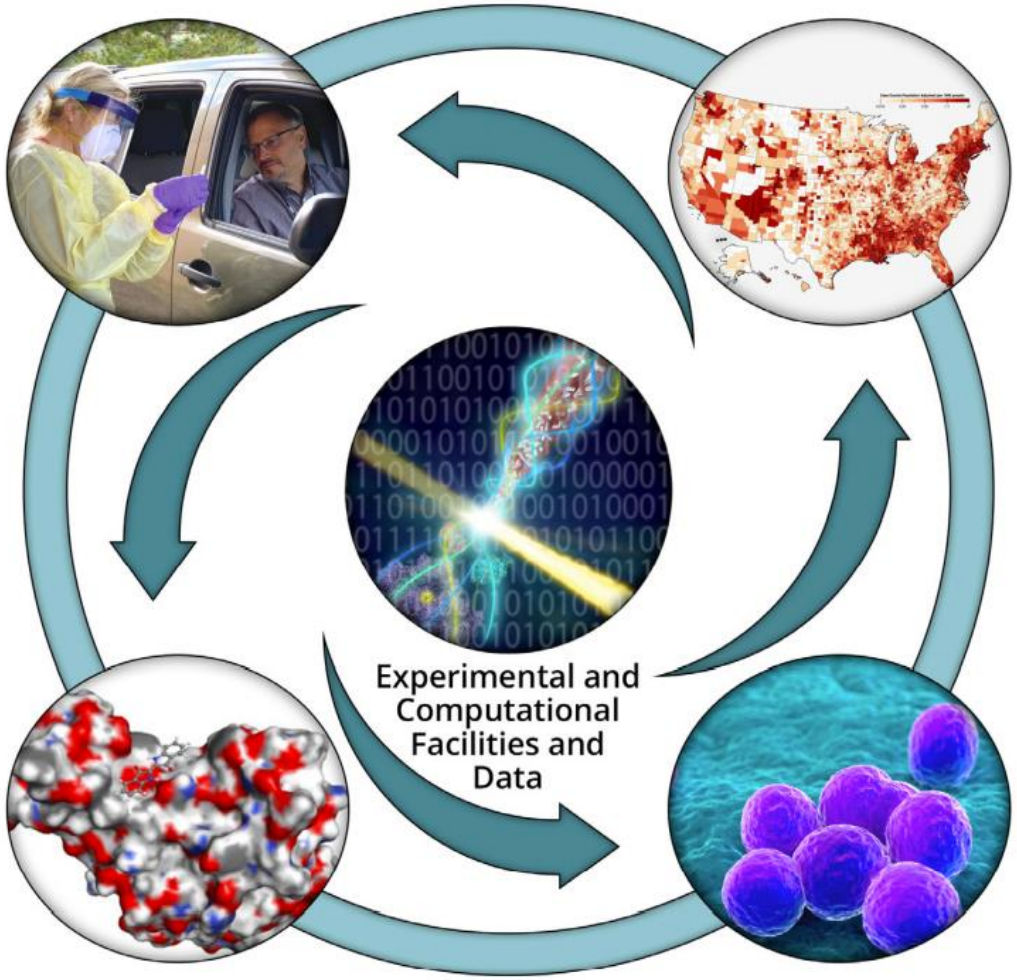




SARS-CoV-2 Spike protein bound with human ACE2

Research at labs & user facilities key for Biopreparedness

Surveillance, Testing, and **Diagnostics**



Epidemiological **Modeling**

Molecular Mechanisms, Systems Biology, and **Therapeutic** Development

Materials and Manufacturing

Report identified 5 *Priority Research Opportunities*

- Decode **pathogen emergence**, evolution, and host-pathogen dynamics in real time
- Build a **multiscale understanding** of biomolecular interactions to catalyze design of targeted interventions
- Elucidate multiscale ecosystem complexities for robust **epidemiological modeling**
- Exploit biotic–abiotic interfaces to accelerate design, discovery, and **manufacturing of materials**
- Accelerate biopreparedness by **integrating experimentation, computing, and globally distributed data**

⇒ *Biopreparedness Research Virtual Environment (BRaVE) Initiative ($35M FY23)*

(also needs **rapid access**, HPC assets, sample & prep, permissions, public-private-partnerships, including **international** relationships)