



# Bio-Scales

## Identifying gene functions across biological scales

Complex systems at every scale of life, from cells to organisms to the global ecosystem, impact the movement of energy and materials. Understanding the intricate ways that interactions between genes and traits influence outcomes on the ecosystem scale can inform a range of solutions for issues such as removing carbon from the atmosphere through biological means, managing nutrient cycles, reducing mercury pollution, recovering from extreme weather events, and designing secure biosystems.

For instance, identifying and engineering genes in plants that allocate carbon to roots can increase biological carbon capture while creating harder feedstocks for bioproduct and biofuels production. Also, tuning plants and their microbiomes for more efficient uptake of nitrogen will reduce the need to use nitrogen fertilizers that cause toxic algal blooms along national coastlines and waterways.

## Addressing a critical bottleneck in biology

Although DNA sequences are readily available, connecting genes to desired traits in plants and microbes and determining the ecosystem effects of those gene functions is a challenge requiring extensive, integrated capabilities—from synthetic biology to large-scale experiments in natural environments. Oak Ridge National Laboratory is working to foster technological advances and accelerate identification of gene function, across species, across scales, and at low cost.

**Molecules, cells and organisms**—Evaluating gene effects through protein synthesis, promoter characterization, transposon library generation, and development of genetic systems for non-model organisms

**Communities, synthetic environments**—Defining and characterizing gene function in groups of organisms in controlled laboratory settings, from microfluidic platforms to greenhouse-based studies

**Ecosystems, natural environments**—Measuring and characterizing organisms across diverse natural biomes to enable population-scale studies and verification of gene function in the field

**Analytical imaging and characterization**—Developing and using new technologies for phenotypic characterization of molecular and cellular systems

**High-performance computing and simulation**—Driving knowledge integration and discovery for defining gene function through supercomputing and explainable artificial intelligence



**IDENTIFYING**  
key gene  
functions



**ANALYZING**  
complex biological  
systems



**VALIDATING**  
gene function  
across scales



**TRANSLATING**  
data into knowledge  
with supercomputing



**ENGINEERING**  
genes to yield  
desired traits



**SECURING**  
biosystems  
through design



**SUPPORTING**  
a thriving  
bioeconomy



“We apply a range of expertise and capabilities to translate DNA sequences into new knowledge about gene functions that drive key organismal and ecosystem processes.”

**Mitch Doktycz, Group Leader, Biological and Nanoscale Systems**

# Comprehensive Capabilities



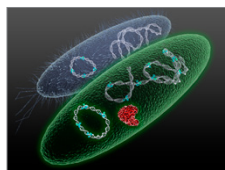
**Supercomputing and simulation—**  
Applying supercomputing and artificial intelligence to mine massive data sets, yielding new insights; modeling processes from molecular to ecosystem-scale



**Data analytics—**Collecting, assembling, and interpreting real-time data through remote sensing and automated measurement capabilities



**Imaging and neutron science—**  
Analyzing plants and microbes using mass spectrometry, imaging-based tools, stable isotope capabilities, and two of the world's most powerful sources of neutrons



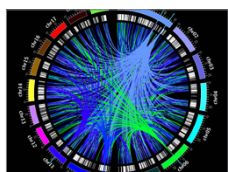
**Synthetic biology—**Developing new methods and tools to bioengineer organisms, including non-model microbes; creating synthetic environments such as microfluidic platforms



**Population-scale studies—**  
Leveraging genome-wide data sets and quantitative trait locus analyses to identify candidate gene mechanisms



**High-throughput phenotyping—**  
Automating measurement of a range of key plant characteristics using the most diverse suite of imaging capabilities of any system worldwide



**'Omics measurements—**Profiling and quantifying proteins and metabolites from diverse biological samples to understand molecular mechanisms at organism, biome, and ecosystem scales



**Large-scale natural environments —**  
Evaluating organism characteristics and ecosystem processes through highly-instrumented ecosystem experiments, common gardens, and field sites

## Recent Impacts

- Identified gene networks in poplar trees that control callus formation and analogous genes in humans that control tumor formation, advancing understanding for bioenergy and cancer research
- Discovered the gene that controls an important symbiotic relationship between plants and soil fungi and successfully facilitated the symbiosis in a plant that typically resists it
- Demonstrated a way to isolate and grow targeted bacteria using genomic data, making strides toward resolving the grand challenge of uncultivated microbial “dark matter,” which remain unstudied in the laboratory
- Pinpointed the genetic variation (single nucleotide polymorphism) that triggers a metabolic pathway in poplar trees and validated the discovery by inserting the gene and producing the same function in rice, where this pathway is not native

## Partnerships and Collaborations

Research focused on Bio-Scales leverages a range of projects and resources at ORNL and across the national laboratory system that are supported by DOE's Biological and Environmental Research program in the Office of Science. This includes DOE's Bioenergy Research Centers, the Systems Biology Knowledgebase and user facilities such as the Joint Genome Institute at Lawrence Berkeley National Laboratory and the Environmental Molecular Sciences Laboratory at Pacific Northwest National Laboratory.

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