biogears®

Open Source Human Physiology Engine

BioGears is the most comprehensive, open source mathematical model of human physiology available.

BioGears democratizes medical modeling and simulation, and will transform healthcare training technologies.

Interested?

Your readers will be too.

Who

Scientists and engineers at Applied Research Associates (ARA) are developing BioGears. To complete this work, ARA has partnered with medical doctors, and physiology, and pharmacology subject matter experts.

For media inquires, please contact Jenn at 919.582.3438 or jcarter@ara.com

What

BioGears is an open source, comprehensive, extensible human physiology engine released under an Apache 2.0 license. BioGears simulates resting physiology and real-time changes in physiology due to injuries and medical interventions. BioGears provides a virtual physiological patient platform that can be extended and customized for a variety of scenarios and use cases to enable safe and effective medical training and education. The engine can be used as a standalone application or integrated with simulators, sensor interfaces, and models of all fidelities.

When/Where

BioGears has been under development since September 2013. The team developing BioGears is located in Raleigh, NC.

Why

ARA solves problems of national importance. The implication of using BioGears in training tools, means that healthcare professionals will be able to train on virtual physiological patients - improving their skills and patient outcomes.

Our goal is for BioGears to become the standard for physiological modeling. The BioGears platform can be extended, customized, and modified for multiple use cases. Our Software Development Kit (SDK) and extensive documentation were created with our end user groups in mind: simulation content developers, biomedical modelers, MedSim technology integrators, and researchers/educators.

About

BioGears is being integrated with serious games and manikins to improve training effectiveness by simulating real-time physiologic response to injuries and medical interventions.

Our four primary work areas ensure all users have the information and access they need to use BioGears in the next generation of medical research, training tools, and health devices and hardware.

BioGears Engine

Mathematical models for a wide range of physiology systems, medical interfaces, and substances lower the barrier to create medical training tools.

Common Data Model

Standard inputs, outputs, units, and naming conventions make model addition and product integration quick and easy.

Our Community

BioGearsEngine.com is a place for discussion and sharing among our community of users. Explore our showcase scenarios, forums, and tutorials.

Documentation and Validation

Tutorials, code-based documentation, and scenario examples make BioGears easy to understand and use. Validation ensures accurate model output.

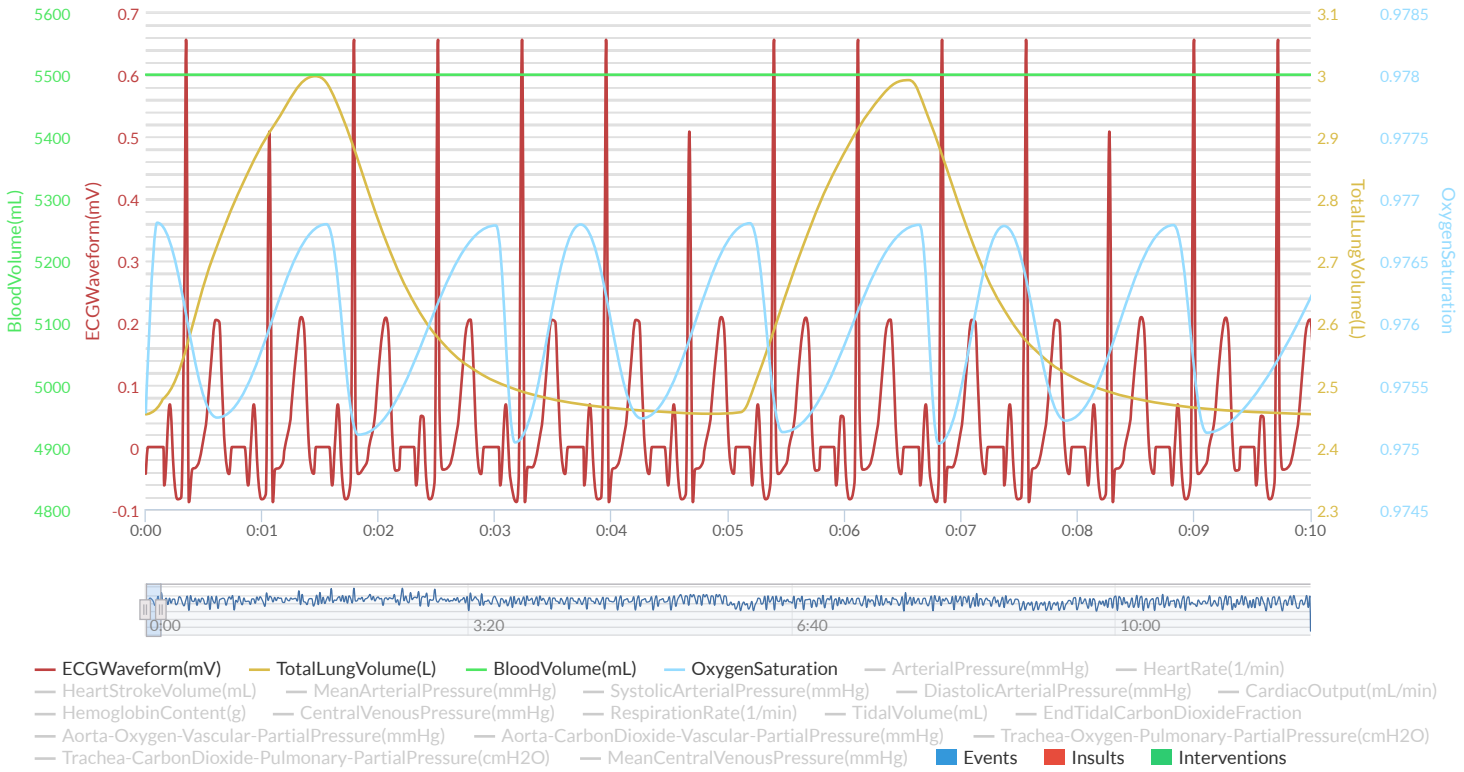
Where We Are

To date, the BioGears Engine and related files have over 4,500 downloads.

BioGears has been seamlessly integrated with multiple immersive medical education technologies and is helping healthcare professionals learn and retain life-saving skills.

BioGears is available for download via an Apache 2.0 license and includes multiple system models and examples of multiple engine interfaces.

Our website also includes multiple showcase scenarios that demonstrate the degrees of patient customization, the numerous insults and injuries, and the assessments available in the engine. For instance, our Respiratory system includes 'insults' such as: pneumothorax, asthma attack, bronchoconstriction, and airway obstruction and 'interventions' such as intubation, and needle decompression.



Where We Are Going

Imagine a virtual physiological patient.

BioGears will establish an extensible software and modeling platform that enables us to model accurate physiologic human response to injuries, medical procedures, changes in nutrition, drug dosages, chronic conditions, and multiple other physiologic events.

At maturity, BioGears® will be a whole body simulation comprised of accurate system-level models, features, and substances, outlined below.

Systems

Cardiovascular system computes hemodynamics

Respiratory system computes pulmonary functions

Energy balance system computes temperature, exercise readiness, and nutrient usage

Substances system computes diffusion, gas exchange, and drug effects

Environment modifies ambient values and thermal properties

Renal and Gastrointestinal Systems compute nutrient consumption and clearance

Endocrine and nervous systems maintain homeostasis through feed-back mechanisms

Features

- Library of Drugs
- Drug Administration through multiple routes

- Electrocardiogram
- Anesthesia Machine

- CPR
- Pulmonary Fuction Test
- Complete Blood Count
- Urine Panel

- Chronic Conditions
- Insults & Interventions

Substances

Drugs

- PK Model
- PD Model

Blood

- Hemoglobin
- Gases
- Ions

Hormones

- Epinephrine
- Norepinephrine
- Insulin

Nutrients

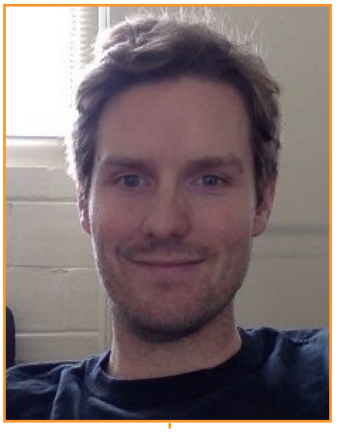
- Fat
- Sugars
- Protein

Research Team

The BioGears team includes ARA's scientists and engineers, mentors at the U.S. Army's Telemedicine and Advanced Technology Research Centers (TATRC), Medical Modeling and Simulation Innovation Center (MMSIC), and pharmacology, medical, and physiology research collaborators. Our diverse team brings a truly integrative approach to model development and medical simulation technologies.

To chat with our team about BioGears, *contact us*!

Meet Austin.



Austin Baird, PhD is the principal investigator for BioGears and leads the team of scientists, engineers and clinicians working on the project. Austin has years of experience working on cutting edge research and development programs. Austin earned a Ph.D. in Applied Mathematics from UNC Chapel Hill and completed his postdoctoral research at Duke University. Dr. Baird has research interests in biomedical modeling and simulation, mathematical biology, data visualization, and computational development of complex mathematical problems.

Thomas B. Talbot, MD
Program Mentor and Technical Advisor

Harvey Magee
Grants Office Representative, TATRC

Bryan Bergeron, MD
Collaborator, Medical Simulation Expert

Q&A

1. Who sponsors BioGears?

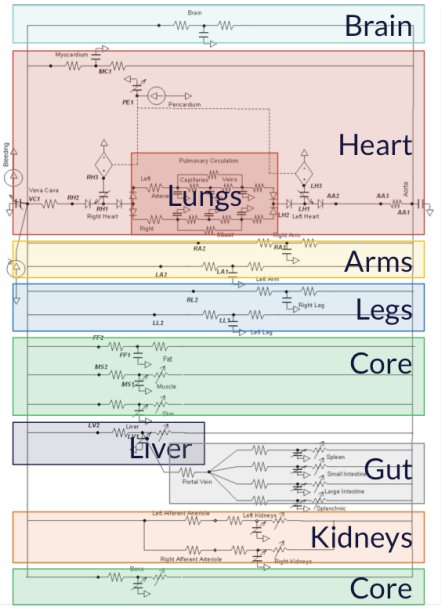
BioGears is a 5-year, $7M program funded by the Defense Medical Research Development Program (DMRDP), Joint Program Committee-1 (JPC-1). Our collaborative partners and mentors at the U.S. Army's Telemedicine & Advanced Technology Research Center (TATRC), Medical Modeling and Simulation Innovation Center (MMSIC), administer this program under USAMRMC award number W81XWH-13-2-0068.

2. Tell me about the R&D behind BioGears and a little more about how it works?

BioGears is a closed-loop system that uses physics-based lumped parameter models to simulate real-time system-level physiologic behaviors. Our lumped parameter models use electric analog circuits to represent the physiologic characteristics of a system.

BioGears developed a generalized circuit solver that uses an electronic-hydraulic/thermal analogy to model the body's fluid dynamics and thermodynamics. These electric analog circuit models use circuit parameters, such as resistors (resistance to flow through airways /blood vessels) and capacitors (ability of the vessel or airway to dilate or constrict), to simulate human physiology. Additionally, substances (such as drugs, hormones, and nutrients) are circulated through BioGears systems. The substances flow with fluid (air/blood) and can be removed or transferred between systems via diffusion equations, and clearance or metabolic factors. Substances then interact with the circuit values to modify the system behavior.

Using these circuit models as the basis for BioGears provides a strong base for each individual system and provides a mechanism for incorporating different injuries and patient conditions into the model. An example of our cardiovascular system is below:



Conditions:

- Heart Failure
- Anemia
- Arrhythmias
- Pulmonary Shunt

Actions:

- Insults:
  - Pericardial Effusion
  - Hemorrhage
- Interventions:
  - CPR
  - IV Fluid Administration
  - Tourniquet (by reducing/eliminating Hemorrhage)

Assessments:

- ECG waveform

3. Is the BioGears Modeling approach control-based or physics-based?

In short, BioGears uses both approaches. Unlike many other whole body physiology calculations , BioGears is not state-based. The lumped parameter models are closed-loop systems that represent individual systems (i.e. Cardiovascular, Respiratory, Renal, Energy, etc). Our models are physics-based and are solved using differential equations.

Many of the interfaces (actions, injuries, interventions, etc.) are implemented using a control-based systems approach and tied to the physics-based model through feedback loops. This method preserves the physics-based modeling approach, while allowing multiple effects to be introduced in real-time. The significance of this modeling approach is that BioGears uses physic-based calculations in a way that can be used for training technologies that require real-time models for dynamic user interaction.

4. You mention that BioGears is customizable and has been integrated into medical education tools. Can you provide an example?

The engine's flexibility allows researchers, modelers, and training content developers to execute simulations for differing critical care scenarios by varying patient parameters, insults and injuries, and intervention times.

Over the past two years, the BioGears team has worked with the Applied Research Associates Virtual Heroes Division in developing 'Combat Medic'. This is a serious game sponsored by Army RDECOM-STTC to train Combat Medics on how to treat the top three preventable causes of death on the battlefield: Hemorrhage, Airway Obstruction, and Tension Pneumothorax (collapsed lung). This training tool uses an immersive environment built using Epic's Unreal Game Engine. Our team is also currently working to integrate BioGears into several medical manikins.

The BioGears team has developed several unique scenarios to simulate the injuries and medical interventions for the above three cases. BioGears provides application programming interfaces (APIs) for content developers to easily retrieve accurate physiology state from BioGears. Because BioGears runs faster than real time, it responds to user actions and provides data that powers realistic visuals, and vital sign responses in the combat medic training application.

As trainees interact with, and treat digital patients, the physiology engine dynamically updates, allowing trainees to see how their actions impact the physiological response of a patient in real-time:

Hemorrhage

Airway Obstruction

Tension Pneumothorax

*Images provided courtesy of the Combat Medic Project, funded by RDECOM-STTC

Topics of Interest

Consider some of these popular topics and angles for your story.

- Could BioGears be integrated with virtual reality and augmented reality sensor systems for 3-D training and visualizations?
- Could BioGears be used to support prolonged field care training and force readiness metrics for the military?
- How will an accurate whole-body virtual physiological patient change the state-of-the-art in medical training technologies?
- What are the potential implications of BioGears to the average consumer? Will people be able to create a customized patient using their health data, that is now readily available in wearable health tracking devices?
- How will BioGears impact the military medical training community? How will this help prepare our medics, physicians, and surgeons for unique trauma cases?