



# The Strategic Depth of BioGears

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Original Government Proponent “Public Physiology Research Program”



# MMB4 VS. GF

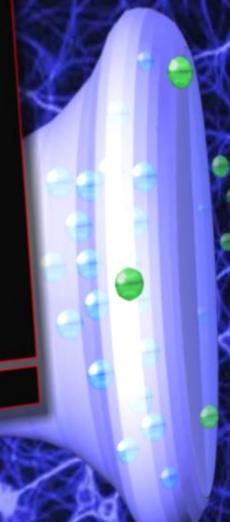
T.O.X.I.C  
01 : 10

Oxime: 7  
Anticholinergic: 0 mg  
Anticonvulsant: 0 mg

Let's try MMB4 instead

mmb4 oxime administered  
7 nerve agent molecules destroyed

mmb4 oxime administered  
6 nerve agent molecules destroyed



## CERVIX CITY



HIGH POWER VIM W/ VINEGAR  
A dense, white epithelium is shown in the center of the slide extending into the endocervical canal. Dysplastic epithelium appears white after application of vinegar due to a slight de-pigmentation of the cells and an increased light reflection from the cell's larger nuclei.



## Cutaneous Anthrax

Facial Eschar in a child, palpebral edema

Arm Series

Neck Series

Facial Lesions

Bullous Lesions

Children

Scarring

Other

To select a topic,  
click on its name

Choose numbered  
images for each topic

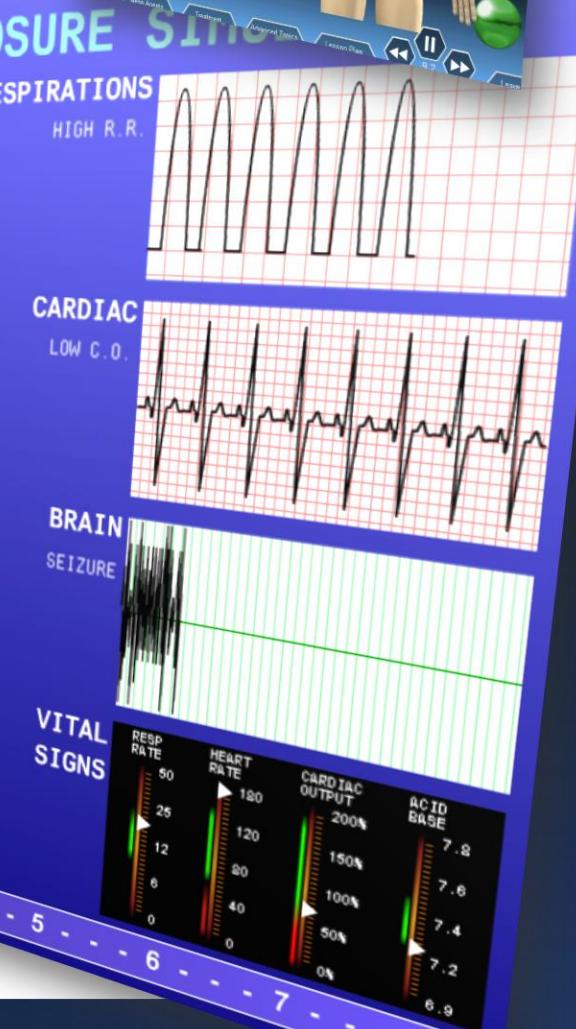


## CYANIDE RESPIRATORY SCENARIO

00:00 Cyanide exposure  
00:15 Increased rate and depth of breathing  
00:30 Loss of consciousness  
00:60 Seizures

Previous - 0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - Next

Timeline in Minutes



# 2011 TATRC: What need were we trying to fill?

- Saw need to stop replicating underlying development tool technologies
- Open source developer tools can decrease R&D effort, cost and risk for future applications
  - Physiology Engine (BioGears)
  - VR Surgery Engine (OpenSurgSim)
  - VR Task Trainer Standard Platform (TOPS - USUHS)
  - Open Medical Asset Repository (Medical Media Exchange, USC)
  - Open Medical Gesture System (OpenMG, USC)
  - Virtual Standardized Patient Library (USC Standard Patient, USC)
  - Advanced Modular Manikin (University of Washington)
- Physiology Capabilities Targeting Real-Time Clinical Applications

# Public Physiology Research Platform

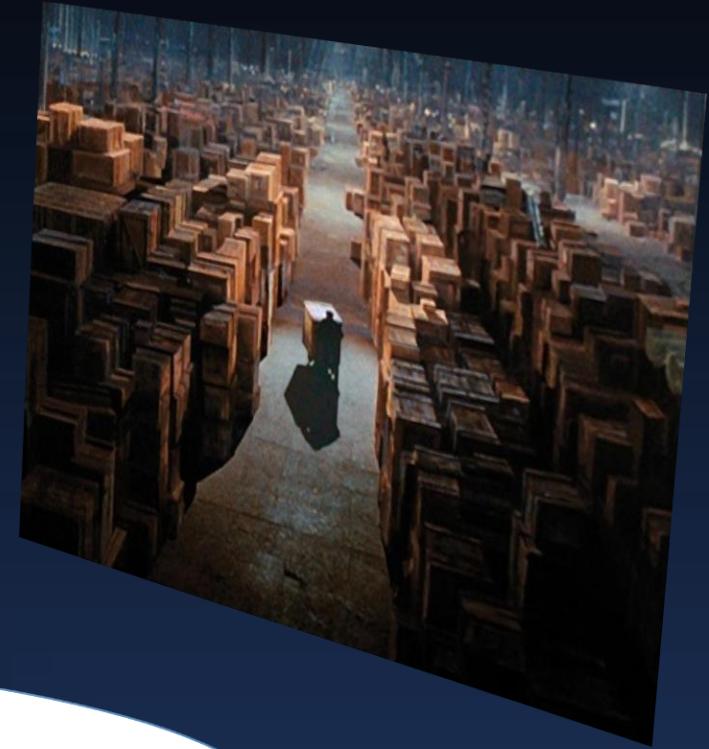
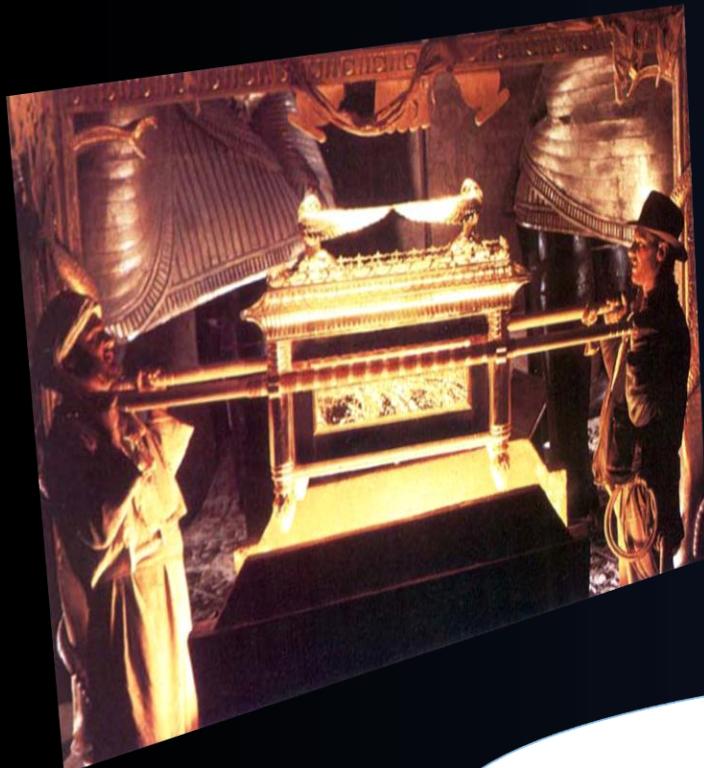
- New \$7 Million research effort through AFSIM
  - Defense Health Medical Research Program / JPC-1
  - Telemedicine & Advanced Technology Research Center
  - R&D team is **[TO BE AWARDED SUMMER 2012]**
- New generation modular physiology engine
  - Broad capabilities
  - Public input period during development
  - Hackable
  - Free for anyone to use in their own projects



# 2010-2012 TATRC / JPC-1a MSIS

- \$7M Solicitation – “Public Physiology Research Platform”
  - Open-Source & Free
  - General Purpose Physiology Engine (Military + Other)
  - Real-Time Clinically Focused
  - Equation or circuit analogue based. No Computationally Intense Modeling
  - Hackable & Interfaces with state machines
  - Modular and extensible
  - Multiple Systems
    - Respiratory, Cardiovascular, Energy, Renal, GI, Environment, Nervous system, exocrine & endocrine systems, body variations, pharmaceutical agents, threat agents, exercise.....
- 2012 Award to Applied Research Associates
  - Best proposal, talented team, great vision, working engine, drug capability, commitment to open source, community engagement plan

# Our Surprising Struggle



biogears™

# Approaches to simulating biology

- **Modeling Systems**

- Physiology Engines
- Kinetic Models

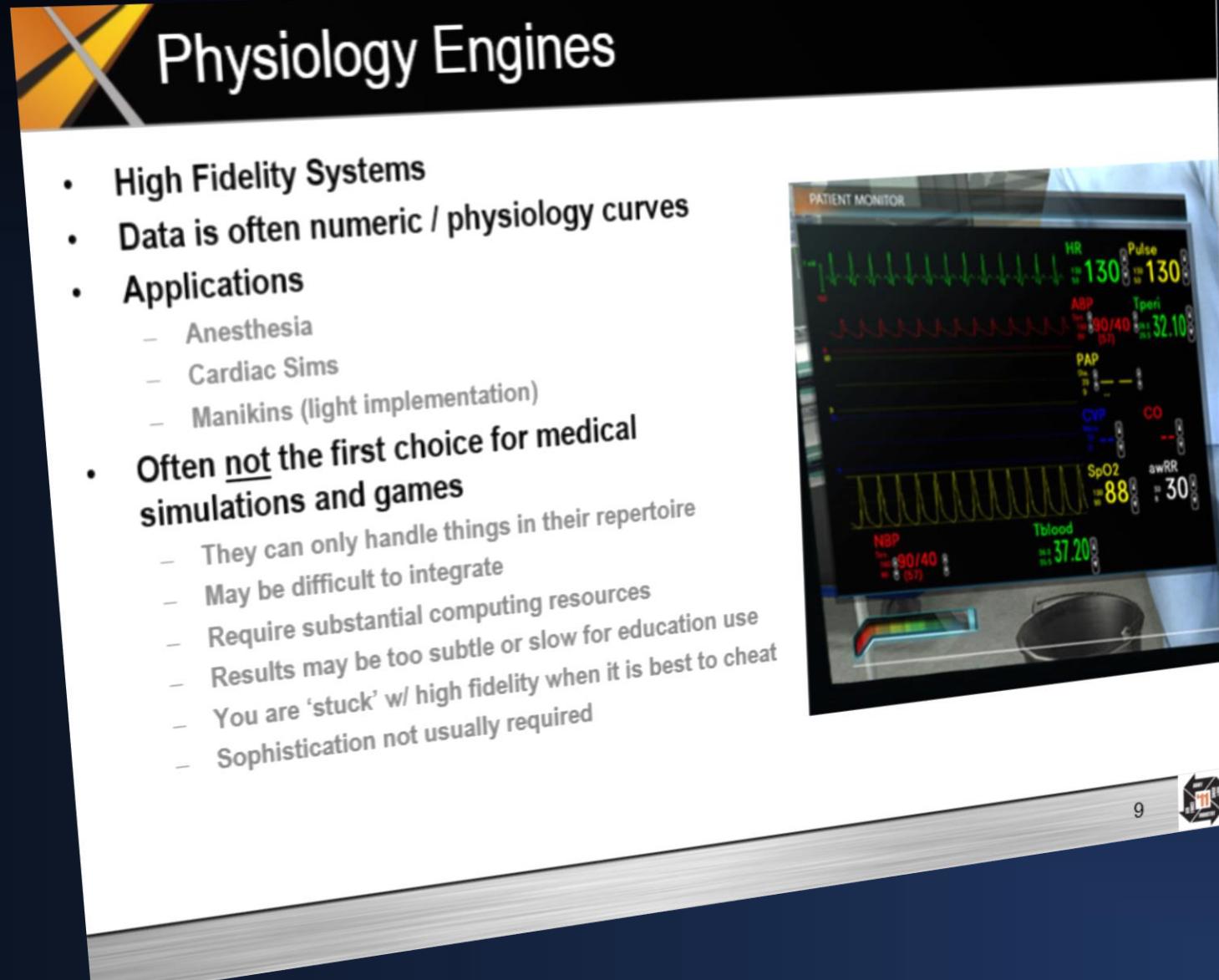
- **Rule Based Systems**

- Complex State Machines
- Simple State Machines

- **Other Systems**

- Health Score Systems
- Branching Cases

# My “Old” take on Physiology Engines



**Physiology Engines**

- High Fidelity Systems
- Data is often numeric / physiology curves
- Applications
  - Anesthesia
  - Cardiac Sims
  - Manikins (light implementation)
- Often not the first choice for medical simulations and games
  - They can only handle things in their repertoire
  - May be difficult to integrate
  - Require substantial computing resources
  - Results may be too subtle or slow for education use
  - You are ‘stuck’ w/ high fidelity when it is best to cheat
  - Sophistication not usually required

PATIENT MONITOR

HR 130 Pulse 130

ABP 90/40 Tperi 32.10

PAP

CVP CO

SpO2 88 awRR 30

NBP 90/40 Tblood 37.20





# Comparison of Approaches

|  | Physiology Engines                          | Complex State Models                             | Simple State Models   | Health Scores       | Static Presentations |
|--|---|--|---|---------------------|----------------------|
| Handling of unexpected & complex inputs    | Easy  | Difficult  | Impossible  | Moderate            | N/A                  |
| Ease to correlate visualization with model | Difficult                                   | Easy   | Very Easy   | Moderate            | Very Easy            |
| Response to user input                     | Gradual                                     | Instant  | Instant   | Gradual / Instant   | None                 |
| Graceful recovery from learner errors      | Yes   | Challenging                                      | No  | Yes                 | N/A                  |
| Suitability for lengthy scenarios          | High  | Low  | Low   | High                | Low                  |
| Biological Fidelity                        | High  | Moderate   | Low   | Low                 | Low                  |
| Typical perception of biological fidelity  | Moderate-High                               | High   | Low   | Moderate            | None                 |
| Best Use Scenario                          | Advanced Simulations & Exploratory Learning | Interactive Case Scenarios & Game Based Training | Interactive Case Scenarios, Presentations & Mini-activities | Game Based Training | Case Studies         |
| Development Effort                         | Difficult                                   | Moderate   | Easy  | Easy                | Very Easy            |



# Complex State Machines

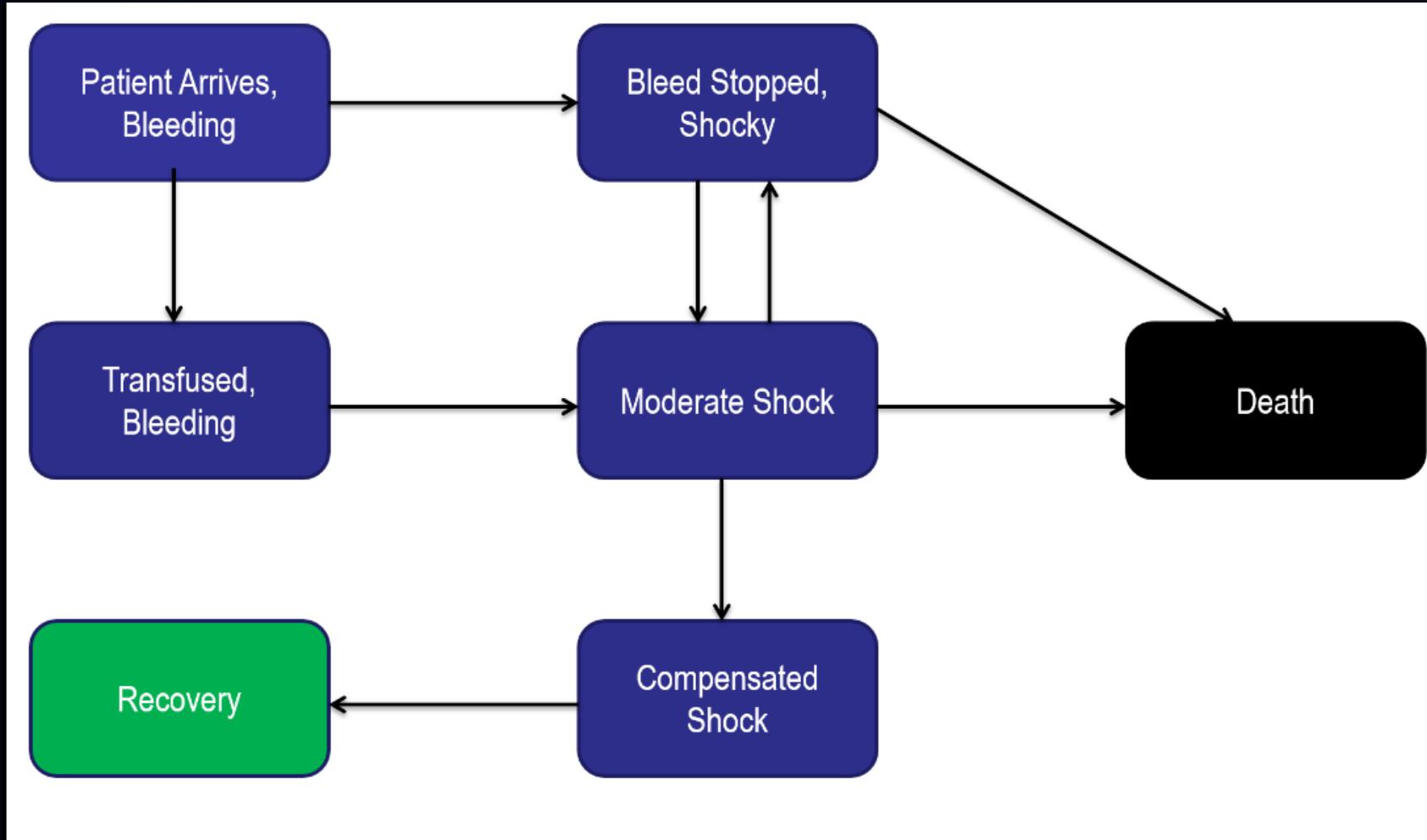
- **Advantages**

- Immediate and controlled feedback from user inputs
- More predictable than physiology engine
- Can be written to go where the author wants it to
- If done well, lends a realistic & sophisticated appearances

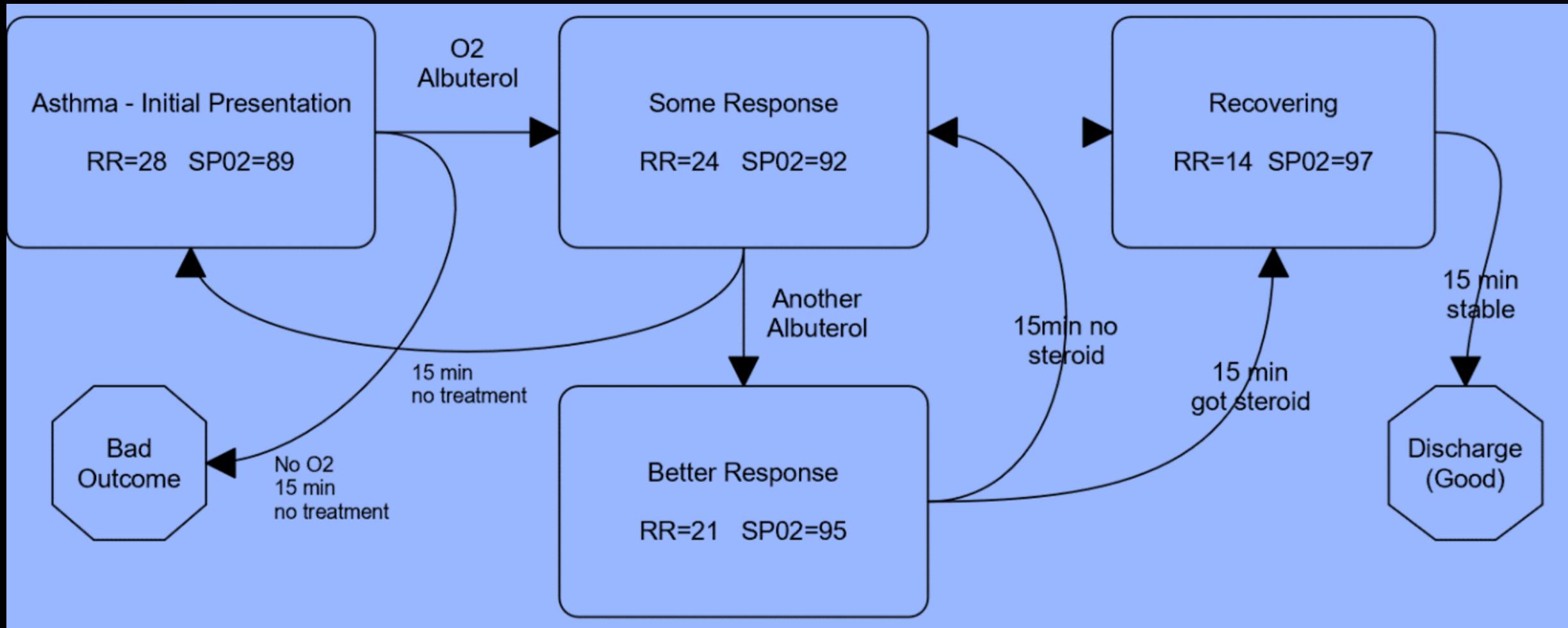
- **Disadvantages**

- Programming complexity increases exponentially
- Difficult to recover from user errors
- Individual coding for every step

# Complex State Machines



# Complex State Machines vs Physiology Engine



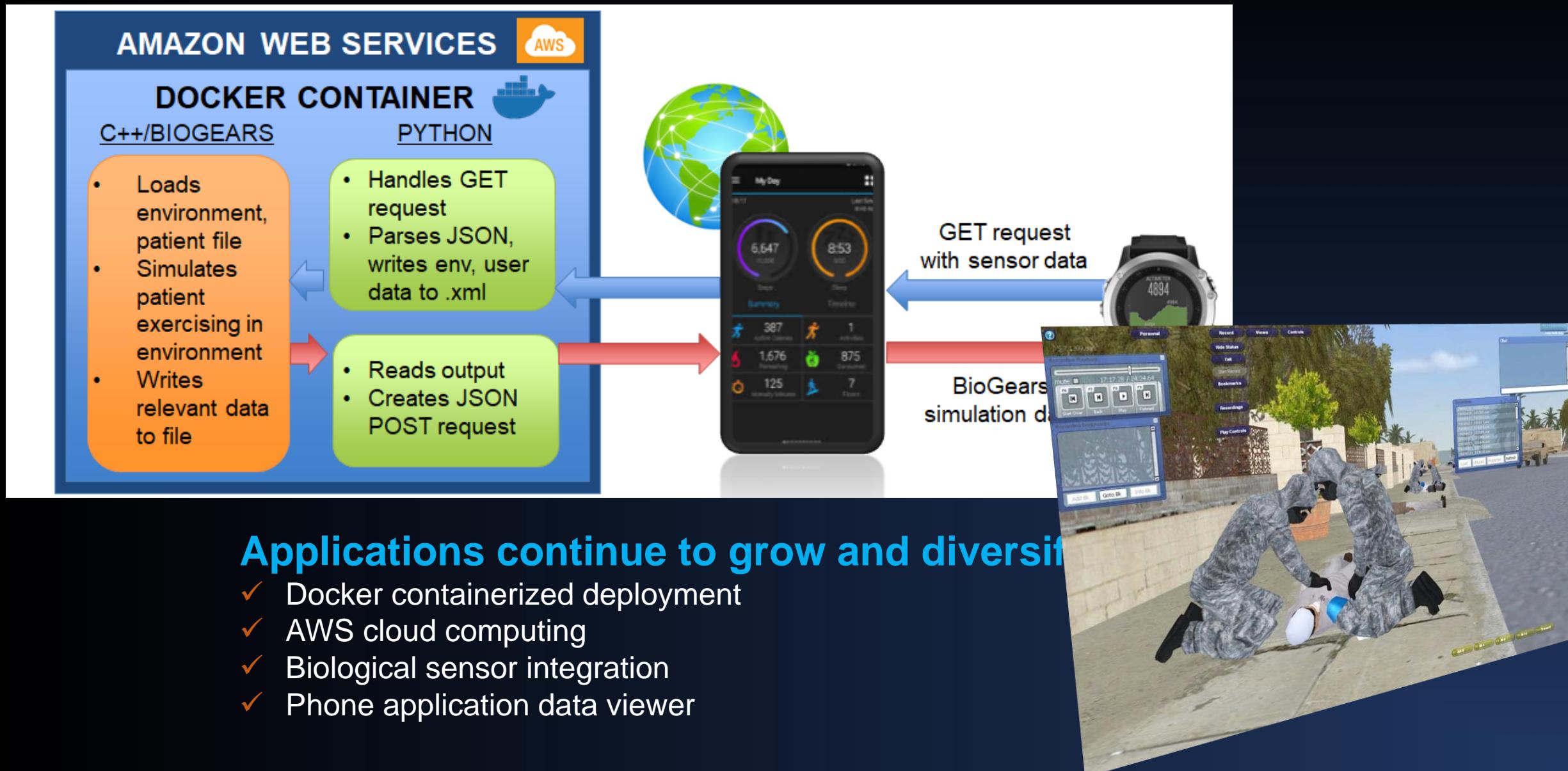
# Complex State Machines vs Physiology Engine



# Important BioGears Strategic Milestones

- ✓ GOAL: Broad adoption as standard open-source physiology engine
  - Branches and unique versions
- ✓ Compilable by developers on a variety of platforms
- ✓ Savable States
- ✓ Light and capable of running on simple embedded systems in real-time
- ✓ Cloud Service Instantiation
  - Usable & Experimentable by Physicians, Teachers, Students & Others
    - Robust Visualization
    - User Interface System
    - Scriptable Scenarios
  - State-based Hybrid Scenario Capability

# BioGears on the Cloud



# The UI: Making BioGears Usable & Experiment Worthy

- Work on Desktop & Mobile, taking advantage of each platform
- Consistency
- Ease of use
- Free Play & Support for Scenarios
- Customizability
- Showcase BioGears can do that other platforms cannot
- Appear to be alive and vibrant
- Showcase detailed substance information & messaging capabilities

SCENARIO: Default Adult Male  
Age: 22 Male Fat % 22.5 Temp: 36.2  
Height: 175cm Weight: 62 kg BSA: 354 BSA: 22.5

75 110

HR

SBP

12

RR

68

DBP

99



SAT

TIME: 0:00:00

Data



00:00:00



1.5X

Variables Displayed

Button 1

Button 2

Button 3

Button 4

Button 5

Button 6

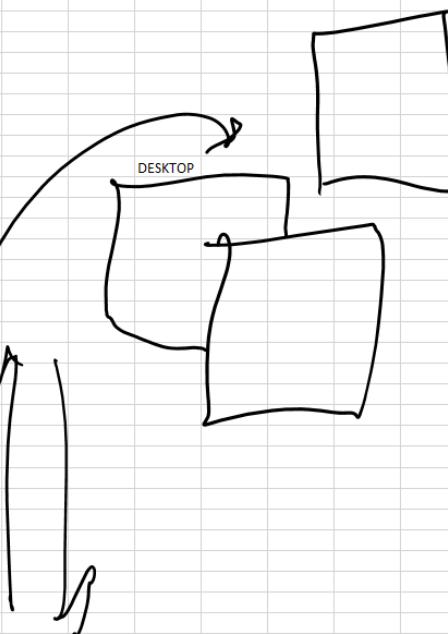
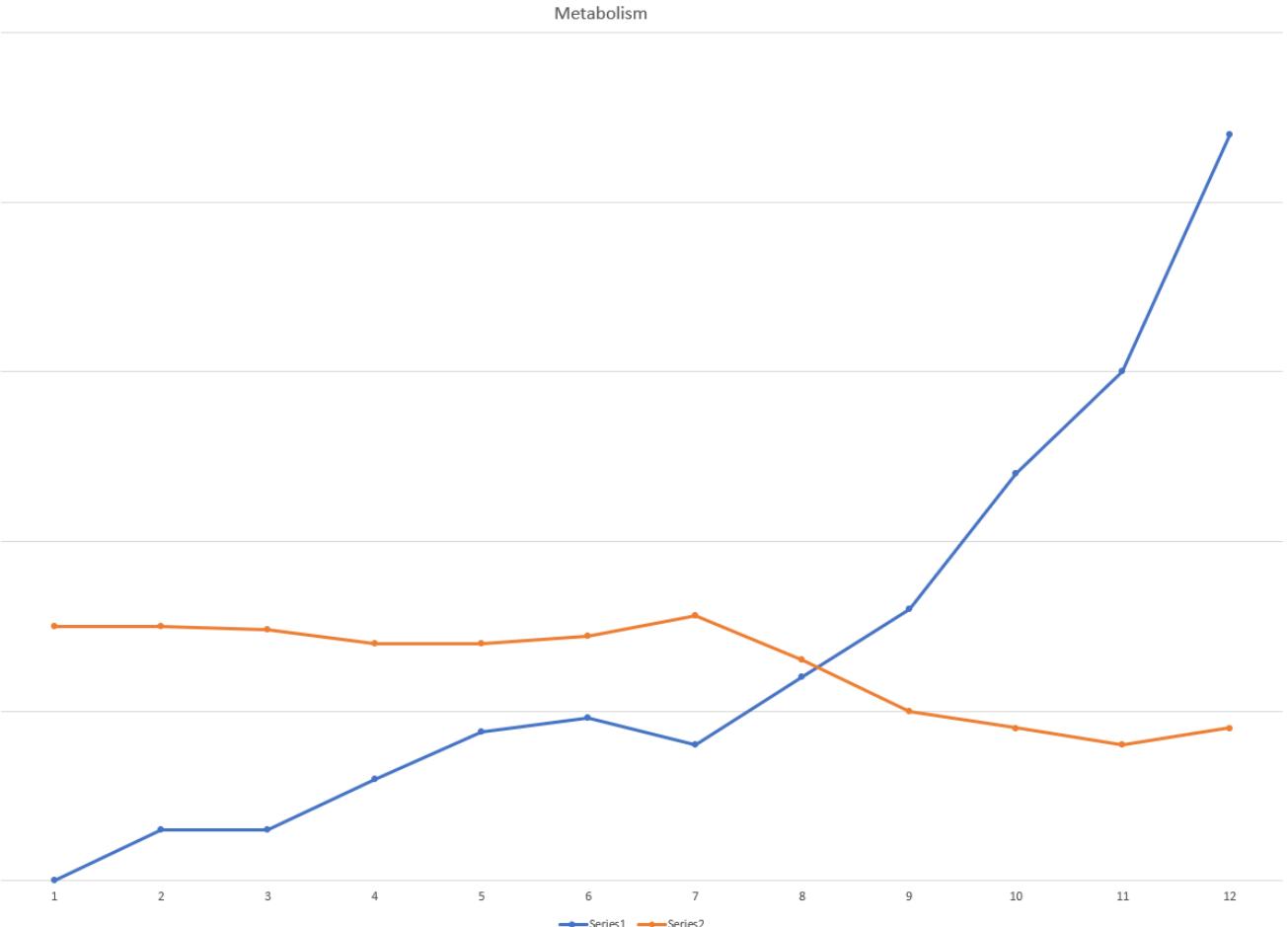
Reserved

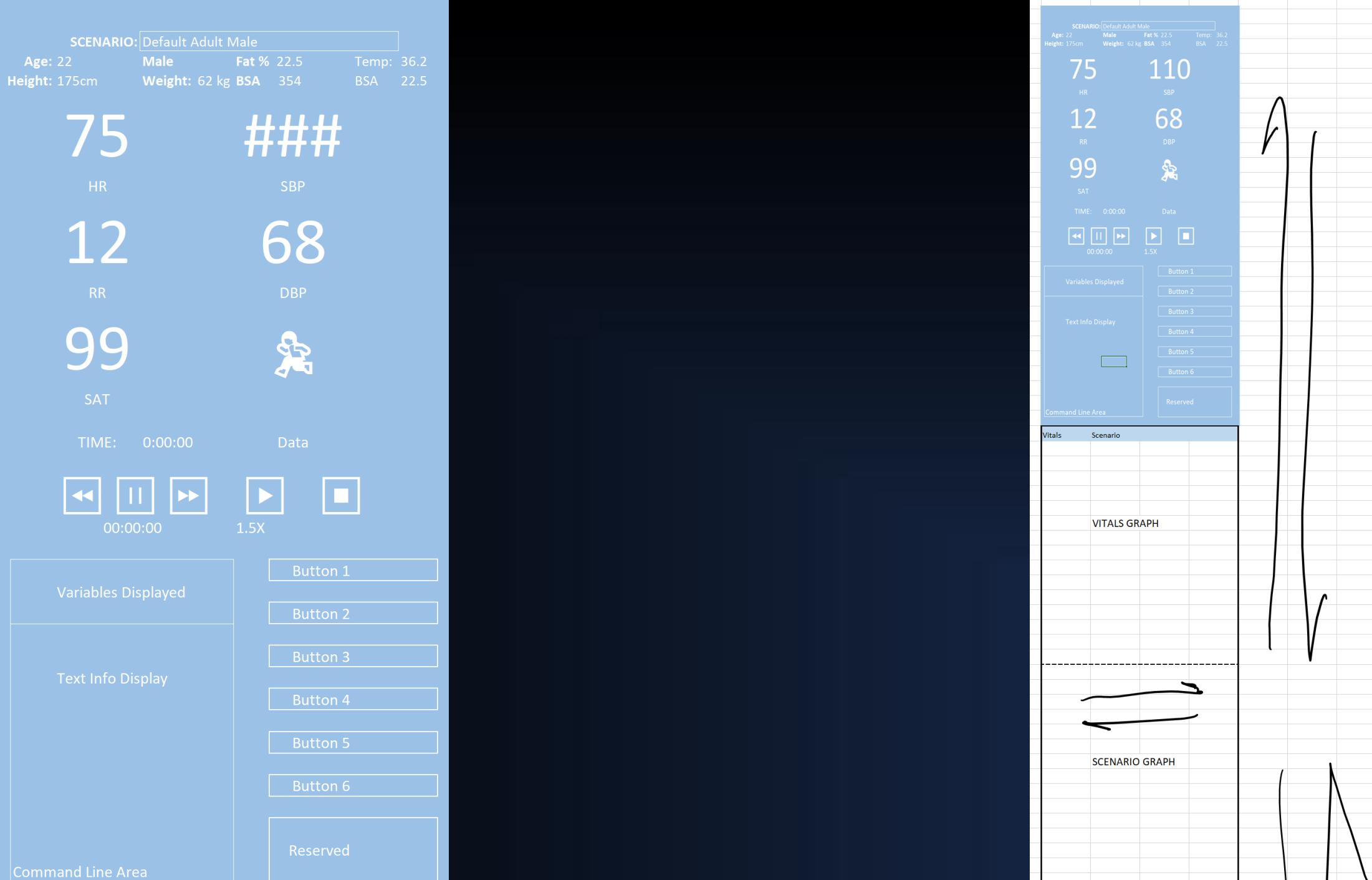
Text Info Display

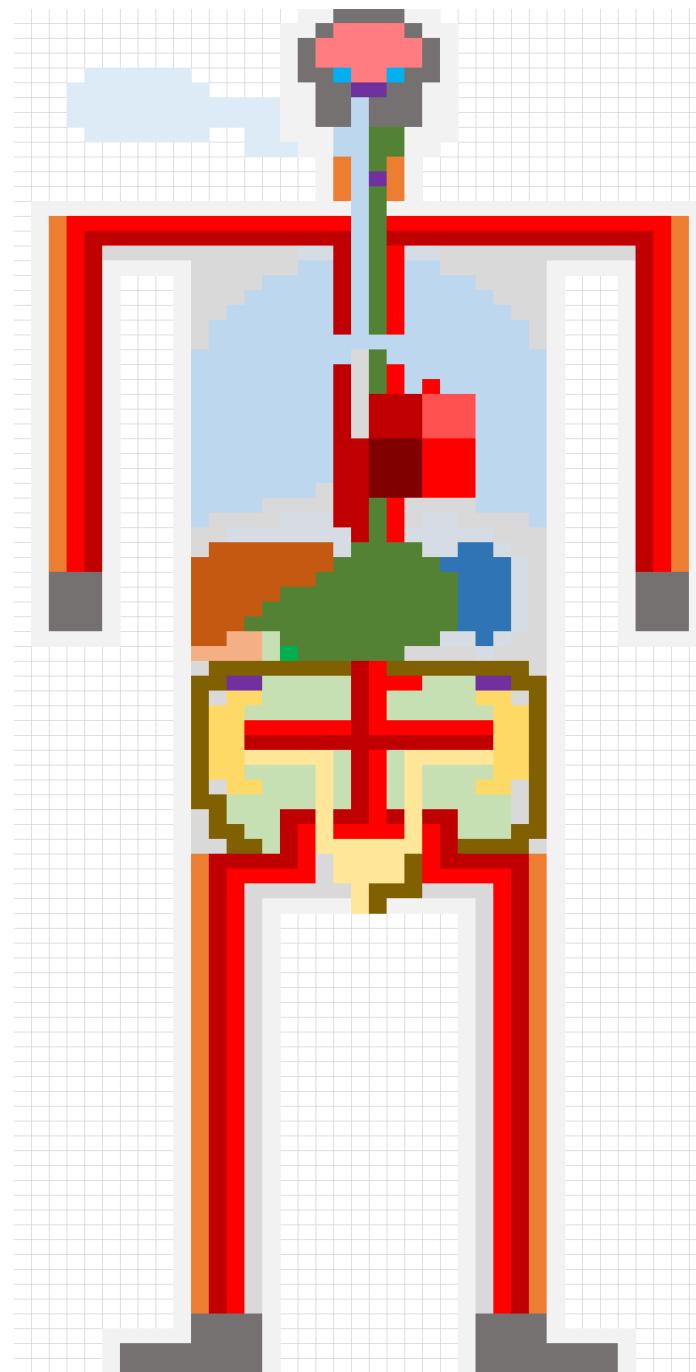


Command Line Area

VITALS SCENARIO CARDIAC RESPIRATORY ENERGY ENDOCRINE CHEMISTRY SUBSTANCES ACTIONS SCENARIO BUILDER

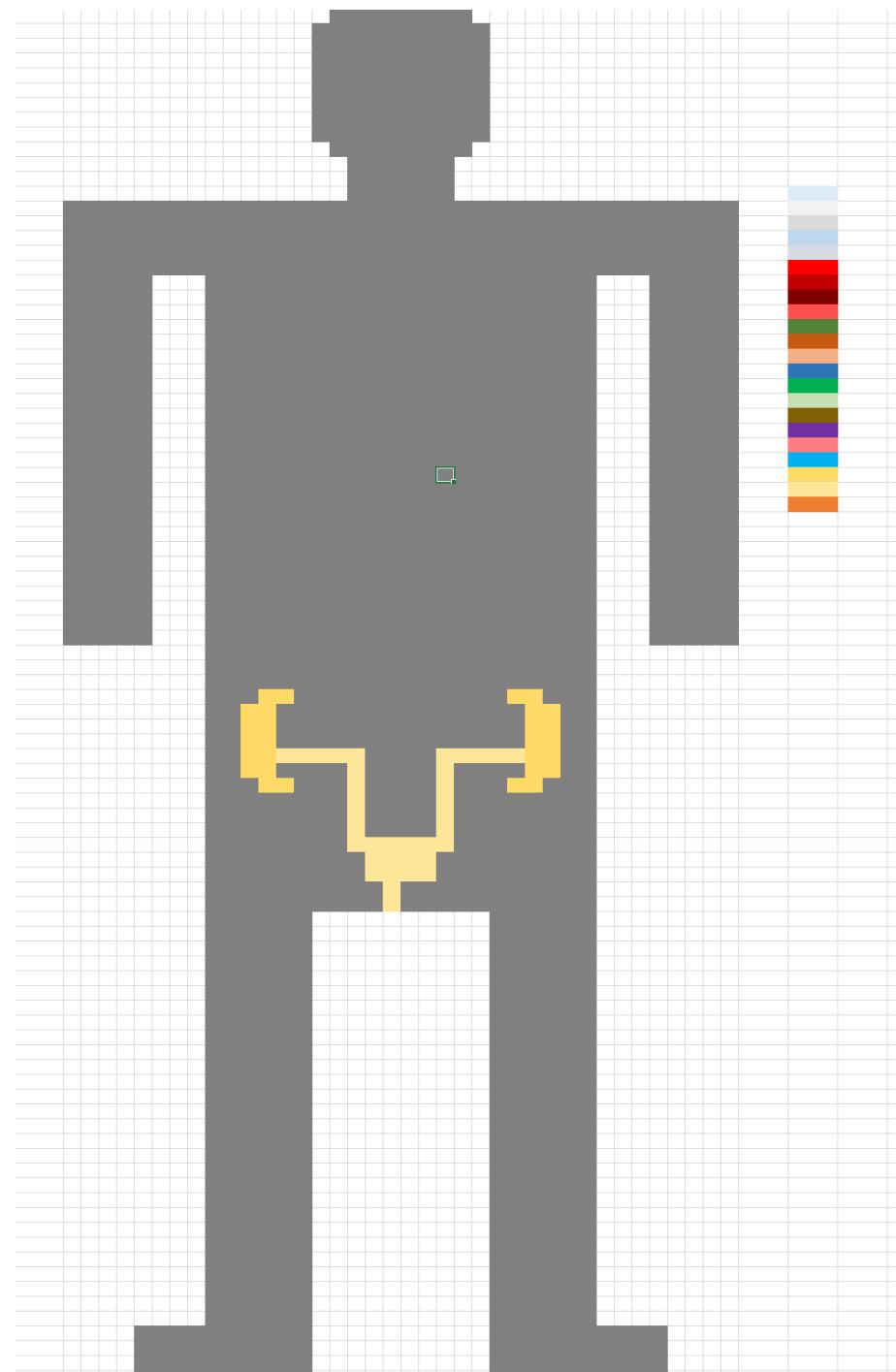
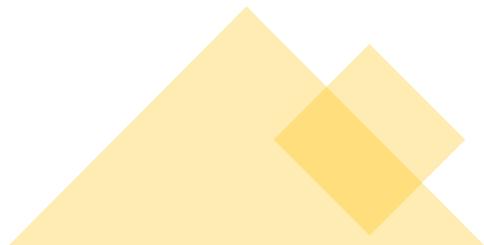






|   |
|---|
| Ambient Air                                 |
| Skin  |
| Fat   |
| Lung  |
| Lymph                                       |
| Artery / Heart Left Ventricle               |
| Vein / Heart Right Atrium                   |
| Heart Right Ventricle                       |
| Heart Left Atrium                           |
| Esophagus & Stomach                         |
| Liver                                       |
| Pancreas                                    |
| Spleen                                      |
| Gallbladder                                 |
| Small Intestine                             |
| Large Intestine & Colon                     |
| Endocrine System (Pineal, Thyroid, Adrenal) |
| Brain                                       |
| Eyes  |
| Kidney                                      |
| Ureters and Bladder                         |
| Muscle                                      |
| Bone  |

| BIOGEARS GAS COMPARTMENTS | LIQUID COMPARTMENTS         | LIQUID SIMPLIFIED | CODE | MAPS |
|---------------------------|-----------------------------|-------------------|------|------|
| LeftAlveoli               | RightHeart                  | RightHeart        | rh   | pa   |
| RightLungPulmonary        | RightPulmonaryArteries      |                   |      | pa   |
| RightDeadSpace            | LeftPulmonaryArteries       |                   |      |      |
| RightAlveoli              | PulmonaryArteries           | PulmonaryArteries | pa   | pa   |
| Stomach                   | RightPulmonaryCapillaries   |                   |      | pa   |
| PleuralCavity             | LeftPulmonaryCapillaries    |                   |      | pa   |
| LeftPleuralCavity         | PulmonaryCapillaries        |                   |      | pa   |
| RightPleuralCavity        | RightPulmonaryVeins         |                   |      | pv   |
| Leftlung                  | LeftPulmonaryVeins          | PulmonaryVeins    | pv   | pv   |
| Rightlung                 | LeftHeart                   | LeftHeart         | lh   |      |
| Lungs                     | Aorta                       | Aorta             | ao   |      |
| PleuralCavity             | Brain                       | Brain             | br   |      |
| LeftAlveoliLeak           | Bone                        | Bone              | bo   |      |
| LeftChestLeak             | Fat                         | Fat               | f    |      |
| RightAlveoliLeak          | LargeIntestine              | LargeIntestine    | li   |      |
| RightChestLeak            | Liver                       | Liver             | lv   |      |
|                           | LeftArm                     | LeftArm           | lar  |      |
|                           | LeftKidney                  | LeftKidney        | lk   |      |
|                           | LeftLeg                     | LeftLeg           | llg  |      |
|                           | Muscle                      | Muscle            | m    |      |
|                           | Myocardium                  | Myocardium        | h    | mc   |
|                           | Pericardium                 |                   |      |      |
|                           | RightArm                    | RightArm          | rar  |      |
|                           | RightKidney                 | RightKidney       | rk   |      |
|                           | RightLeg                    | RightLeg          | rlg  |      |
|                           | Skin                        | Skin              | sk   |      |
|                           | SmallIntestine              | SmallIntestine    | si   |      |
|                           | Splanchnic                  |                   |      |      |
|                           | Spleen                      | Spleen            | sp   |      |
|                           | VenaCava                    | VenaCava          | vc   |      |
|                           | Kidneys                     | Kidneys           | k    |      |
|                           | Heart                       | Heart             | h    |      |
|                           | Leftlung                    | Leftlung          | ll   |      |
|                           | Rightlung                   | Rightlung         | rl   |      |
|                           | Lungs                       | Lungs             | l    |      |
|                           | Gut                         | Gut               | g    |      |
|                           | RightRenalArtery            | RightRenalArtery  | rra  |      |
|                           | RightAfferentArteriole      | RightKidney       |      |      |
|                           | RightGlomerularCapillaries  | RightKidney       |      |      |
|                           | RightEfferentArteriole      | RightKidney       |      |      |
|                           | RightPeritubularCapillaries | RightKidney       |      |      |
|                           | RightRenalVein              | RightRenalVein    | rrv  |      |
|                           | RightBowmansCapsules        | RightKidney       |      |      |
|                           | RightTubules                | RightKidney       |      |      |
|                           | LeftRenalArtery             | LeftRenalArtery   | ira  |      |
|                           | LeftAfferentArteriole       | LeftKidney        |      |      |
|                           | LeftGlomerularCapillaries   |                   |      |      |



The screenshot shows a code editor window with a dark theme. The title bar reads "biogears\_004.lua". The code itself is a Lua script for a BioGears interface scenario generator. It includes comments explaining constants, a main scenario loop, and button functions. The code is numbered from 1 to 45.

```
1 --[[=====
2     BioGears Interface Scenario Generator Code Sample
3     2019 by Thomas B. Talbot, MD for Applied Research Associates
4     BioGears is Apache 2.0 Open Source
5     Created 08/22/2019, Current Version 02/22/2020
6 =====]]
7 -- TESTED ON https://repl.it/languages/Lua
8
9 -- ***** GET THINGS STARTED *****
10 -- Define CONSTANTS (hidden from users)
11 time = 0
12 simulationOver = 0
13 help = "help"                                     -- this cheat lets us accept help or "help" if command line ar
14 drugs = "drugs"
15 actions = "actions"
16 -- Text for Action Buttons
17 b1 = "Help"
18 b2 = "2"
19 b3 = "3"
20 b4 = "4"
21 b5 = "Asthma Attack"
22 b6 = "Albuterol"
23
24 -- ##### REGISTER TIME DEPENDENT EVENTS #####
25 -- event(30, doSomethingCool)
26
27 -- ***** MAIN SCENARIO LOOP *****
28 print("BioGears Interface\n")
29 print("Type help() to view available commands")
30 repeat
31   print("handoff to command line...")
32   simulationOver = 1
33 until simulationOver == 1
34
35
36 -- ***** BUTTON FUNCTIONS *****
37 function buttonOne () -- this button does XXX
38   -- stuff button does goes here
39 end
40
41 function buttonTwo() -- this button does XXX
42   -- stuff button does goes here
43 end
44
45 function buttonThree() -- this button does XXX
```

main.lua     saved

```
195  enu
196
197  -- ##### ACTIONS #####
198
199  function asthmaattack (severity)          -- generic drug
200    prototype (you copy it)
201    local appliedSeverity = 0.3              -- default to
202    severity
203    local maximum = 1.0
204    local minimum = 0
205    if severity == help then                -- respond to help
206      command request
207      print("A common inflammatory disease of the airways where air flow
208      into the lungs is partially obstructed. This attack is acute asthma,
209      which is an exacerbation of asthma that does not respond to standard
210      treatments. ")
211      print("Severity value must be >=0.0 and <=1.0 .\n")
212      print("EXAMPLES:")
213      print("  asthmaattack()  - delivers default 0.3 severity")
214      print("  asthmaattack(1)  - delivers maximum severity of 1.0")
215      print("  asthmaattack(0.2) - delivers severity of 0.2")
216      print("  asthmaattack(0)   - turns asthma off")
217
218    else
219      if type(severity) == "number" then        -- if custom
220        dose provided, use it instead
221        if severity > maximum then severity = maximum; print("Request
222          over range") end
223        if severity < minimum then severity = minimum; print("Request below
224          range") end
225        appliedSeverity = severity
226      end
227      -- ARA send command to BioGears with albuterolDose amount of drug
228      -- (defaults to inhalation)
229      print("Asthma severity set to " .. appliedSeverity .. " on a 0 to 1
230            scale")
231    end
232  end
233
234
```

BioGears Interface

Type help() to view available commands  
handoff to command line...

► help()

BioGears can give you a list of the following:

list(drugs) - provides list of all drugs

list(actions) - provides list of patient actions

DRUGNAME(help) - instructions how to use drug or action

► list(drugs)

The following drugs are available in this BioGears version:

AIRWAY, CARDIAC & ANTIINFLAMATORY DRUGS

|           |             |                |            |
|-----------|-------------|----------------|------------|
| albuterol | epinephrine | norepinephrine | prednisone |
|-----------|-------------|----------------|------------|

ANESTHESIA DRUGS

|          |            |                 |          |
|----------|------------|-----------------|----------|
| fentanyl | ketamine   | midazolam       | morphine |
| propofol | rocuronium | succinylcholine |          |

DIURETIC DRUGS

|            |             |
|------------|-------------|
| furosemide | vasopressin |
|------------|-------------|

ANTIDOTE DRUGS

|          |          |          |          |             |
|----------|----------|----------|----------|-------------|
| naloxone | fentanyl | naxolone | Morphine | pralidoxime |
|----------|----------|----------|----------|-------------|

drugname(help) - provides instruction on dosing & administration

► albuterol(help)

Albuterol is an inhaled bronchodilator (Beta Agonist)  
inhalation occurs over 30 seconds.

EXAMPLES:

|               |                         |
|---------------|-------------------------|
| albuterol()   | - delivers default 10ug |
| albuterol(20) | - delivers 20ug         |

► albuterol(50)

50ug of Albuterol administered

► asthmaattack(help)

A common inflammatory disease of the airways where air flow into the lungs is partially obstructed. This attack is acute asthma, which is an exacerbation of asthma that does not respond to standard treatments.

Severity value must be >=0.0 and <=1.0 .

EXAMPLES:

|                   |                                    |
|-------------------|------------------------------------|
| asthmaattack()    | - delivers default 0.3 severity    |
| asthmaattack(1)   | - delivers maximum severity of 1.0 |
| asthmaattack(0.2) | - delivers severity of 0.2         |
| asthmaattack(0)   | - turns asthma off                 |

►

# Strategic Relationships

## Physiology Engine

- BioGears & BioGears Lite
- BioGears User Interface
- BioGears Cloud Services

## Advanced Modular Manikin

- AMM Systems
- Simulated Medical Devices & Peripherals

## Virtual Standardized Patient

- Standard Patient

## Advanced Interactions

- Open Medical Gesture
- Robotics, Surgery, Human Sensor Integration, etc
- Human Surrogate Integration

## Universal Patient

- Hybrid state / phys engine
- Open Injury & Battle Damage Model

## Advanced Military NPC

- Synthetic Training Environment
- Full Interactive Character
- Casualties at Scale – Smart BioGears instantiation

A large American flag is flying in the wind against a clear blue sky. The stars and stripes are clearly visible.

# BioGears

*A Unique & Special National Resource*

[Questions: talbot@ict.usc.edu](mailto:talbot@ict.usc.edu)