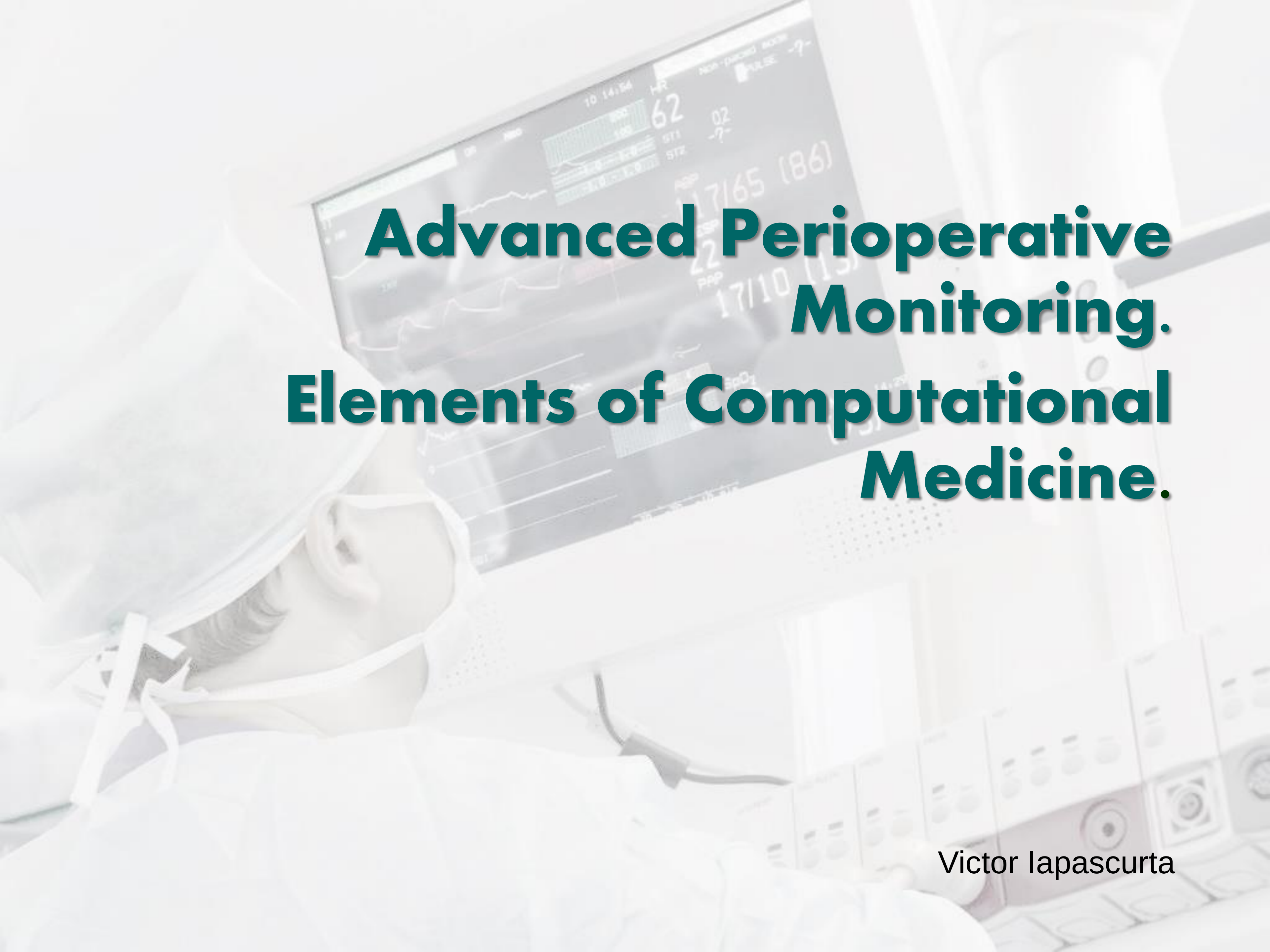
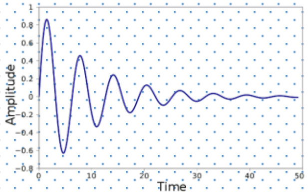


Advanced Perioperative Monitoring.

Elements of Computational Medicine.

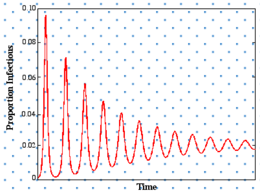
Victor Iapascurta



"In order to get an appropriate understanding of what is really happening in a body system, it is compulsory to supplement the 'usual medical way of reasoning' with elements of the engineering approach. As a result, along with a more knowledgeable physician (e.g. intensivist), the final beneficiary of such a combination will be the patient.

Without this it is hardly possible to speak about clinical monitoring in general and advanced monitoring in particular"

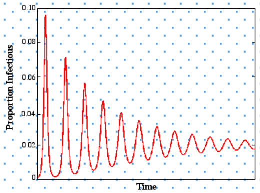
a rule of thumb during the advanced technological era



- **Clinician monitoring** — clinical monitoring using visual inspection, auscultation, and palpation is a primary determinant of patient safety.

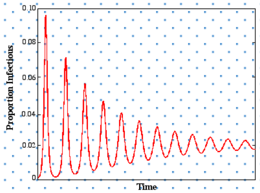
Changes in clinical signs may be subtle, and often precede abnormalities in parameters measured by monitoring devices.

- **Monitoring devices** do not replace clinical observation; rather, they amplify and quantify clinical information



Prerequisites & Basic Concepts

Basic knowledge concerning monitoring in Anesthesia and Intensive Care

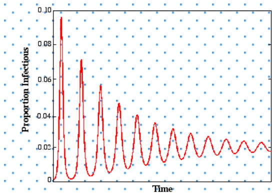


Current course

- extends the ‘monitoring time frame’ to the perioperative period

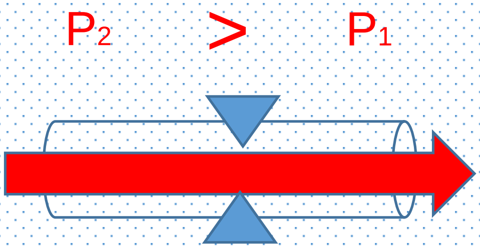
- provides additional in-depth insights based on systemic approach as a concept based on fundamental interdisciplinary knowledge which includes, but is not limited to, physics, modeling, computational sciences, etc.

- is to help the future clinician to navigate in the fast-progressing modern medical field especially concerning the emergence of Medical Artificial Intelligence technologies

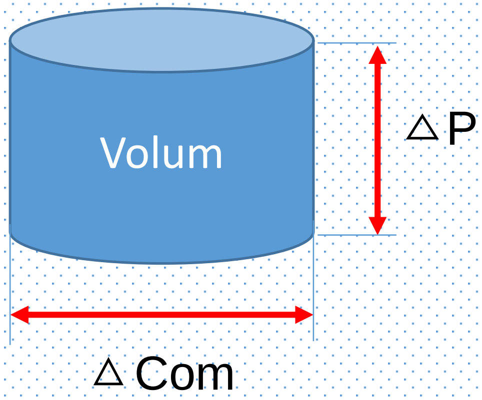


BAASIC CONCEPTS:

$$\text{Flow} = \frac{P_2 - P_1}{\text{Resistance}}$$

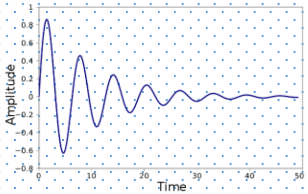


$$\triangle P = \frac{\text{Volume}}{\text{Compliance}}$$



Ohm law: $I = \frac{U}{R}$

$$\text{Volume} = \triangle P \times \text{Compliance}; \quad = \text{Flow} \times \text{time}$$



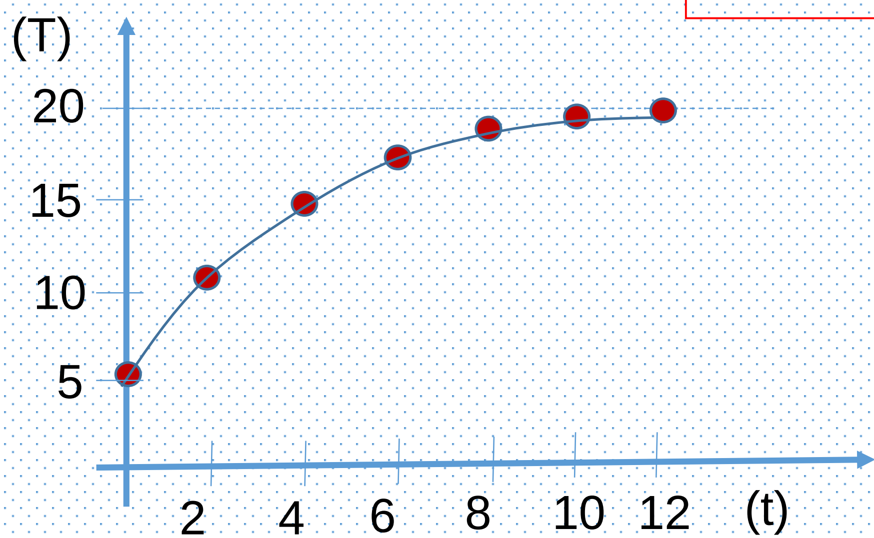
BAASIC CONCEPTS: Newton's Law of Cooling

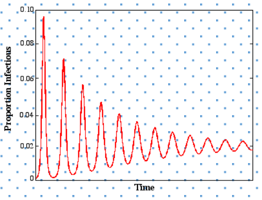
$$\frac{dT}{dt} = k(T - T_s)$$

$$\frac{dT}{dt} = 0{,}2\,(\,20 - T\,)$$ = 0,2 x 15 = 3 C / min

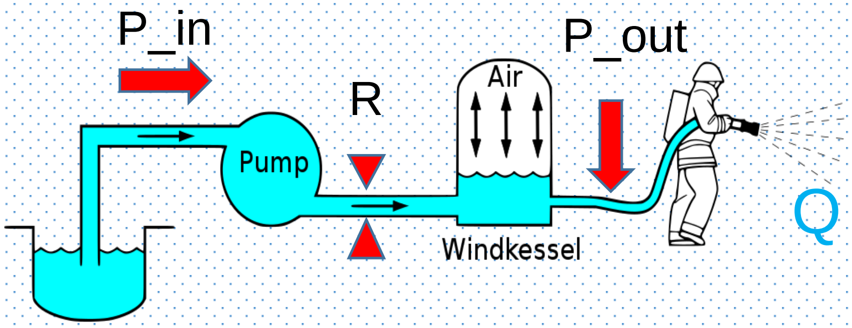
5 + 2 x 3 = 11
11 + 2 x 1,8 = 14,6
. . . .

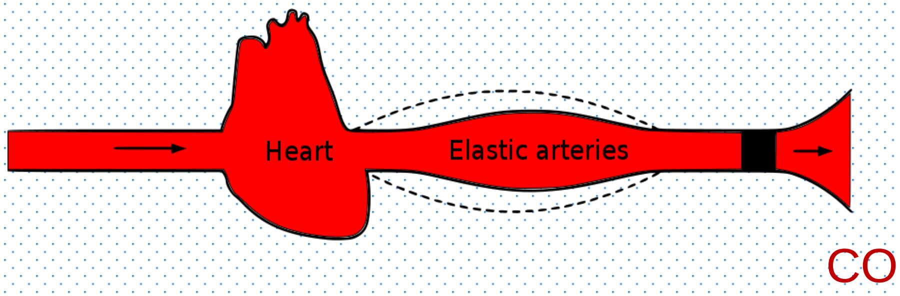
T_0 = 5 C
T_2 = 11 C
T_4 = 14,6 C
T_6 = 16,76 C
T_8 = 18,06 C
T_{10} = 18,45 C
T_{12} = 18,76 C





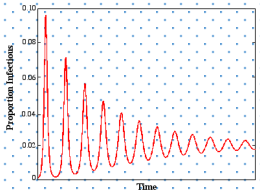
APPLYING BAASIC CONCEPTS: Windkessel Model and BP





- Q = (P_in – P_out) / R
- CO = (MAP – RAP) / SVR
- MAP = (CO * SVR) + RAP
  - MAP = CO * SVR
  - CO = MAP / SVR

DO2 = CO * 1.34 * Hb * SaO2

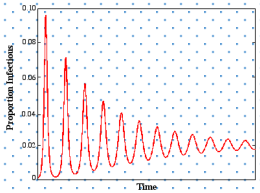


Clinical significance of BP (RAP/CO/SVR)

a. Low RAP = hypovolemic shock.

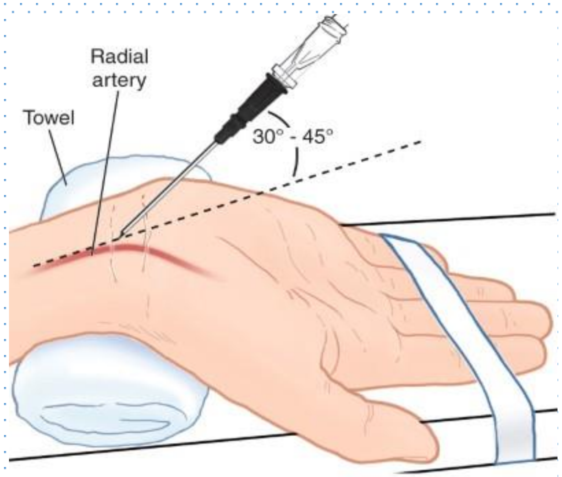
b. Low CO = cardiogenic shock

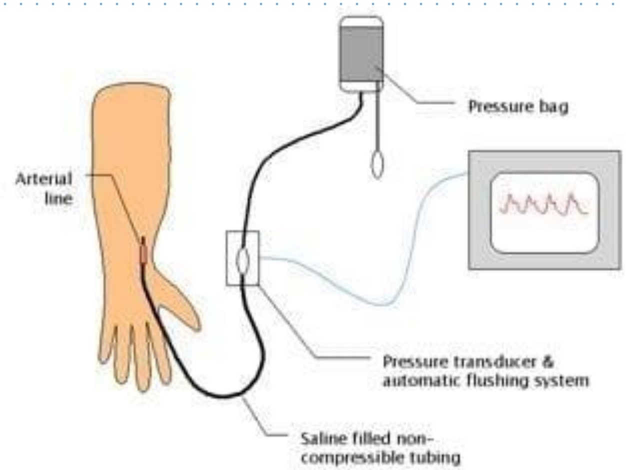
c. Low SVR = vasogenic shock (e.g., septic shock)

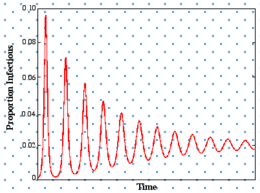


Non invasive BP - oscillometric method

Invasive BP - intraarterial

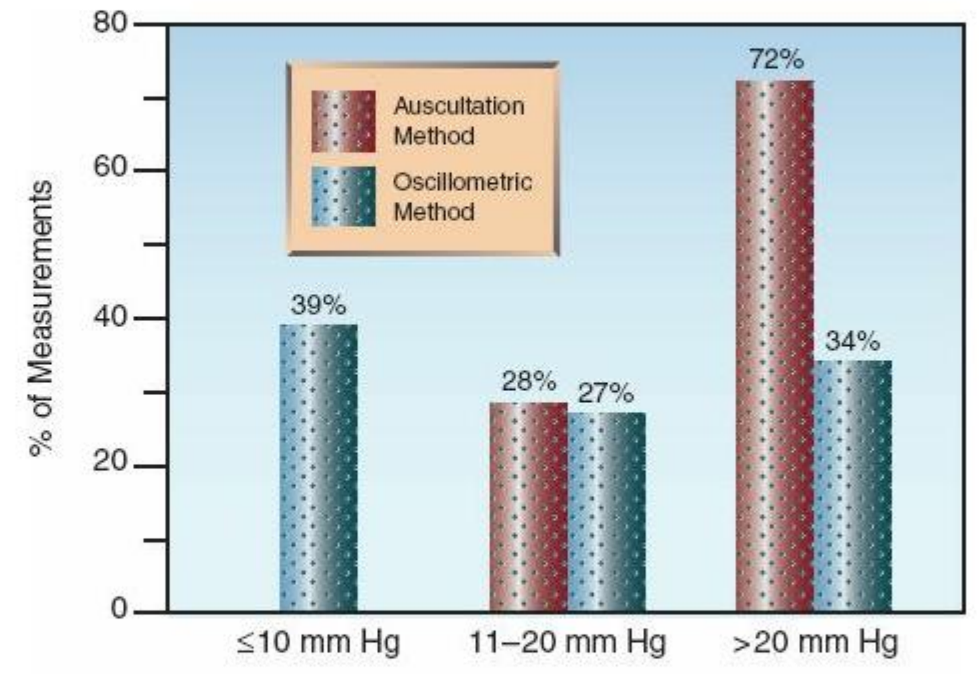




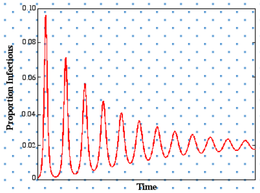


Non invasive BP – oscillometric method

highly error-prone*



* P.Marino, The ICU Book, 2014 e- ed, p.134 based on Bur A, Hirschl M, Herkner H, et al. Accuracy of oscillometric blood pressure measurement according to the relation between cuff size and upper-arm circumference in critically ill patients. Crit Care Med 2000; 28:371–376



What finally counts ?

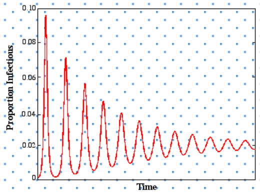
$$DO2 = CO * 1.34 * Hb * SaO2$$

Hemodynamic component (CO)

Hematic component (Hb)

Respiratory component (SaO2)

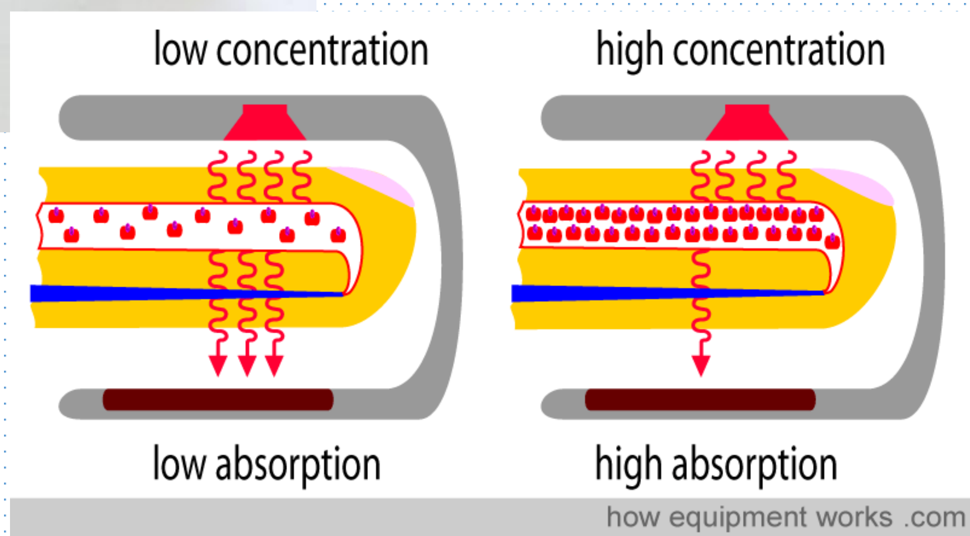
$$VO2 = CO * 1.34 * Hb * (SaO2 - SvO2)$$

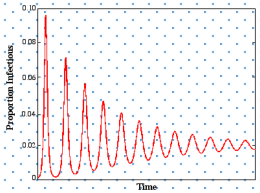


Pulse oximetry

SpO2

SaO2 > 90 %





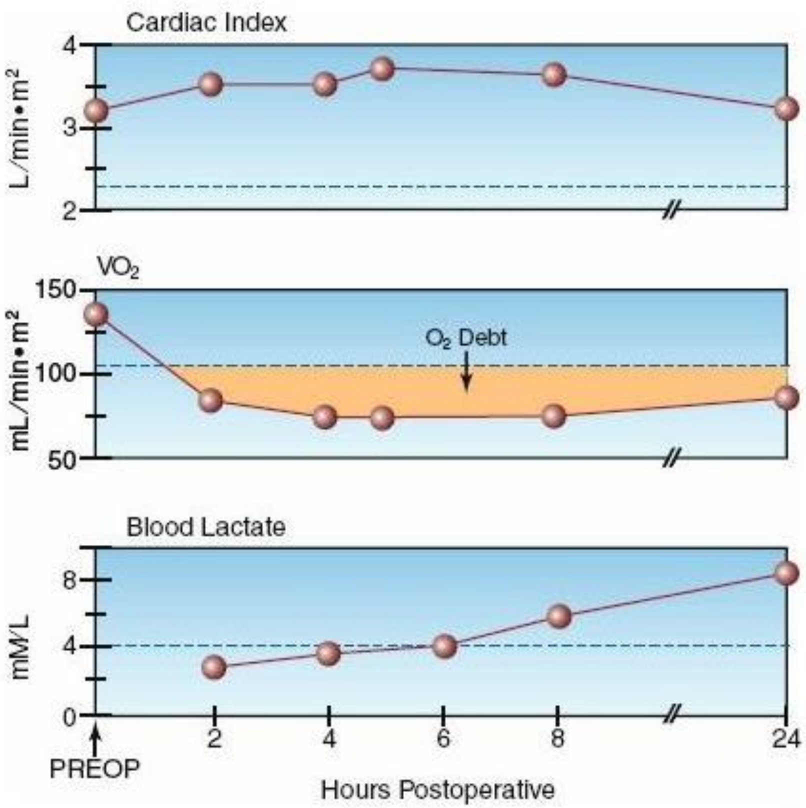
Markers of Inadequate Tissue Oxigenation

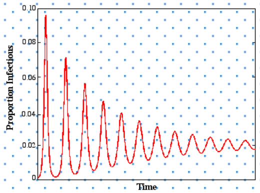
I. Oxygen Markers

1. VO2 > 200 mL/min/m2 or < 110 mL/min/m2
2. (SaO2 – SvO2) ≥ 50 %
3. SvO2 ≤ 50 %

II. Chemical Markers

1. Serum Lactate > 2 mM/L (or ≥ 4 mM/L)
2. Arterial Base Deficit > 2 mM/L



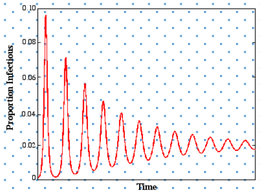


Measuring Cardiac Output (CO)

(methods from invasive to non-invasive)

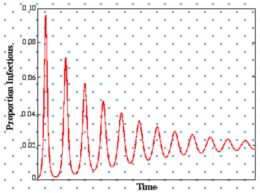
a. Thermodilution method by Swan-Ganz catheter
b. PiCCO, LiDCO Pulse Pressure method
c. FloTrac method based on pulse contour analysis
d. Thoracic Electric Bioimpedance (TEB)
e. Doppler Ultrasound based methods

Other methods: dye dilution method, ultrasound dilution, electrical cardiometry, etc.



Hemodynamic and Oxygen Transport Parameters

Parameter	Abbreviation	Normal Range
Central Venous Pressure	CVP	0 – 8 mm Hg
Pulmonary Artery Wedge Pressure	PAWP	5 – 15 mm Hg
Cardiac Output	CO	4.5 – 8 L/min
Cardiac Index	CI	2.7 – 4 L/min/m2
Stroke Index	SI	38 -60 mL/beat/m2
Systemic Vascular Resistance Index	SVRI	1860 – 2500 dyn*s/cm5/m2
Pulmonary Vascular Resistance Index	PVRI	225 – 315 dyn*s/cm5/m2
O2 saturation (arter.)	SaO2	>90 %
O2 saturation (vein.)	SvO2	>75%
Oxygen Delivery (Index)	DO2	520 – 570 mL/min/m2
Oxygen Uptake (index)	VO2	110 – 160 mL/min/m2
Oxygen Extraction Ratio	O2ER	0.2 – 0.3



Neuromonitoring

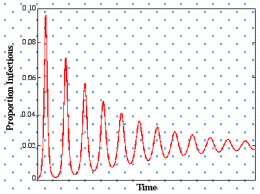
is used to assess the functional integrity of the brain, brain stem, spinal cord, or peripheral nerves.

The goal:

- to alert the surgeon and anesthesiologist to impending injury in order to allow modification of management in time to prevent permanent damage
- to map areas of the nervous system in order to guide management
- monitoring the depth of anesthesia

Monitoring techniques:

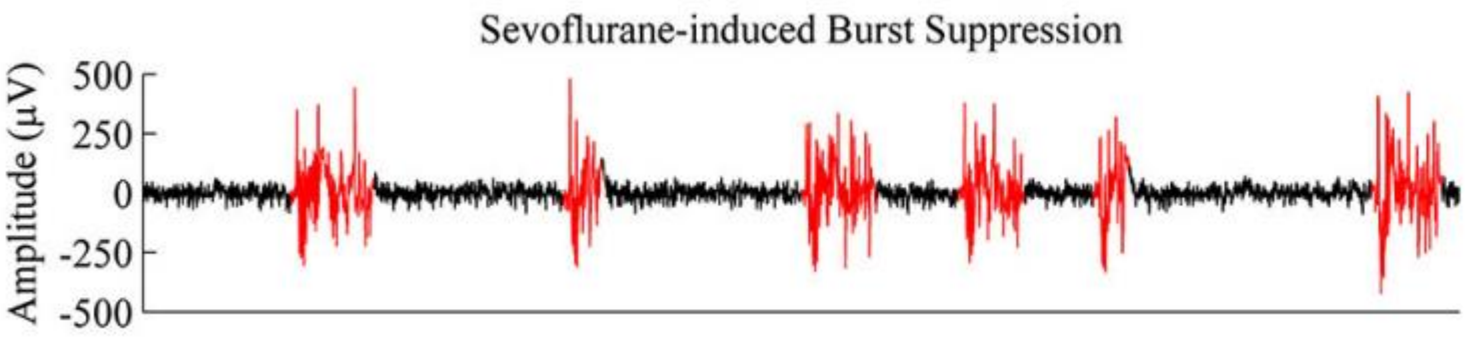
- Electroencephalography (EEG),
- Electromyography (EMG),
- Somatosensory evoked potentials (SSEPs),
- Brainstem auditory evoked potentials (BAEPs),
- Motor evoked potentials (MEPs)



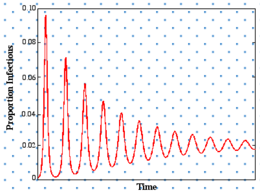
Monitoring the Depth of General Anesthesia DGA

- Bispectral Index monitor (BIS)
- Auditory Evoked Potential monitor (AEP)
- Patient State Analyser (PSA)
- Cerebral state monitor (CSM)
- Index of Consciousness monitor (IoC)
- Entropy monitor

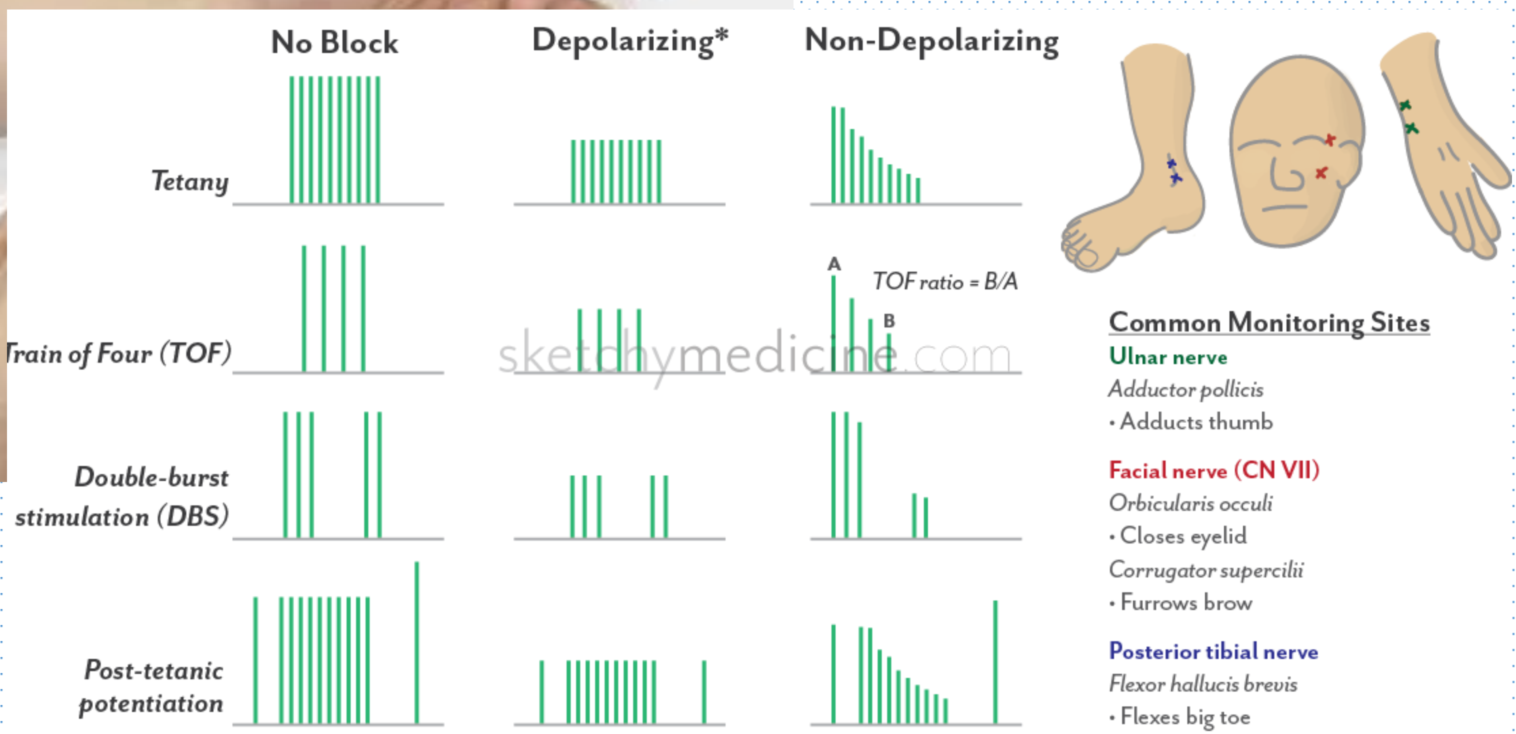
Burst Suppression Mechanism

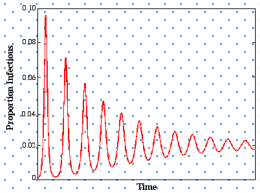


Jonathan D. Kenny et al., Propofol and sevoflurane induce distinct burst suppression patterns in rats, *Frontiers in Systems Neuroscience*, December 2014 | Volume 8 | Article 237



Neuromuscular function monitoring





Monitoring Modalities Summary

Respiratory System Monitoring

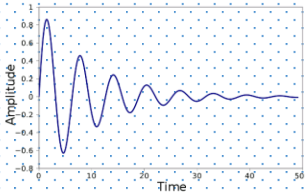
- Oxygenation (cyanosis, pulse oximetry, inspired O2 analyzer)
- Ventilation (capnography, pulmonary mechanics measurements, disconnection alarms)

Circulatory System Monitoring

- Blood Pressure (non-invasive, invasive)
- Electrocardiogram (ECG leads, Ischemia detection, artifacts)
- Other monitoring of circulation (central venous pressure, PA catheter, CO measurement)

Other monitoring techniques and devices

- Neuromonitoring (BIS/ AEP/PSA : DGA)
- Neuromuscular function monitoring
- Tisssue oxigenation chemical markers
- Temperature monitoring
- Urine output, etc.



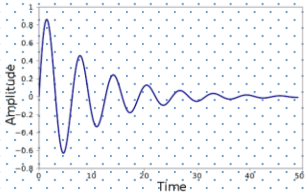
Computational Medicine (CM)

is an emerging discipline devoted to the development of quantitative approaches for understanding the mechanisms, diagnosis and treatment of human disease through applications of mathematics, engineering and computational science.

The core approach of CM is to develop computational models of the molecular biology, physiology, and anatomy of disease, and apply these models to improve patient care.

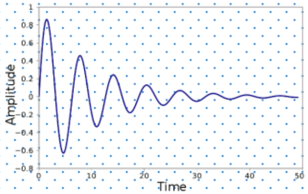
Johns Hopkins School of Medicine

https://www.bme.jhu.edu/graduate/mse/degree-requirements/computational-medicine/



MODEL THINKING IN MEDICINE / A&IC

?



MODEL THINKING IN MEDICINE / A&IC

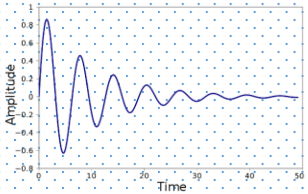
Model = simplified representation or abstraction of reality, that highlights important aspects, at the price of ignoring other aspects.

“Truth … is much too complicated to allow anything but approximations“

John von Neumann

"All models are wrong, but some are useful"

J.P. Box

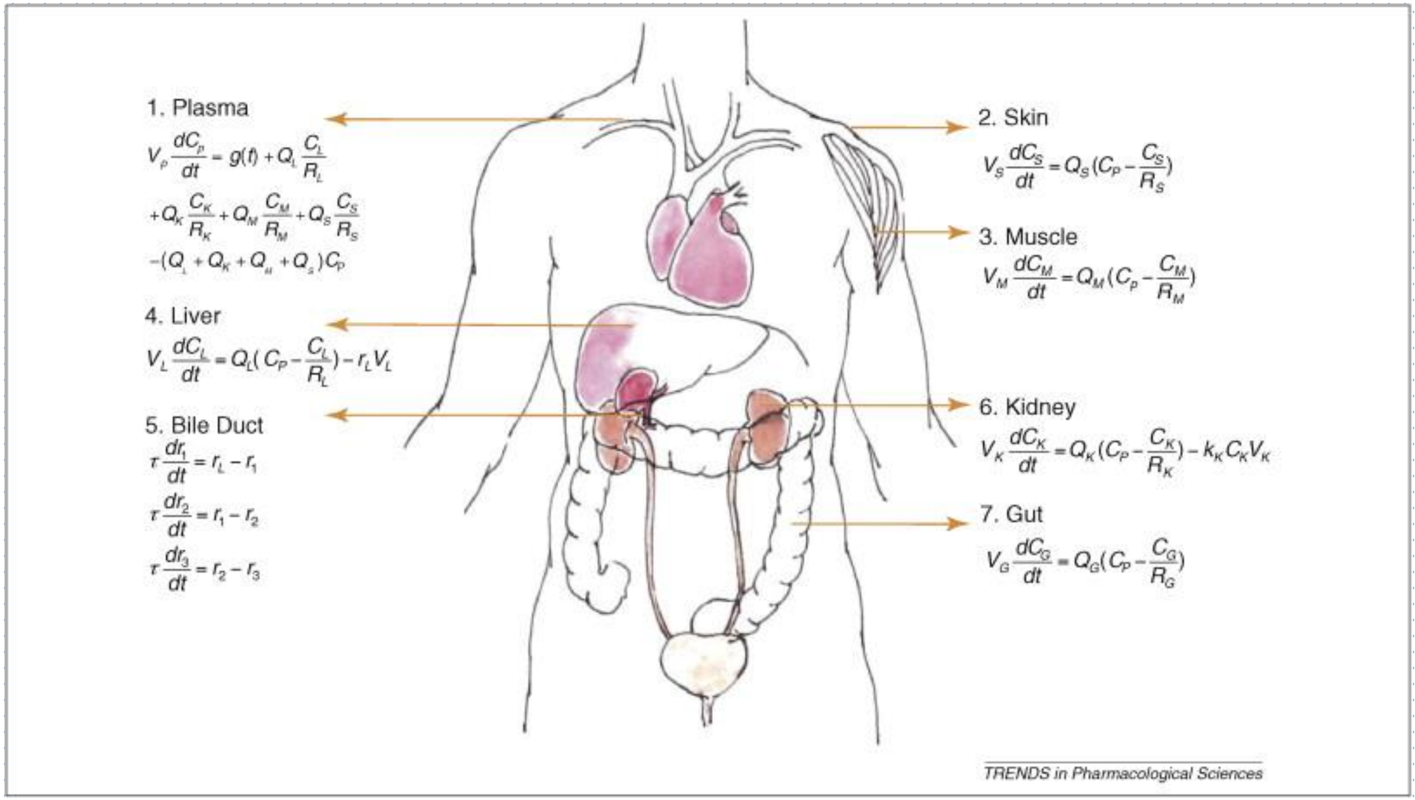


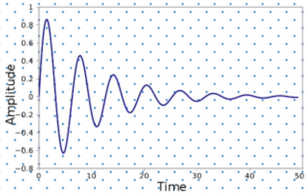
MODEL THINKING IN MEDICINE / A&IC

Types of models:

- Equation Based Models (EBM)
- Statistical Models (SM)
- System Dynamics Models (SDM)
- Agent Based Models (ABM)

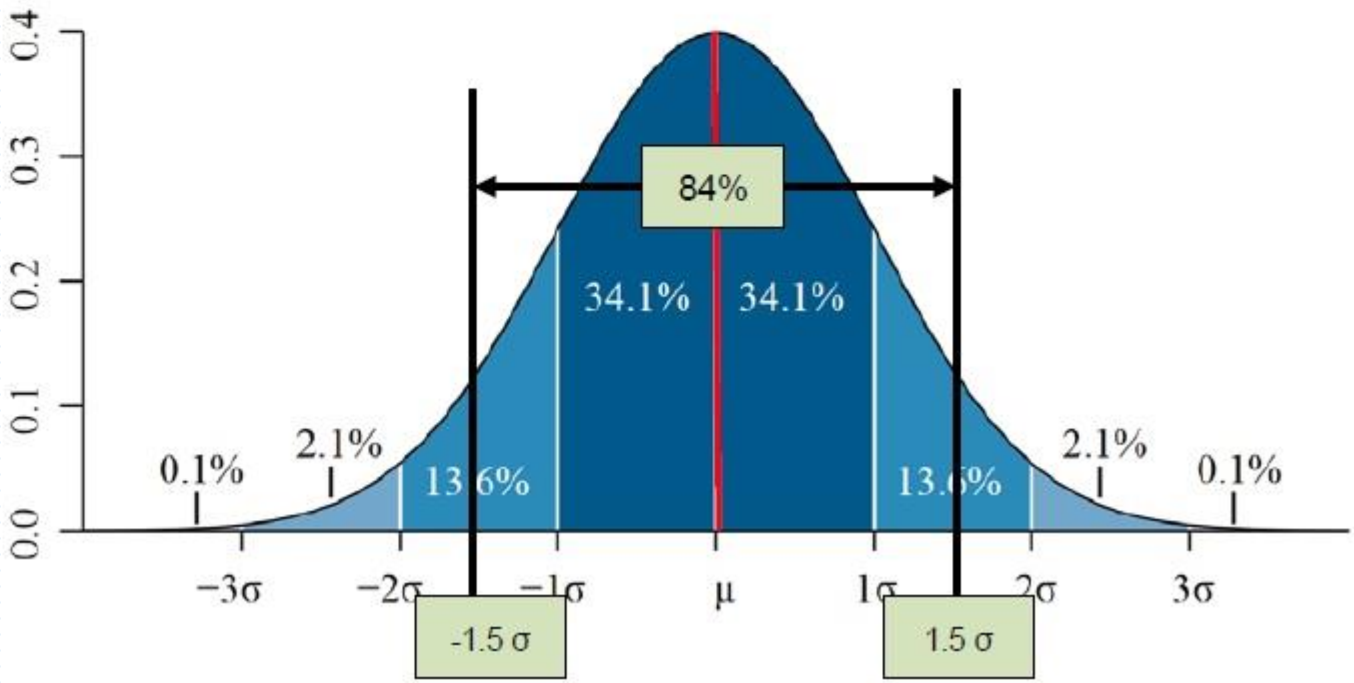
Equation based Models (EBM)

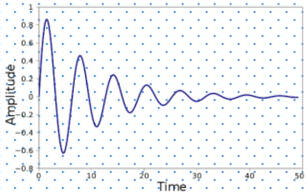




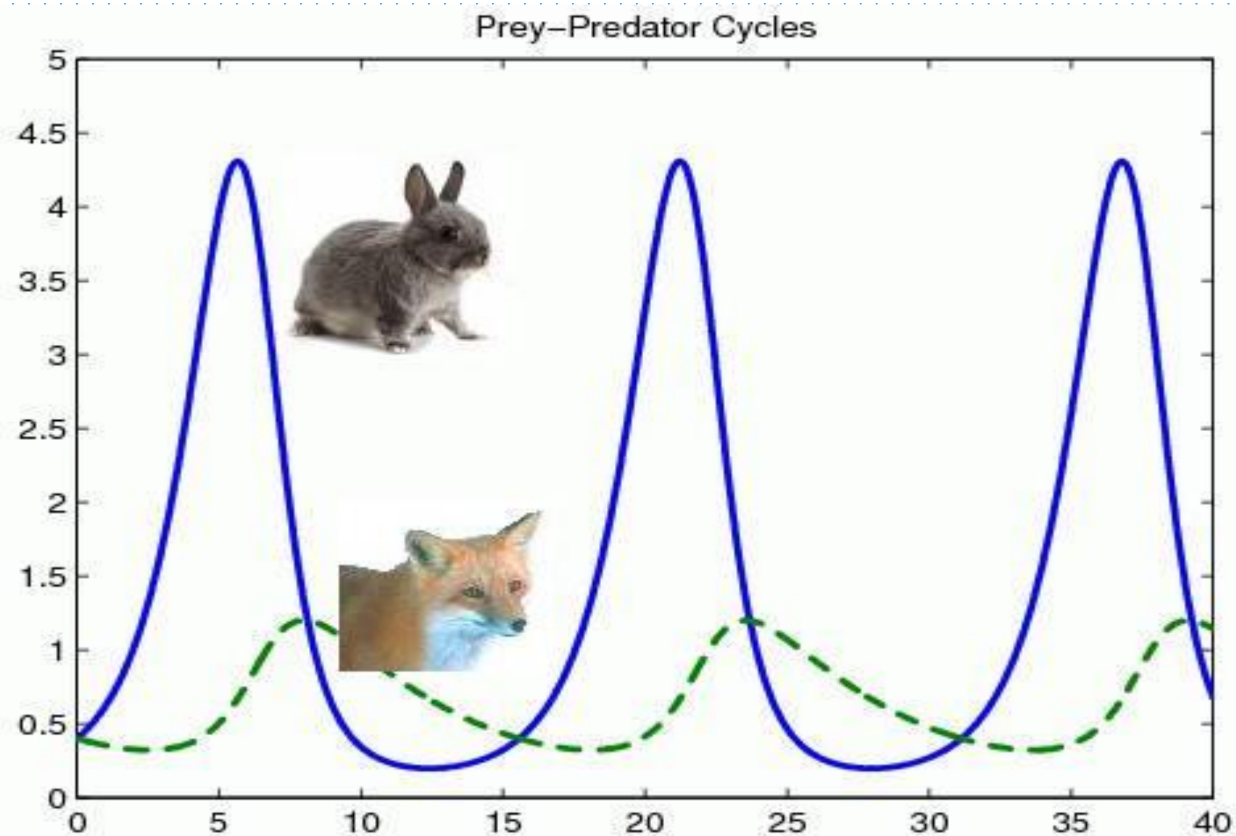
Advanced monitoring &
Computational Medicine

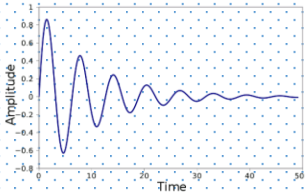
Statistical Models (SM)





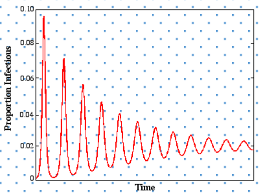
System Dynamics Models (SDM)



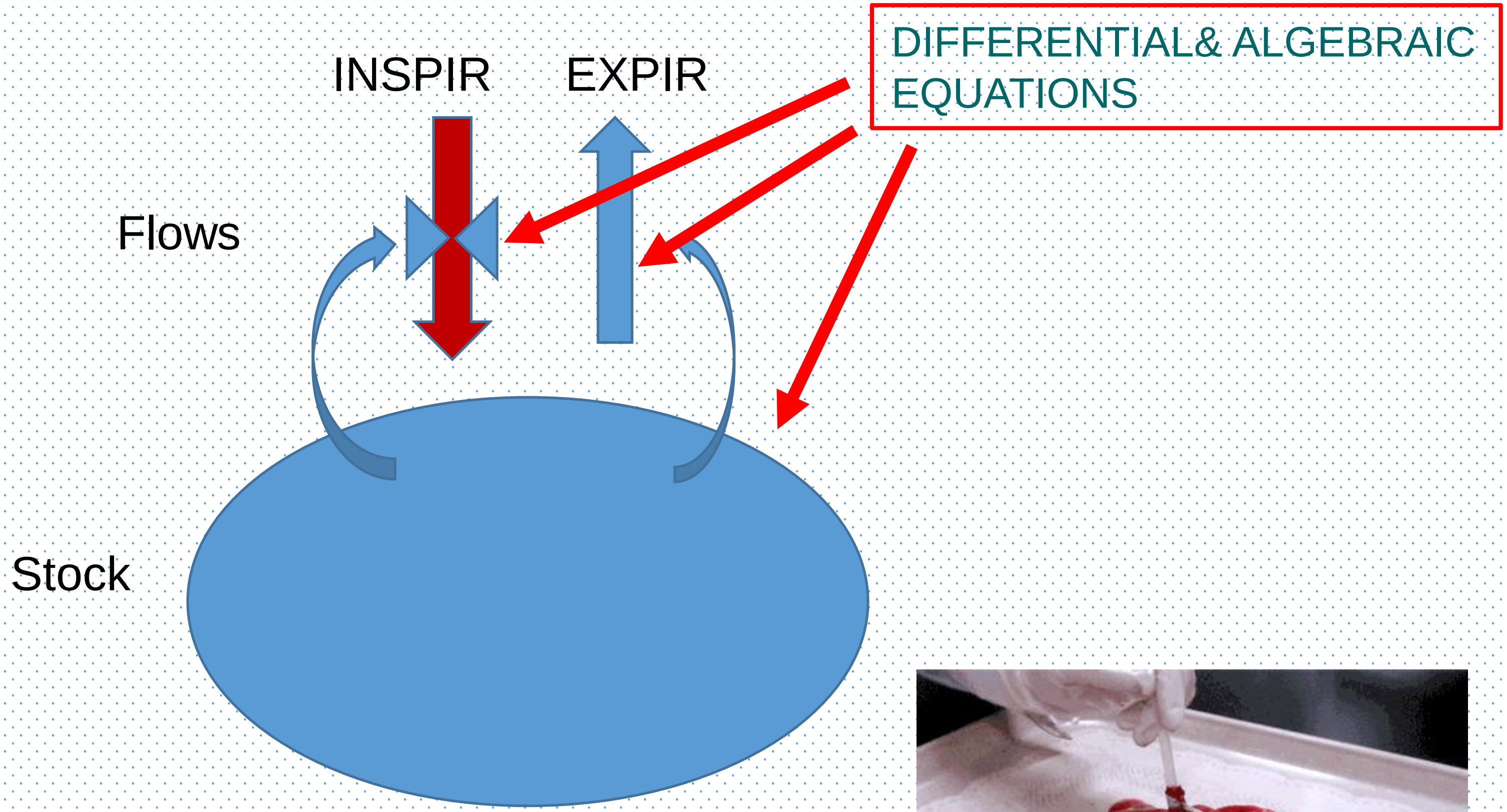


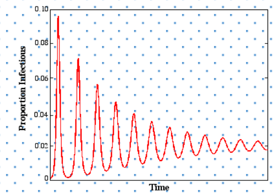
Agent Based Models

Agent Based Modeling (ABM)

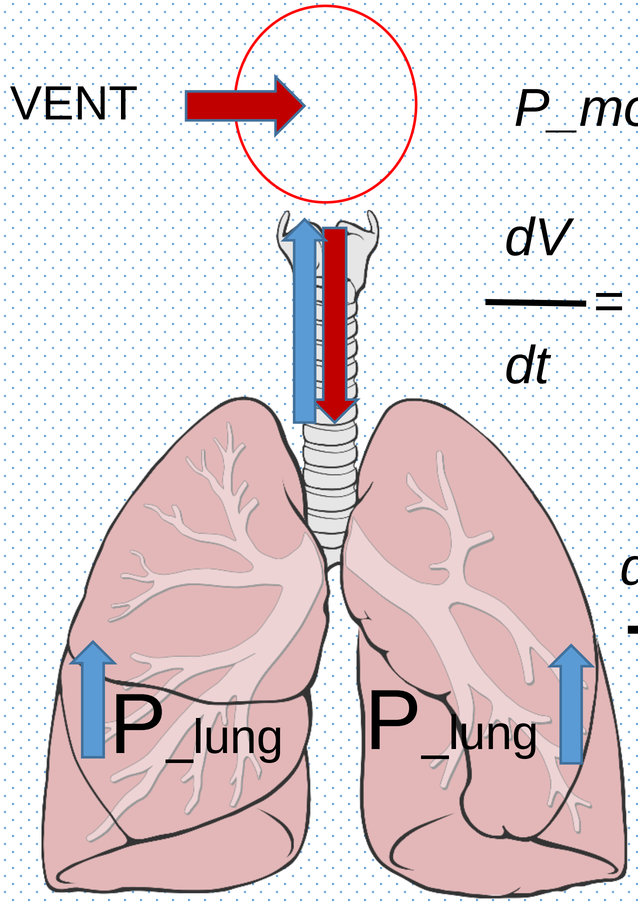


BUILDING A MODEL





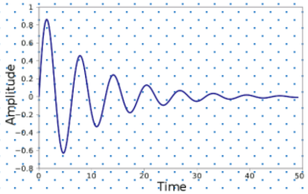
BUILDING A MODEL



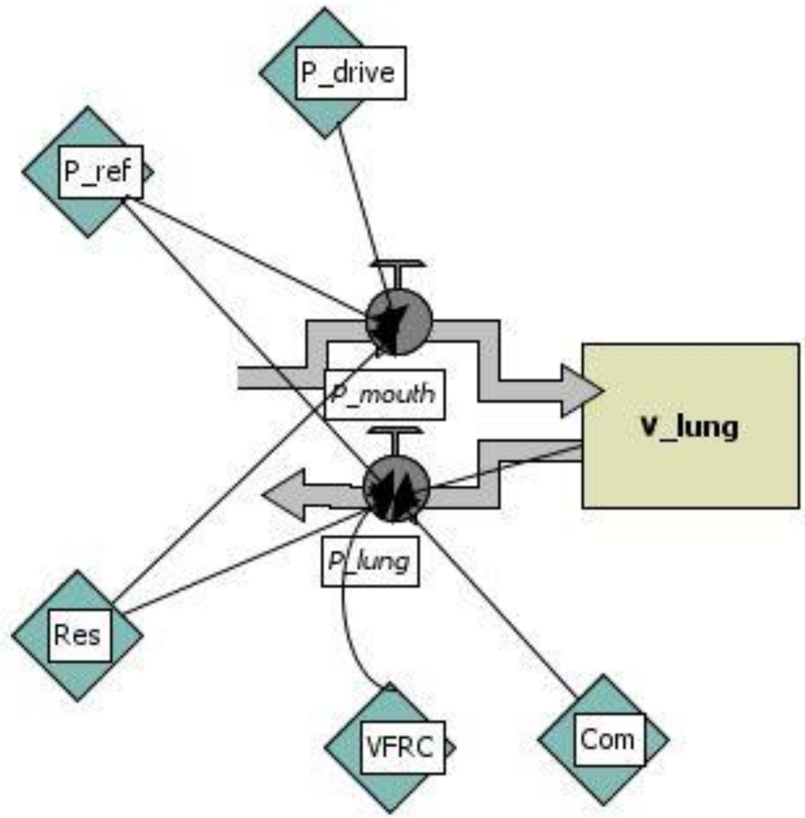
$$P\_mouth = P\_atmos + P\_drive$$

$$\frac{dV}{dt} = P\_mouth - P\_lung / Resist\_aw$$

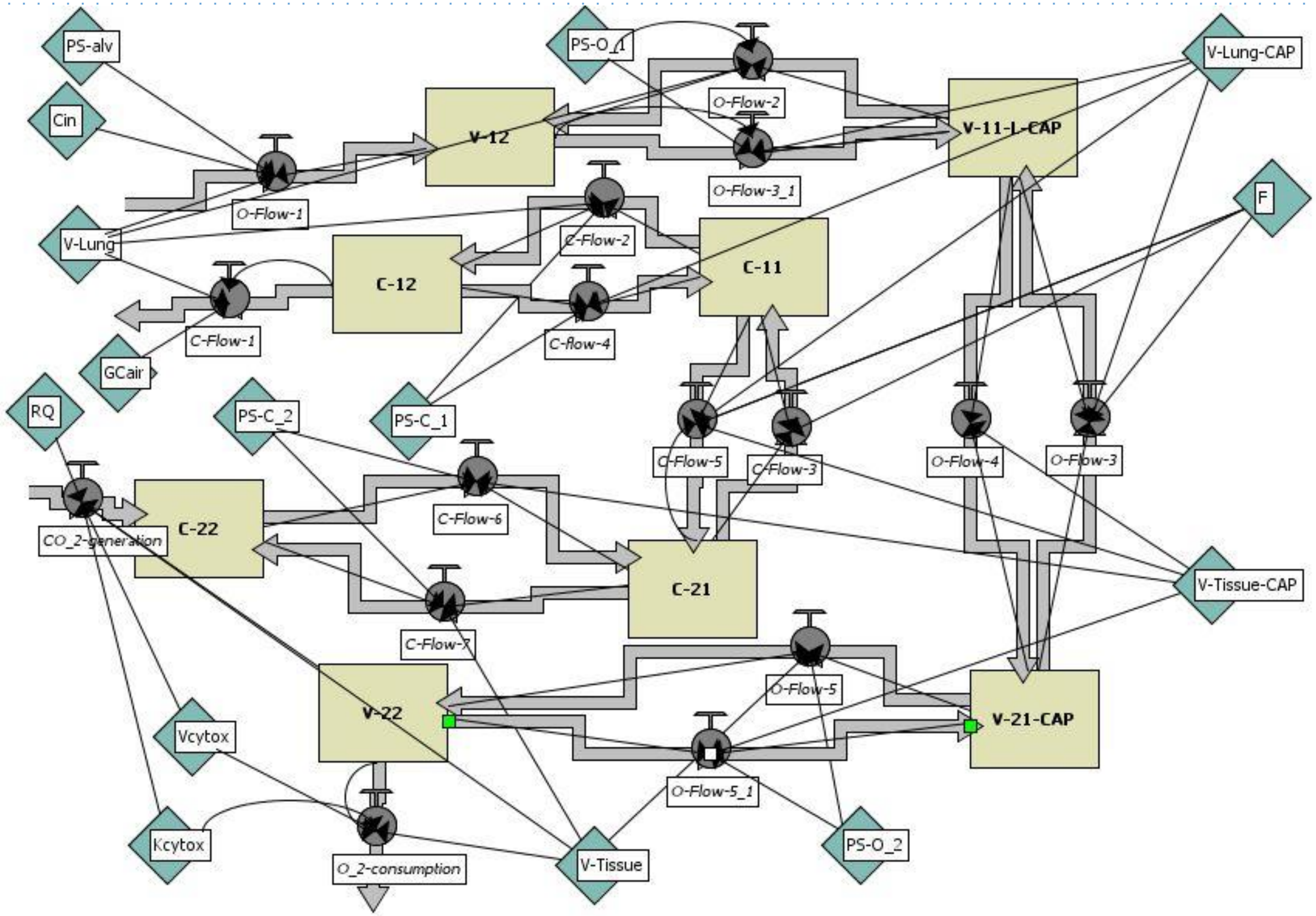
$$\frac{dP\_lung}{dt} = P\_atmos + V\_lung - V\_FRC / Compl$$

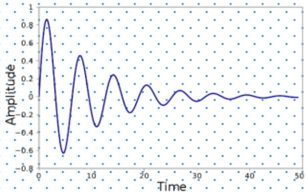


BUILDING A MODEL: SDM scheme

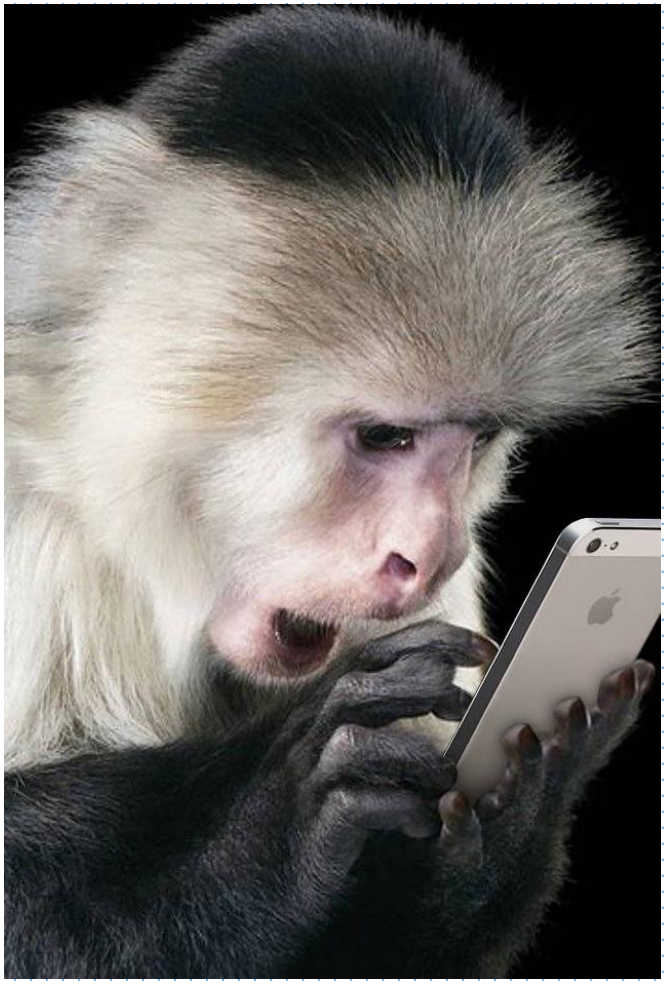


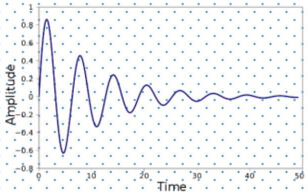
O_2 & CO_2 transport & exchange: lung and peripheral tissues levels



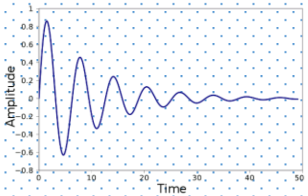


ARTIFICIAL INTELLIGENCE (AI)





ARTIFICIAL INTELLIGENCE (AI)



Artificial Intelligence (AI)

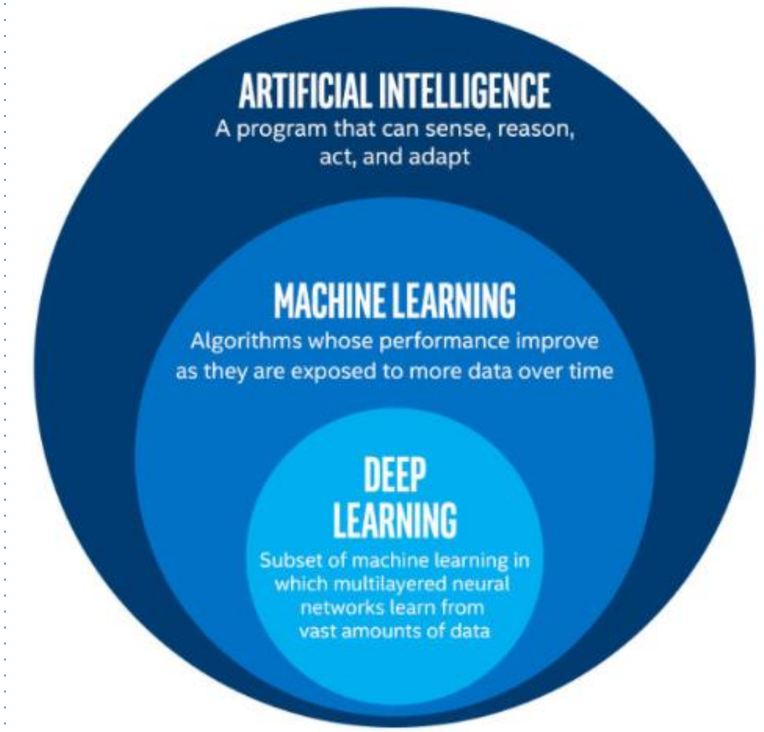
the possibility of computers to emulate human reasoning process

AI General

AI Narrow

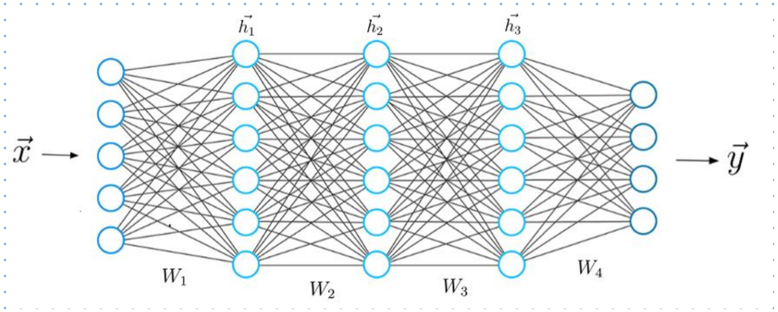
Machine Learning (ML)

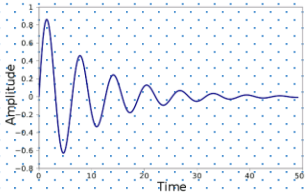
techniques / algorithms used by computers to learn / improve their performance in making informed decisions: supervised, un-supervised, reinforcement, transduction, multi-task, etc.



Deep Learning (DL)

ANN based techniques:
MLP, CNN, RNN





AI - Examples

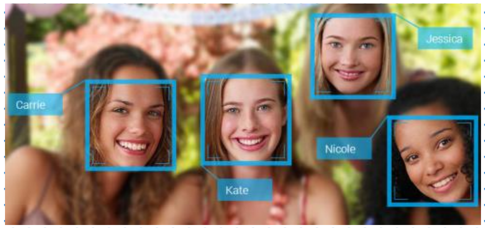


Image recognition

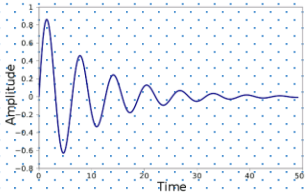
(FB, Mento Park, CA)

Speech recognition

(Apple's SIRI, Cupertino, CA)

Google, AlphaGo, G-apps

(San Francisco, CA)



AI in medicine / anesthesiology

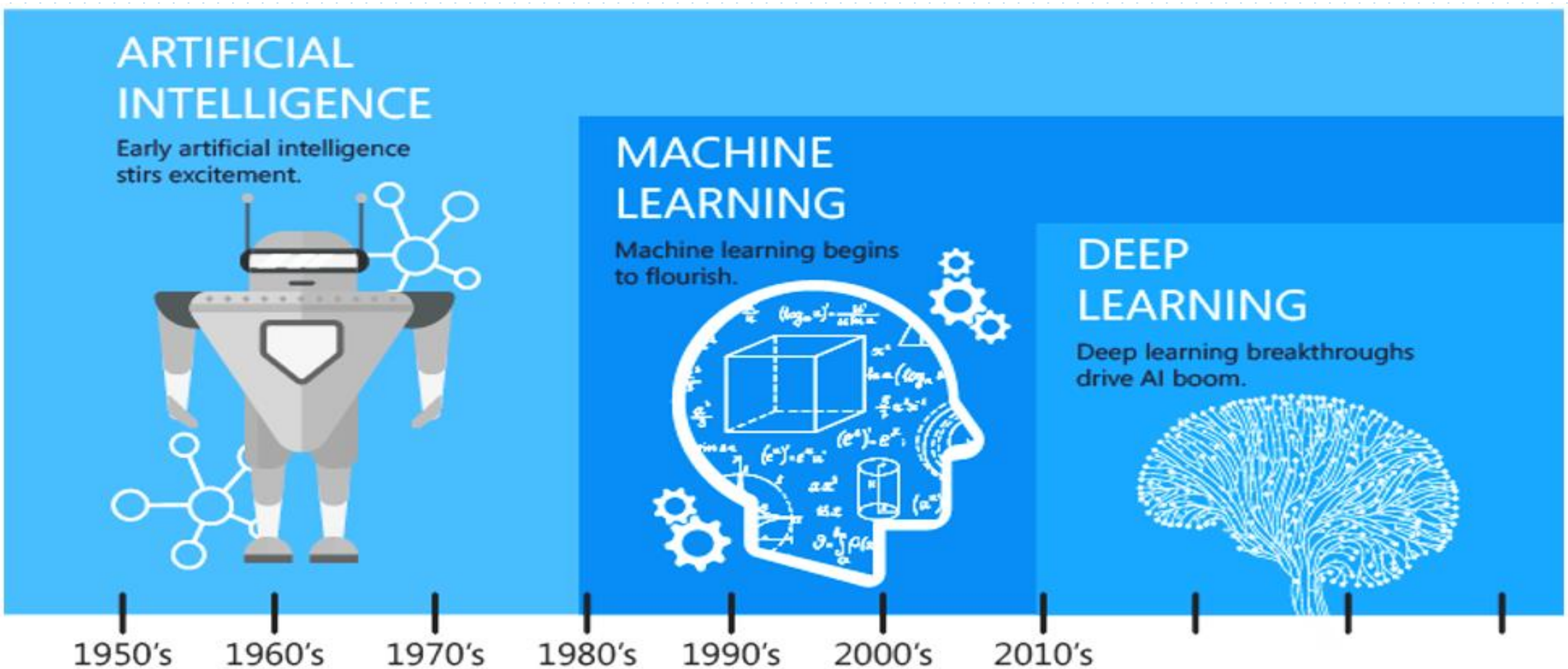
Bickford's Anesthesia System

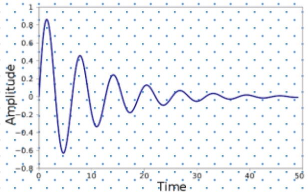
Rule-based Expert Systems

SedAsys, J&J, 2006
McSleep, MUHC, 2008
+ DaVinci MUHC, 2010

Kepler Intubation System, KIS
teleanesthesia, 2011
HumMod, 2011

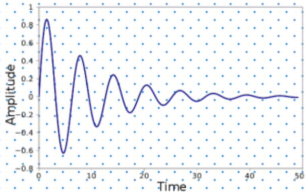
SaMD, FDA, 2019





AI: McSleepy

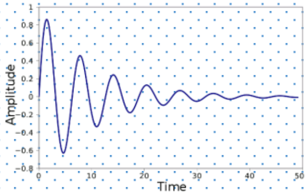
Kepler Intubation System (KIS)



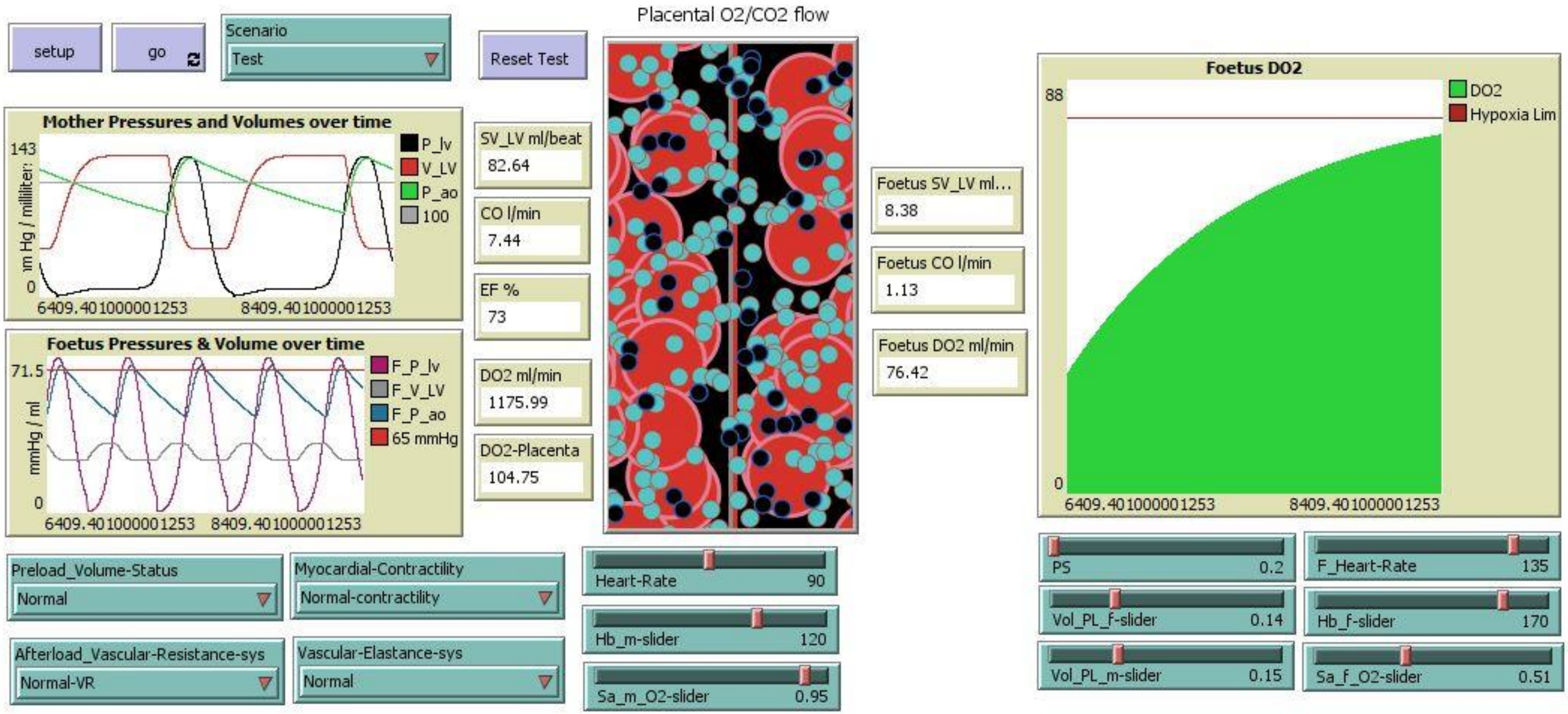
"Artificial Intelligence. It's not intelligence, it might never be. The work of AI is at best clever use of algorithms to analyse large amounts of data. It has become a lazy term applied to too many tools and gadgets."

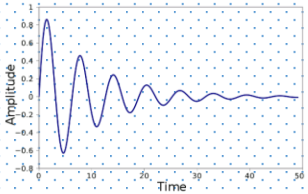
Andy Cotgreave, 2018

Advanced monitoring &
Computational Medicine

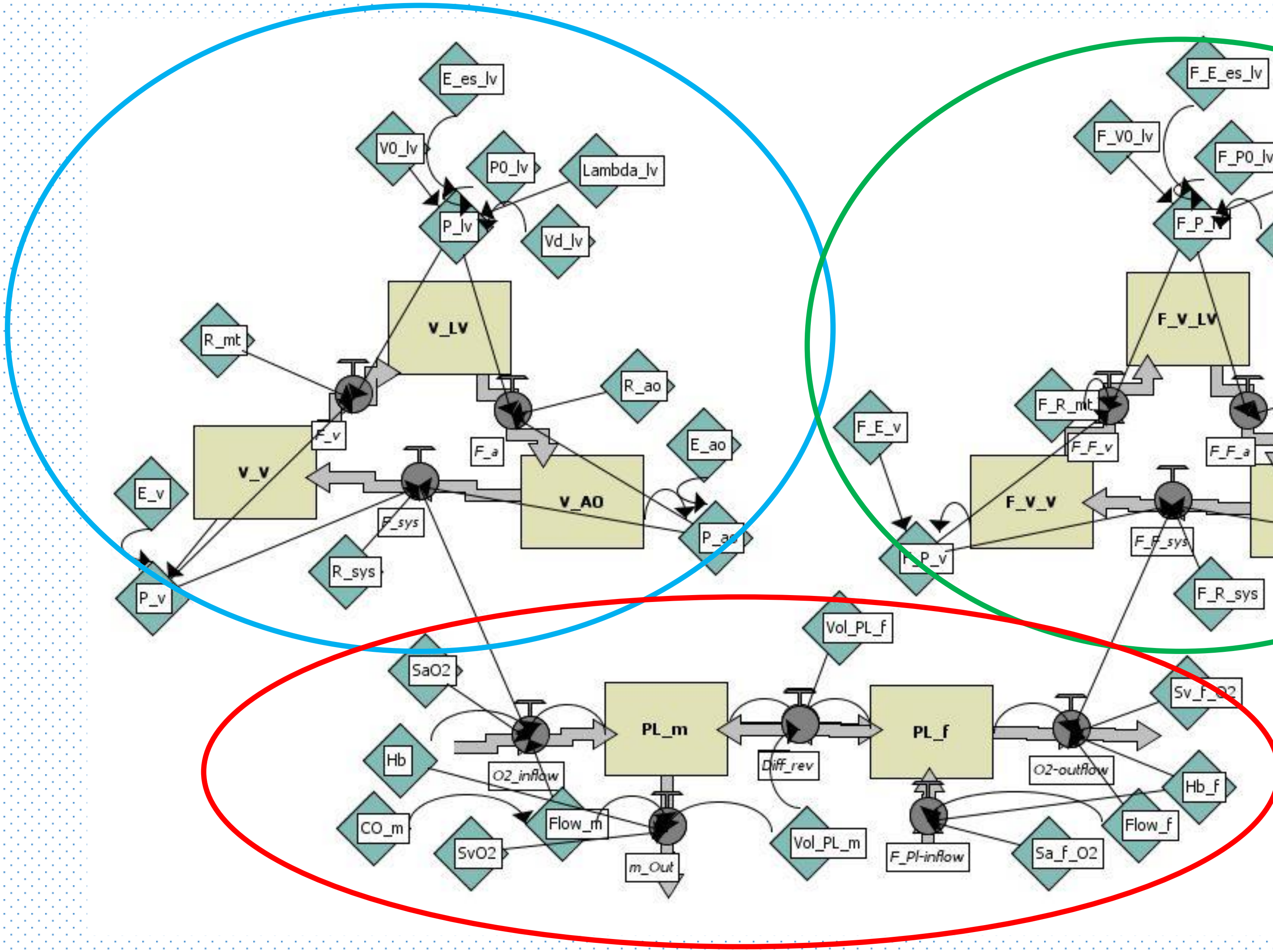


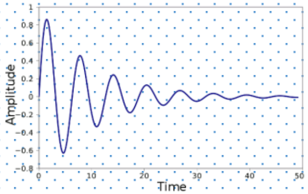
Maternal-Foetal Circulation & Placenta / DO2 Model



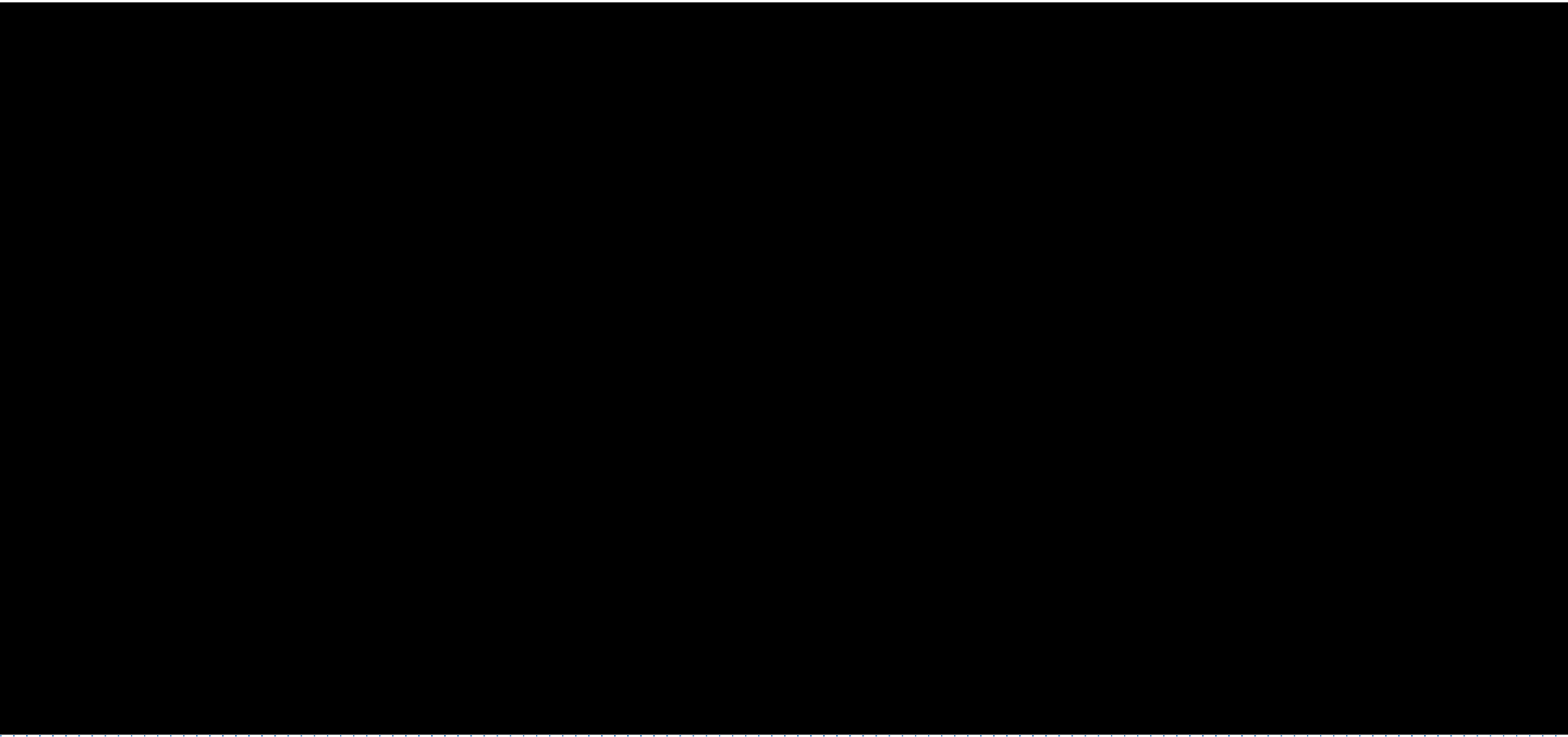


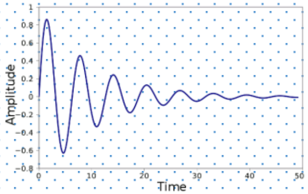
Maternal-Foetal Circulation & Placenta / DO2 Model



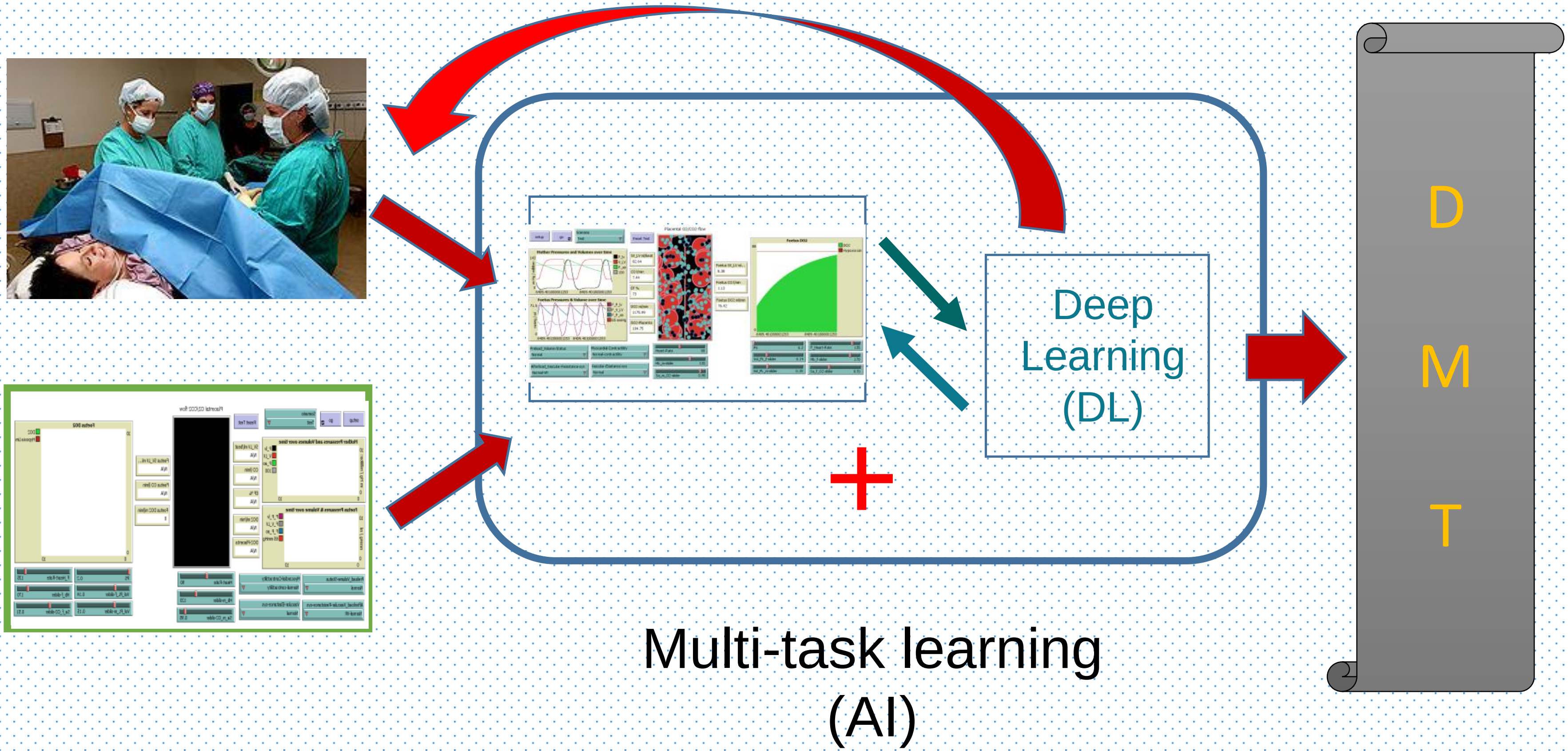


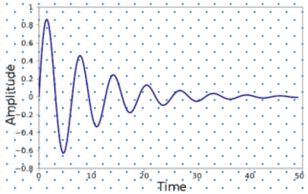
Maternal-Foetal Circulation & Placenta / DO2 Model





INDIVIDUALISED MEDICINE
Clinical Application of the Hybrid Model: Maternal-Foetal Circulation & Placenta / DO2

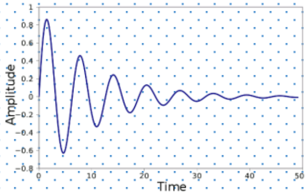




Future of AI ?

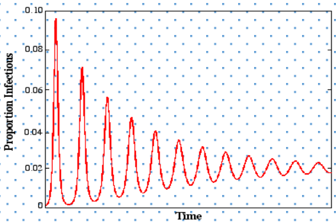
SedAsys

General anesthesia delivered by a computer system



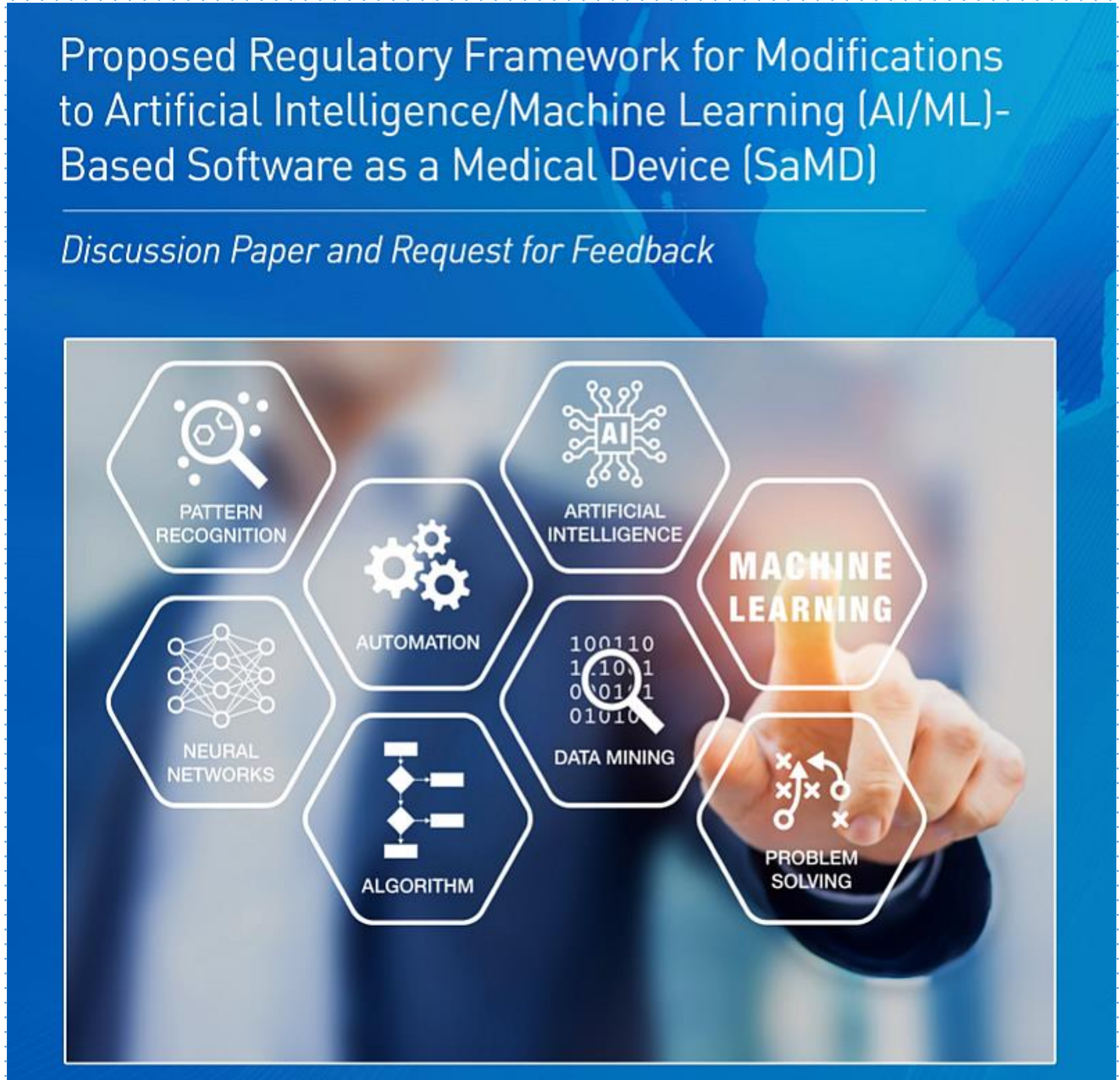
"Recent innovations in artificial intelligence, especially machine learning, may usher in a new era of automation across many industries, including anesthesiology. It would be wise to consider the implications of such potential changes before they have been fully realized"

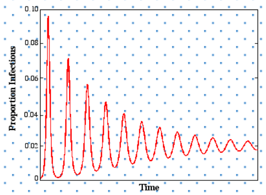
John C. Alexander, MD, MBA, and Girish P. Joshi, MBBS, MD
Department of Anesthesiology and Pain Management,
University of Texas Southwestern Medical Center, Dallas, Texas
2018



- 01/ 2019 - 14 apps
- 07/ 2019 - 26 apps

nowdays - > 30 apps





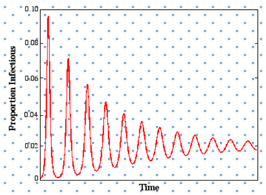
AI future: some possibilities

ALGORITHMIC INFORMATION DYNAMICS (AID)

1 { H T H T H T H T H T }

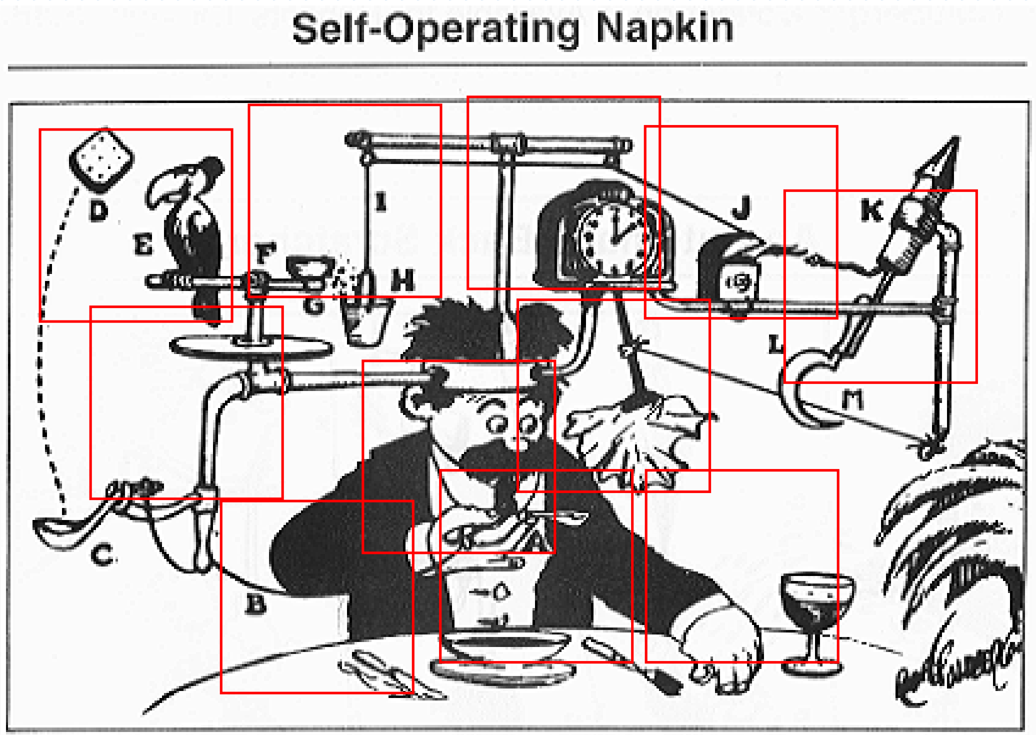
2 { H T T T H H T H H T }

Shannon's Entropy(statistics) ≠ AID



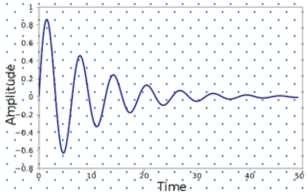
AI future: some possibilities

ALGORITHMIC INFORMATION DYNAMICS (AID)



BLOCK DECOMPOSITION METHOD - $\Sigma\ complexity$

+ Deep Learning



http://modelingcommons.org/account/models/2495
https://www.complex-systems.com/abstracts/v28_i01_a03/
https://www.researchgate.net/profile/Victor_Iapascurta/research