ECEM
ELECTRICAL & COMPUTER ENGINEERING IN MEDICINE

The Phone Oximeter

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CHILD & FAMILY RESEARCH INSTITUTE

Pediatric Anesthesia RESEARCH TEAM

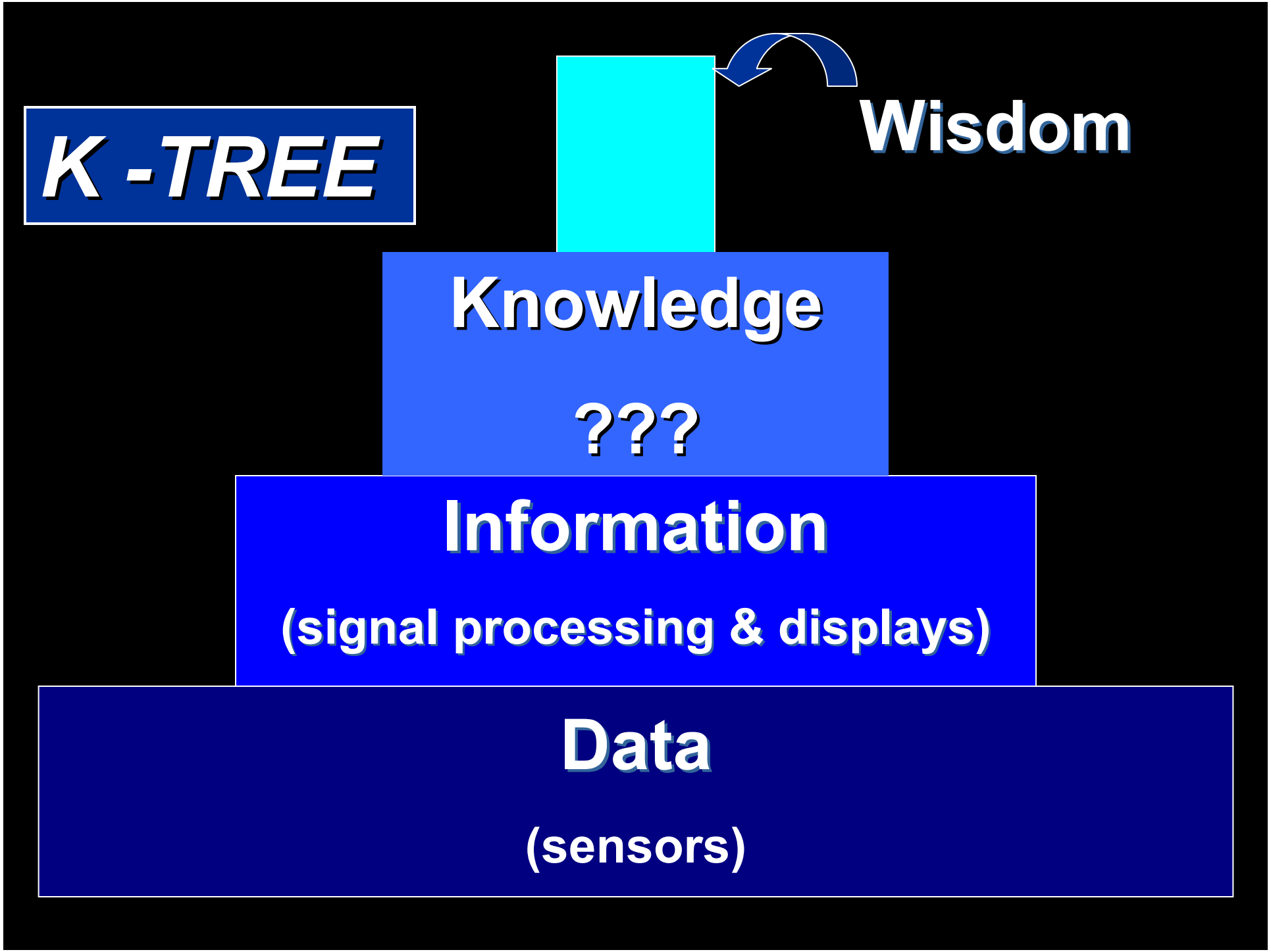
Disclosure

Related Research:

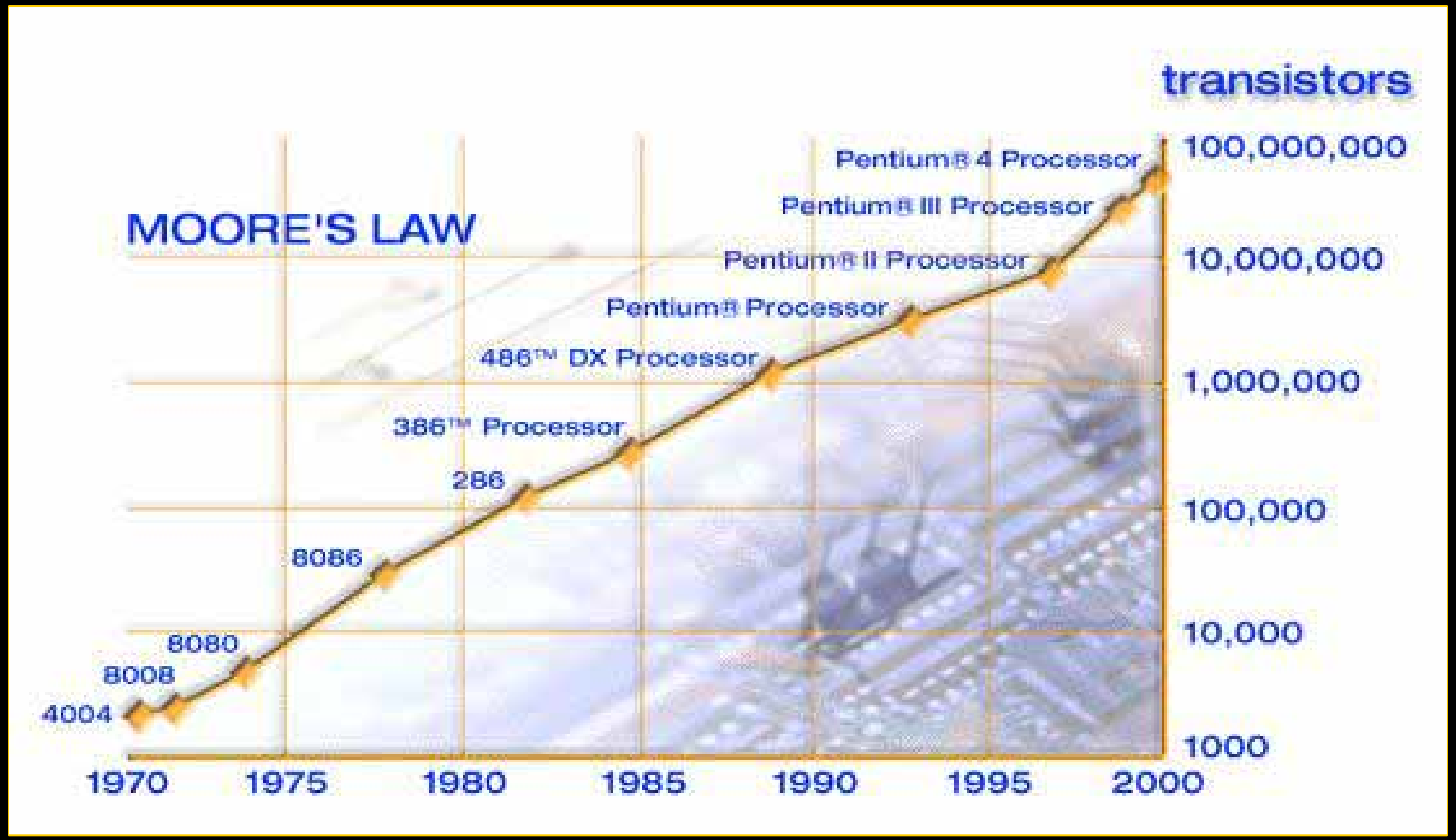
- Martha Piper Fund

Unrelated Research

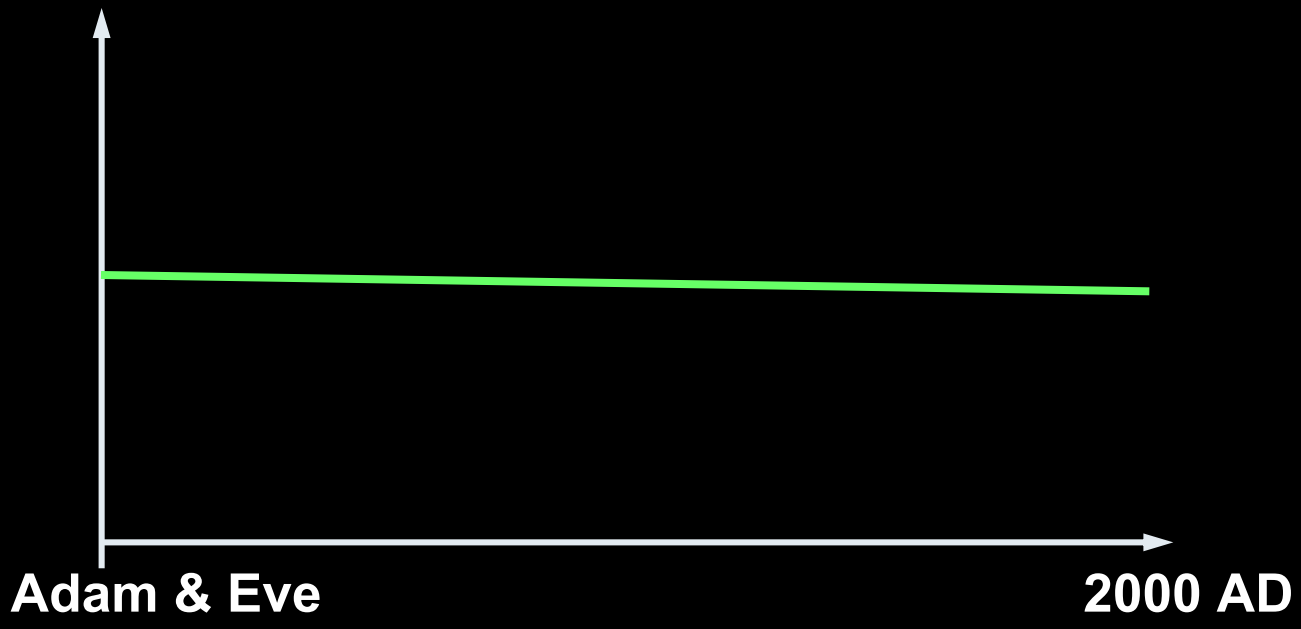
- MSFHR
- CIHR
- BCCH Foundation
- CAS
- CIHR
- Draeger
- NSERC


K -TREE
Wisdom
Knowledge
???
Information
(signal processing & displays)
Data
(sensors)

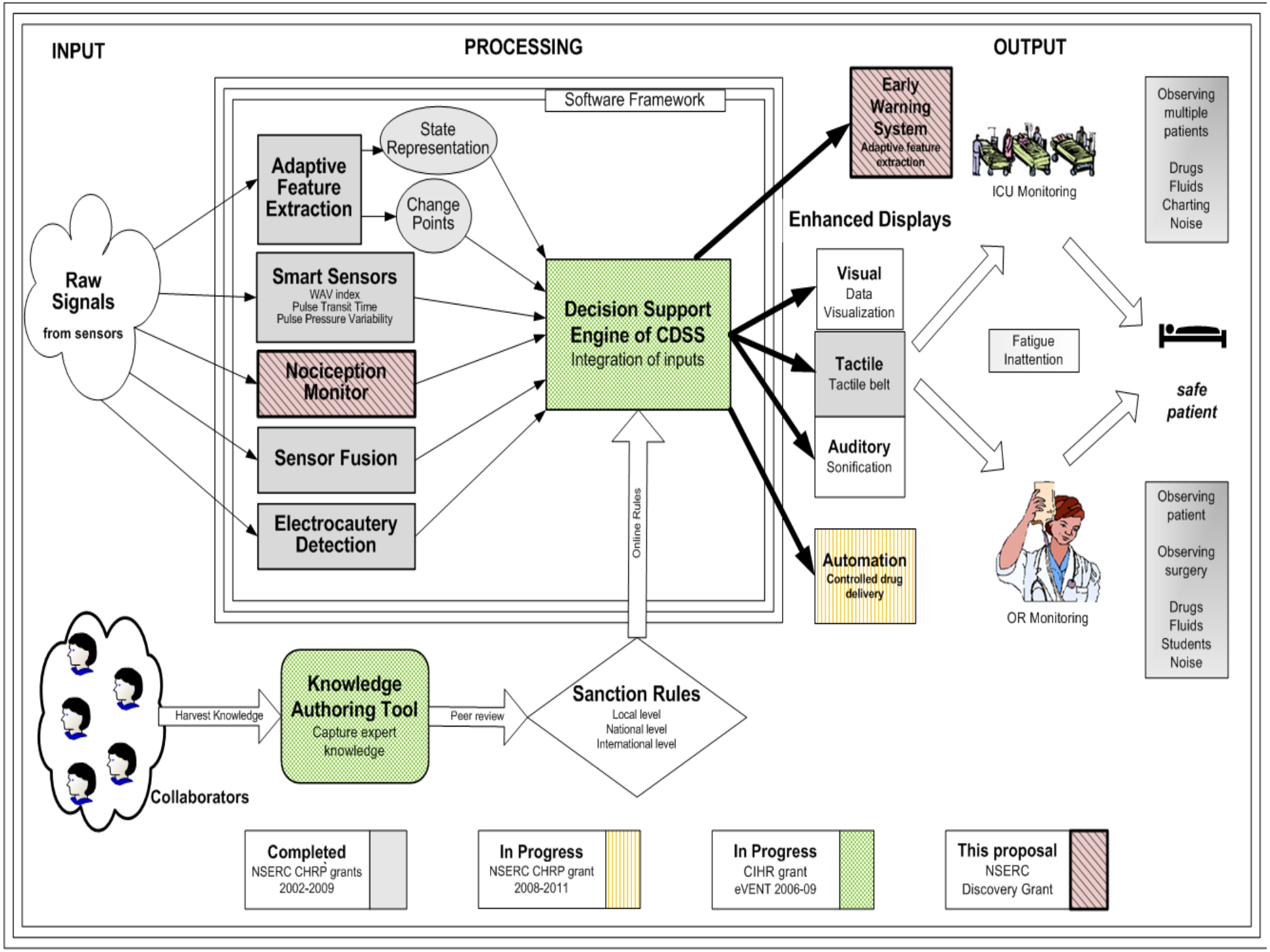
Moore's Law


transistors
MOORE'S LAW
Pentium® 4 Processor
Pentium® III Processor
Pentium® II Processor
Pentium® Processor
486™ DX Processor
386™ Processor
286
8086
8080
8008
4004
100,000,000
10,000,000
1,000,000
100,000
10,000
1000
1970
1975
1980
1985
1990
1995
2000

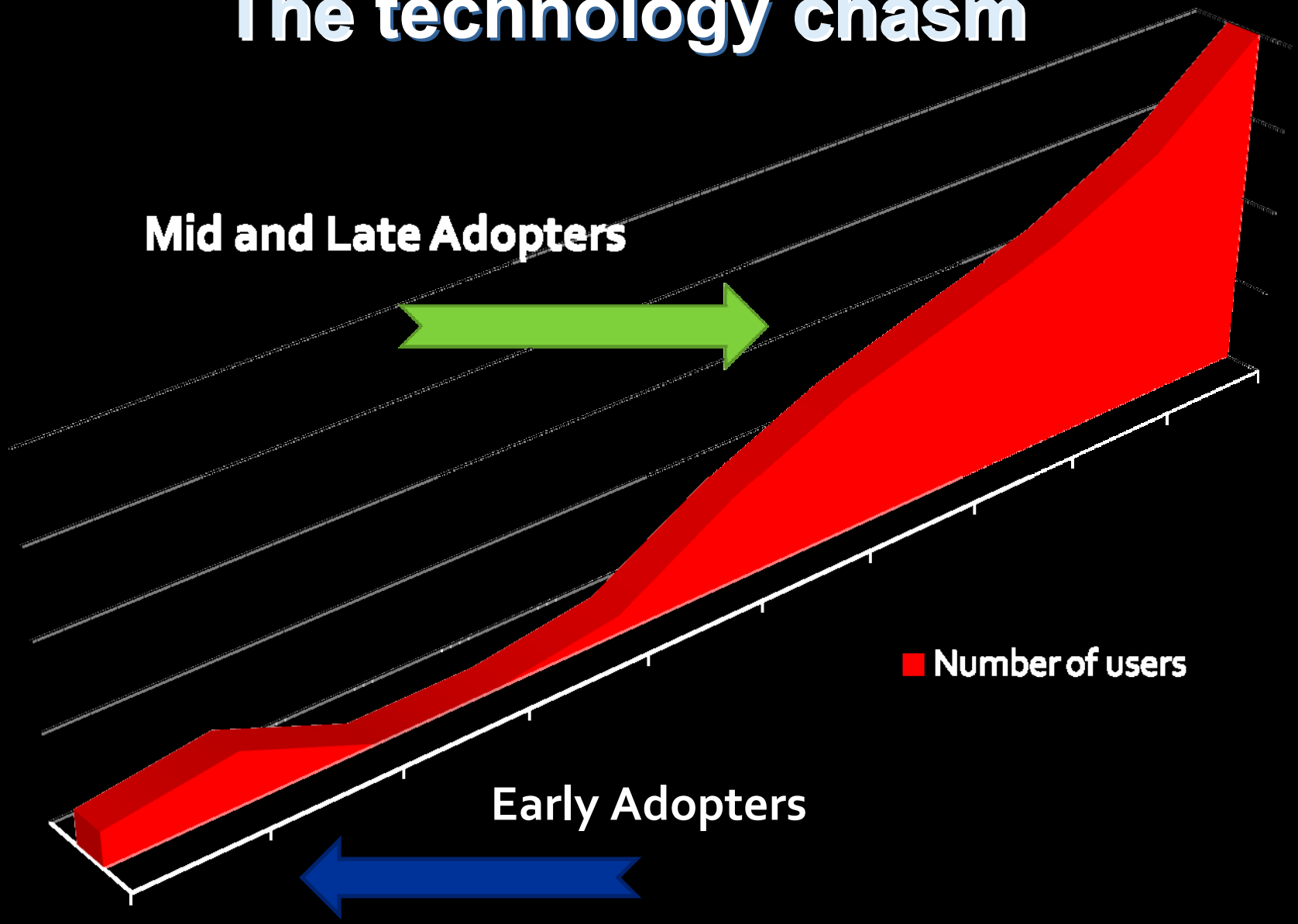
Human Performance Over Time

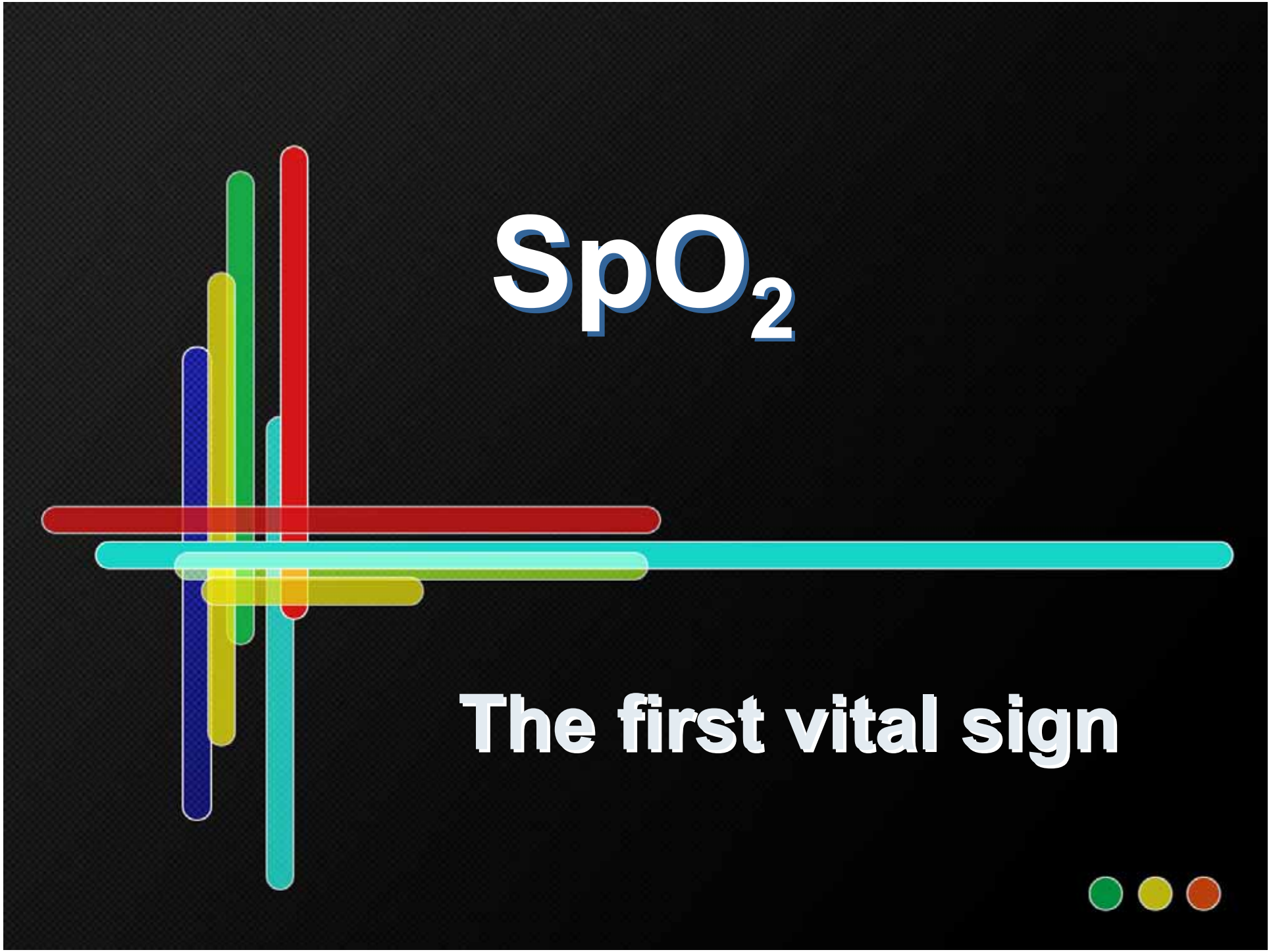


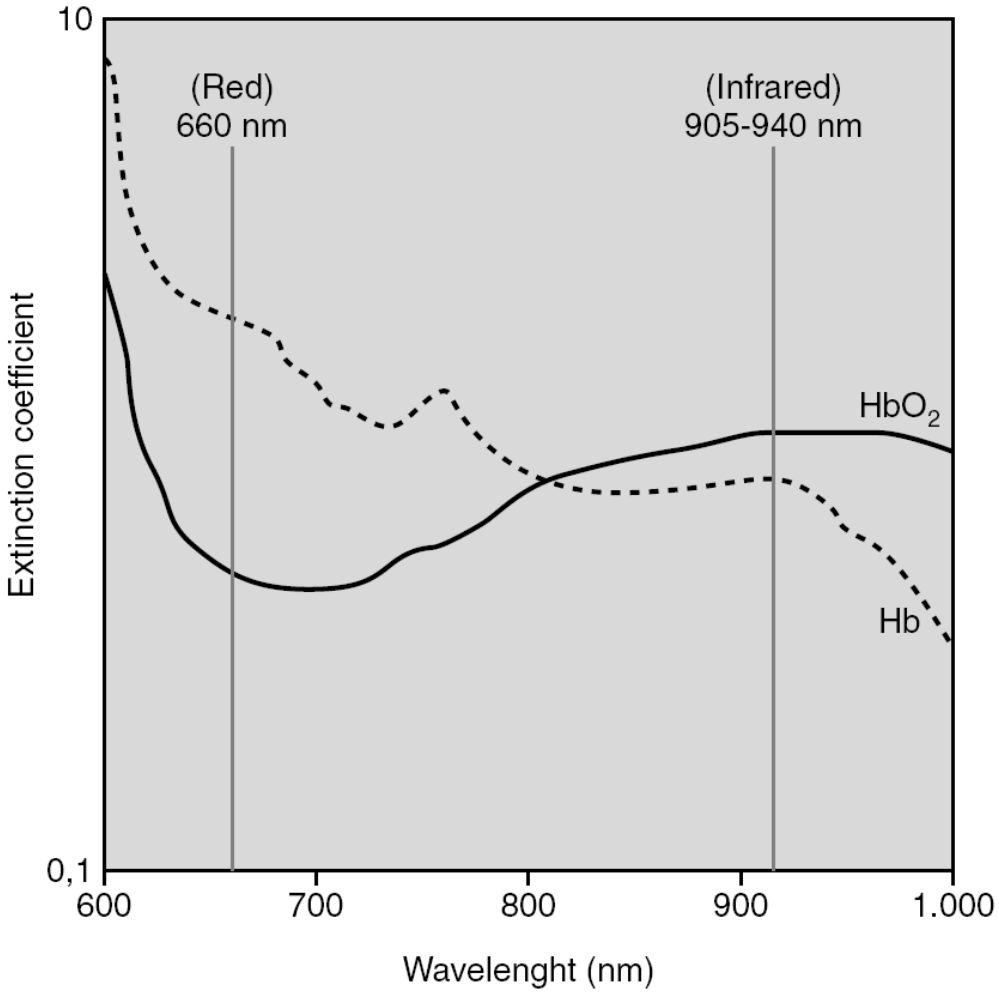
The most precious resource is human vigilance.


INPUT
PROCESSING
OUTPUT
Software Framework
Raw Signals
from sensors
Adaptive Feature Extraction
State Representation
Change Points
Smart Sensors
WAV index
Pulse Transit Time
Pulse Pressure Variability
Nociception Monitor
Sensor Fusion
Electrocautery Detection
Decision Support Engine of CDSS
Integration of inputs
Online Rules
Early Warning System
Adaptive feature extraction
ICU Monitoring
Observing multiple patients
Drugs
Fluids
Charting
Noise
Enhanced Displays
Visual
Data Visualization
Tactile
Tactile belt
Auditory
Sonification
Automation
Controlled drug delivery
Fatigue
Inattention
safe patient
OR Monitoring
Observing patient
Observing surgery
Drugs
Fluids
Students
Noise
Collaborators
Harvest Knowledge
Knowledge Authoring Tool
Capture expert knowledge
Peer review
Sanction Rules
Local level
National level
International level
Completed
NSERC CHRP grants
2002-2009
In Progress
NSERC CHRP grant
2008-2011
In Progress
CIHR grant
eVENT 2006-09
This proposal
NSERC
Discovery Grant

The technology chasm




SpO_2
The first vital sign



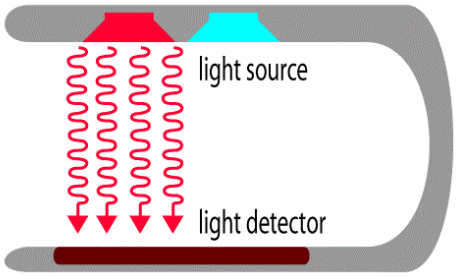
Beer-Lambert Law:

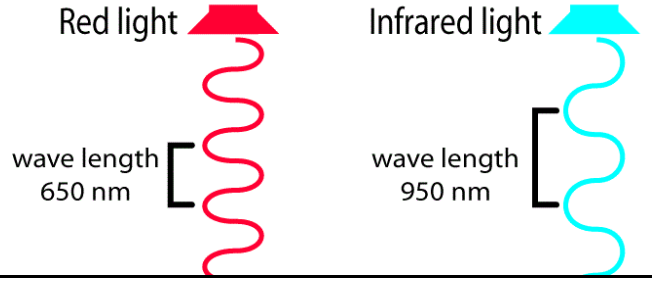
$I_{red,Ir} = I_{oe}^{-\varepsilon cx}$

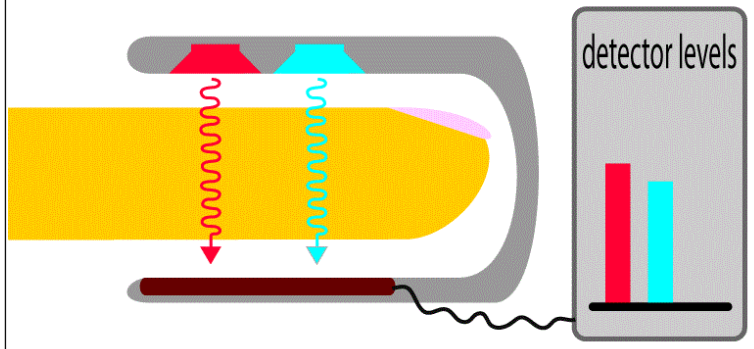
ε = Extinction coefficient

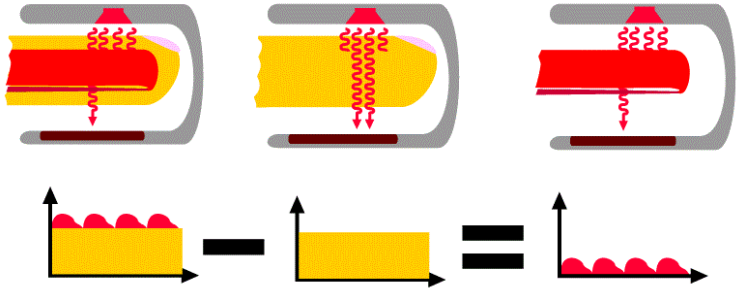
c = Concentration

x = Optical path lenght










99
66
NONIN
7500


SPO


99
95


97
89

Anesthesia

- Current mortality in Canada (near $1:10^6$)
- Developing world (1:1000)
- What makes the difference
- WHO – GOP (safe surgery)

Pulse Oximetry and Safety

Pulse oximetry for perioperative monitoring: systematic review of randomized, controlled trials.

Pedersen, T., Møller, A. M., & Pedersen, B. D. (2003).

Anesthesia and Analgesia, *96*(2), 426-31.

"given the relatively small number of patients studied and the rare events being sought, the studies were not able to show an improvement in various outcomes".

Pulse Oximetry Worldwide

	Number (95% CI)	Percentage (95% CI)
Australasia	<25	<0·1%
North America (high income)	<25	<0·1%
Europe (western)	<25	<0·1%
Asia-Pacific (high income)	106 (16-688)	0·2% (0·04-1·6)
Latin America (southern)	198 (29-1356)	2·5% (0·4-15·4)
Latin America (tropical)	1511 (1163-1963)	7·7% (3·7-15·1)
Europe (central)	1763 (994-3125)	9·4% (5·3-16·2)
Sub-Saharan Africa (southern)	333 (147-753)	15·8% (6·7-32·8)
Latin America (central)	1648 (1133-2399)	19·2% (13·1-27·1)
Middle East, North Africa	4174 (2954-5897)	23·7% (16·6-32·6)
Caribbean	1228 (949-1588)	31·6% (25·5-38·5)
Asia (east)	21445 (11727-39215)	33·8% (17·0-55·8)
Europe (eastern)	19223 (12015-30754)	36·7% (22·2-54·0)
Asia (southeast)	5703 (4629-7027)	37·7% (30·5-45·5)
Latin America (Andean)	936 (733-1196)	41·4% (36·8-46·2)
Asia (central)	4248 (3664-4925)	47·0% (40·6-53·5)
Asia (south)	10064 (8586-11795)	49·0% (42·4-55·6)
Oceania	92 (74-114)	56·9% (46·9-66·4)
Sub-Saharan Africa (west)	1853 (1612-2130)	58·4% (52·9-63·8)
Sub-Saharan Africa (central)	682 (538-865)	67·0% (59·3-73·9)
Sub-Saharan Africa (east)	2461 (2164-2799)	70·4% (65·8-74·7)
Total	77700 (63195-95533)	19·2% (15·2-23·90)

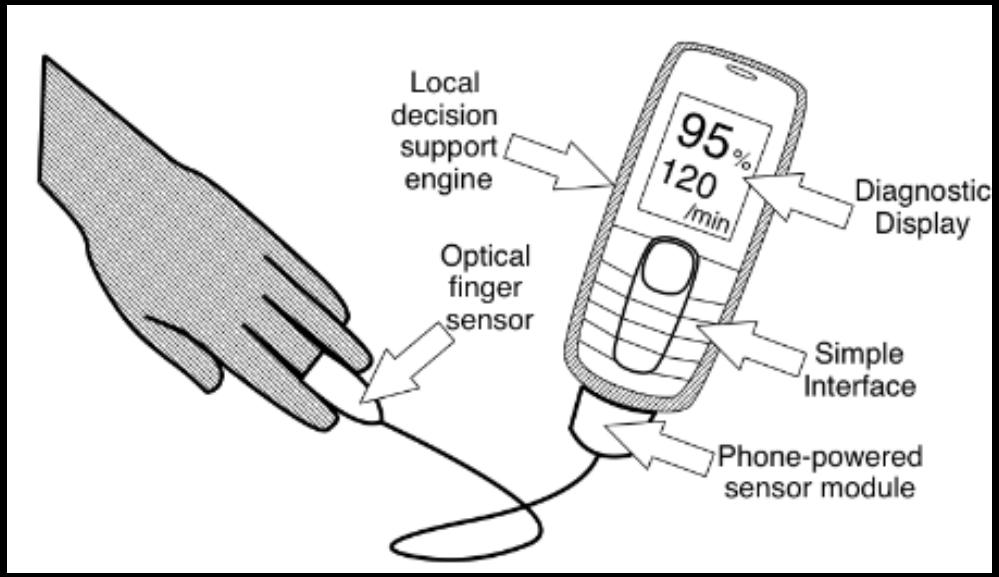
See webappendix p 1 for details of countries in the subregions.

Table 5: Estimated number of operating theatres without pulse oximetry, by subregion, ranked by percentage without pulse oximetry

Funk, L. M., Weiser, T. G., Berry, W. R., Lipsitz, S. R., Merry, A. F., Enright, A. C., et al. (2010). **Global operating theatre distribution and pulse oximetry supply: an estimation from reported data.** *The Lancet*, *6736*(10), 1-9.


PHONE CHARGING
PhoneShop
MTN
hello hello
PHONE CHARGING
Ai-00
NOTICE
LCD HAS NO GUARANTEE

Phone Oximeter



Information from PO

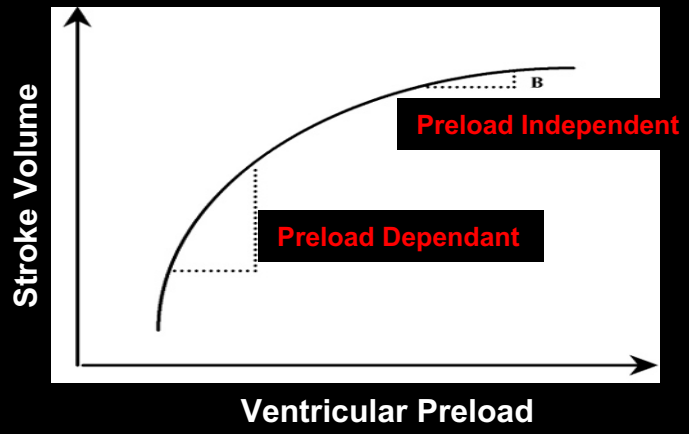
- Heart rate
- Oxygen saturation
- **Pulse volume variation**

Fluid Responsiveness

Clinical Question:

Q: Will patient's cardiac output increase following volume expansion?

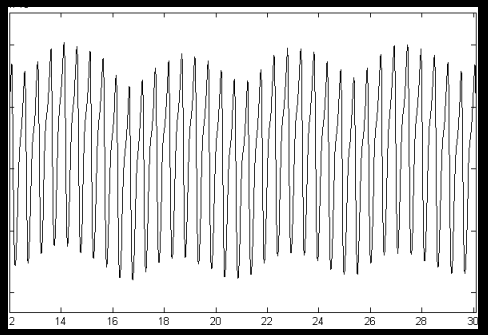
A: Depends on Frank Starling curve



- Gold standard: Cardiac output monitoring **Invasive**
- Static index: Central Venous Pressure **Inaccurate**
- Dynamic indices: PPV, SPV, POP, PVI **Measure Respiratory Induced SV Variation**

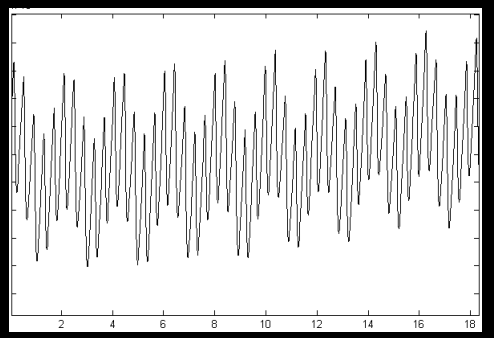
Normal State:

PVI = 5%

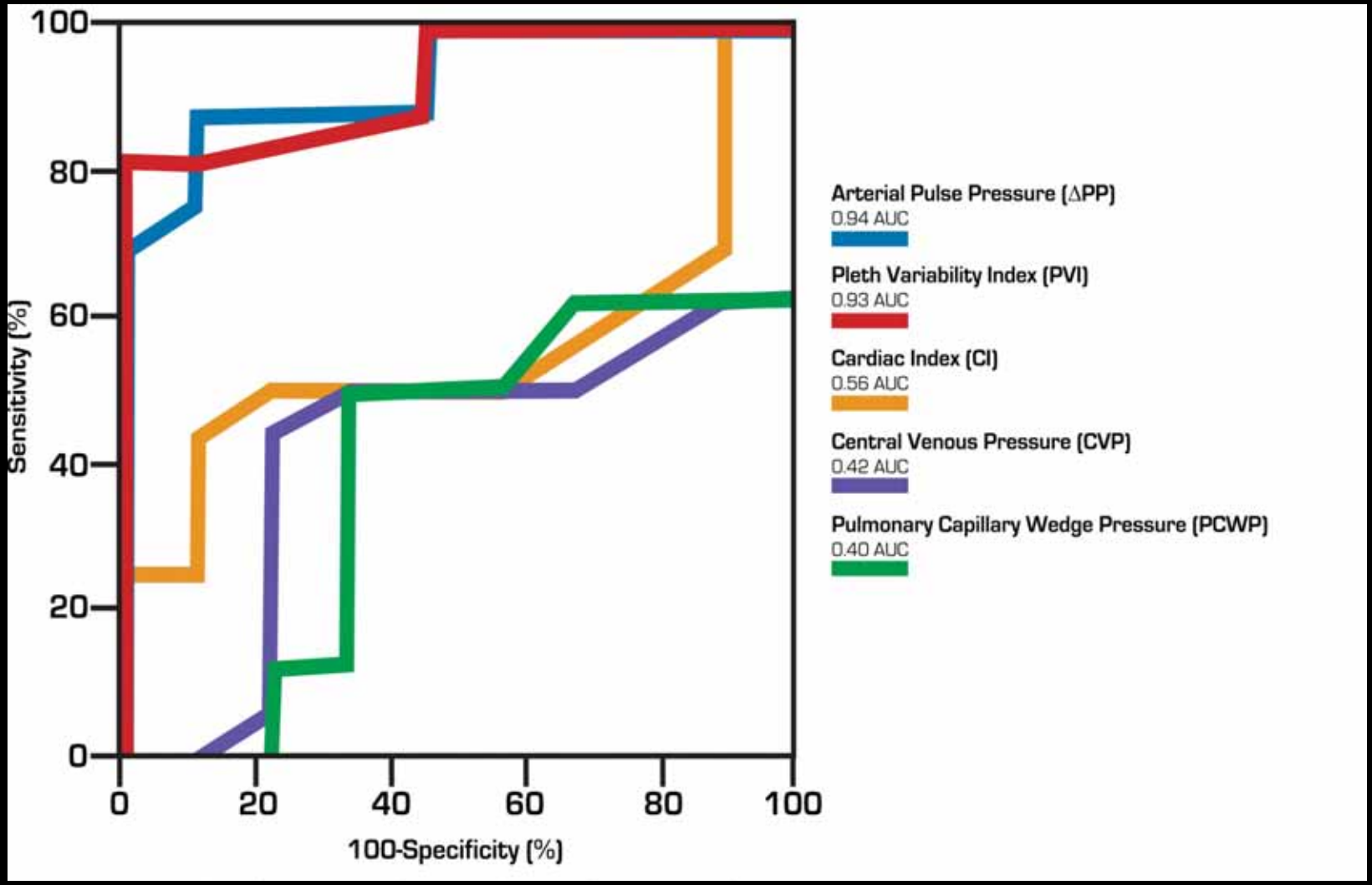


Hypovolemic State:

PVI = 28%

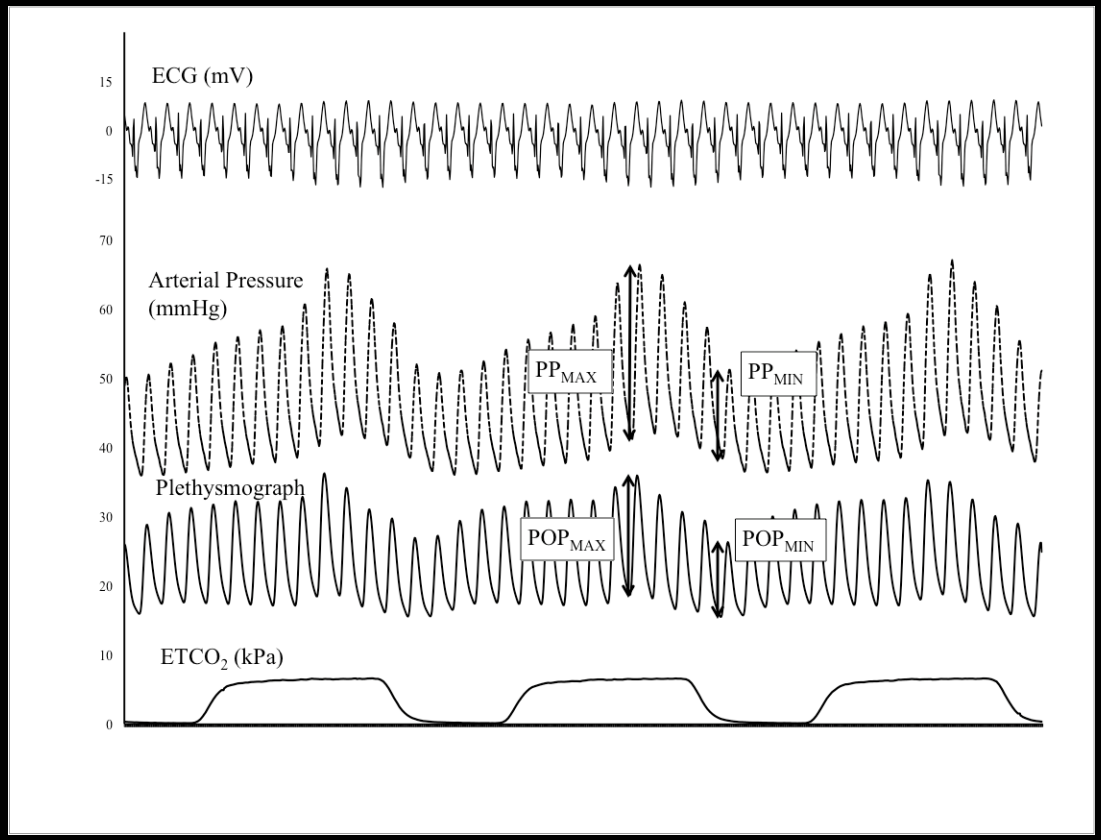


PVI to Predict Fluid Responsiveness in the OR:
ROC Curve



Adapted from Cannesson M. et. al. Br J Anesth 2008;101(2):200-206

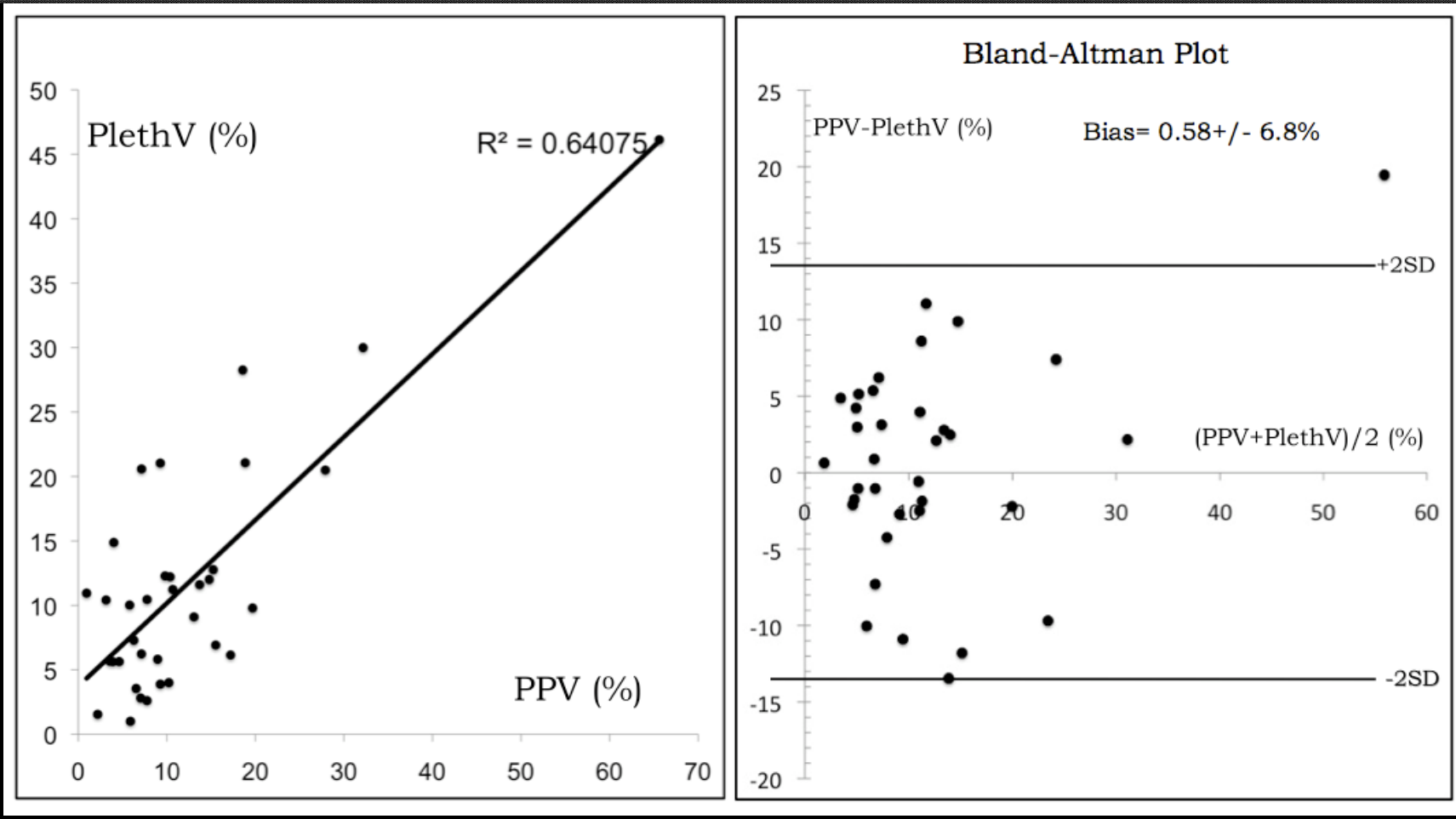
Observational Study



PPV(%) = 100 × ([PPmax - PPmin]/ [(PPmax + PPmin)/2])

PlethV(%) = 100 × ([POPmax - POPmin]/ [(POPmax + P)Pmin)/2]

Relationship between Plethysmographic Variation (PlethV) and Pulse Pressure Variation (PPV)



PPV(%) = 100 × ([Pmax - Pmin]/ [(Pmax + Pmin)/2]

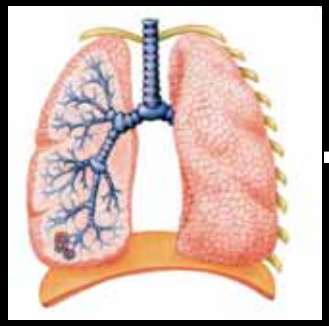
Chandler J, Froese N, Cooke E et al

Information from PO

- Heart rate
- Oxygen saturation
- Abnormal Hb (CO, MetHb)
- Pulse volume variation
- Respiratory rate

Respiratory Interaction

During Spontaneous Inspiration…



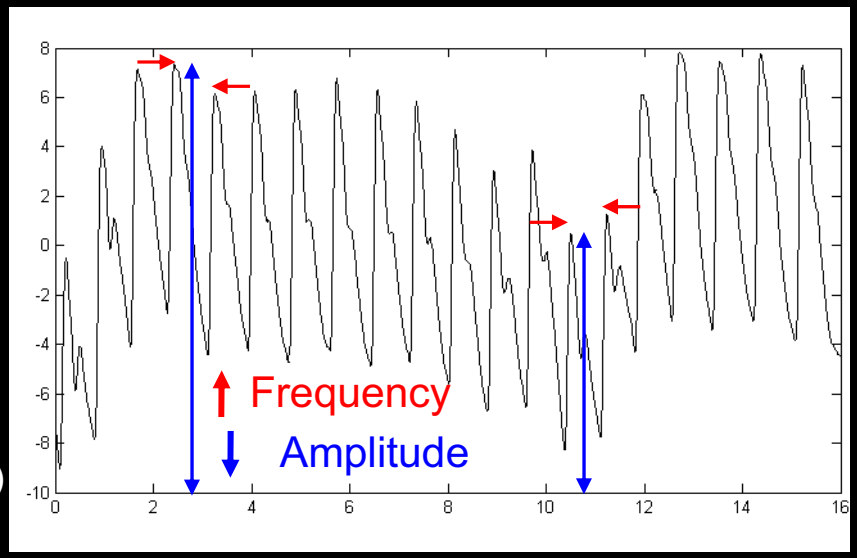
↓ Thoracic Pressure

↓ Cardiac Output

↓ Pulse Strength

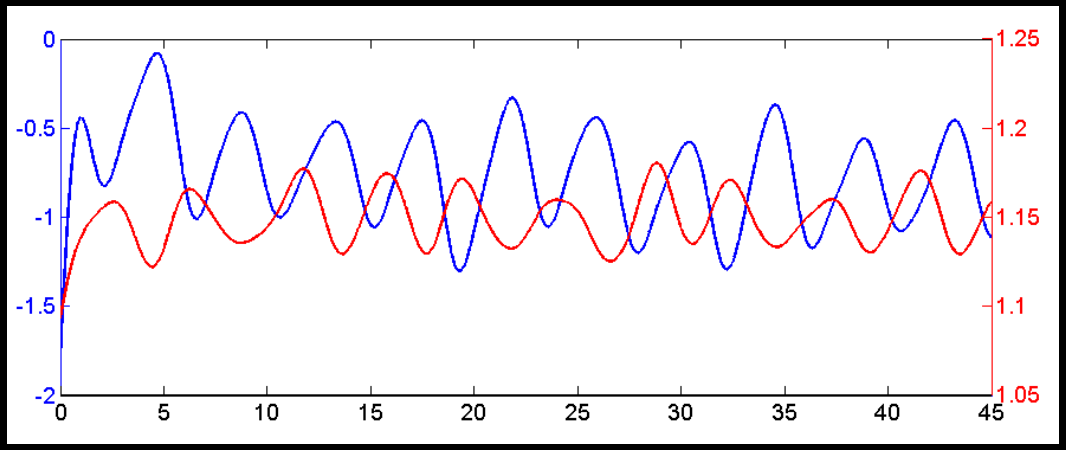
↑ HR

(Sinus Arrhythmia)



Respiratory Induced Intensity Variation (V)

(RIIV)



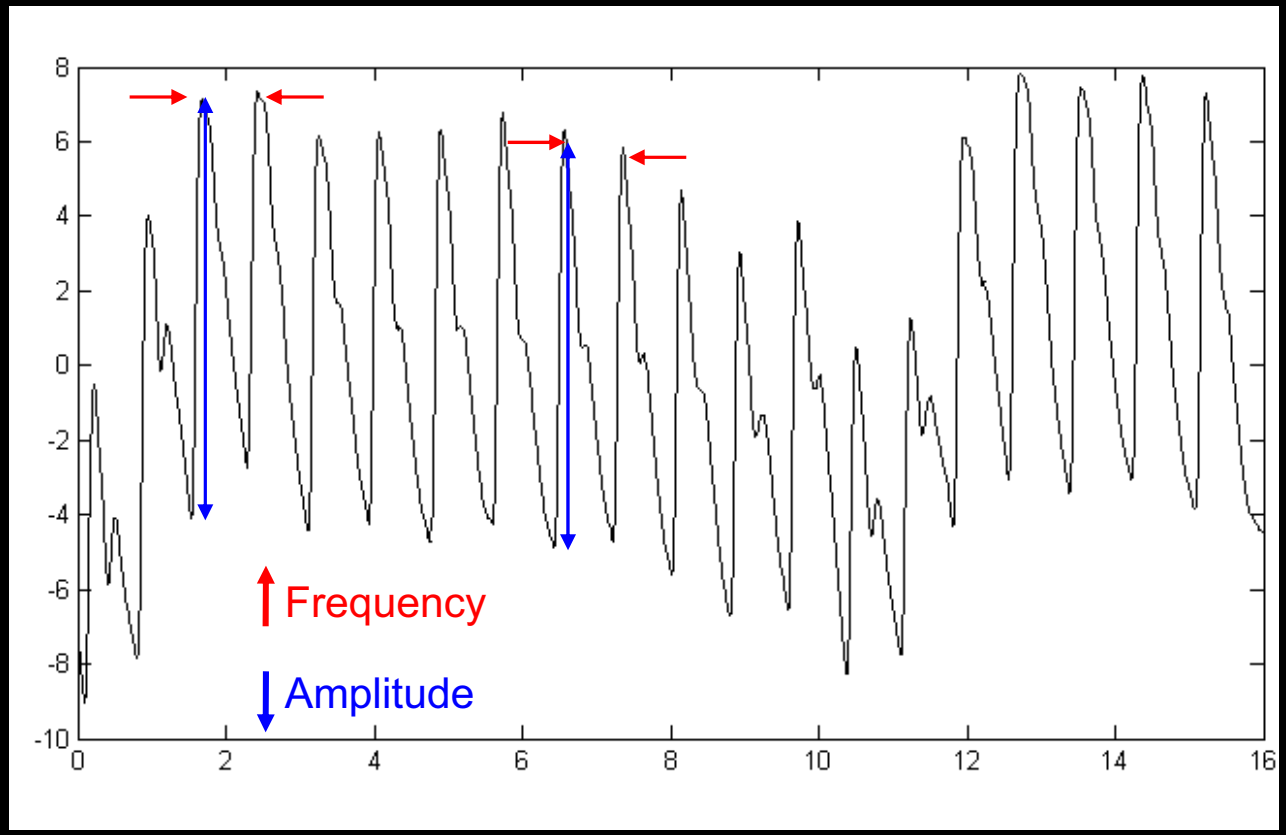
Heart Rate (Hz)

(HR)

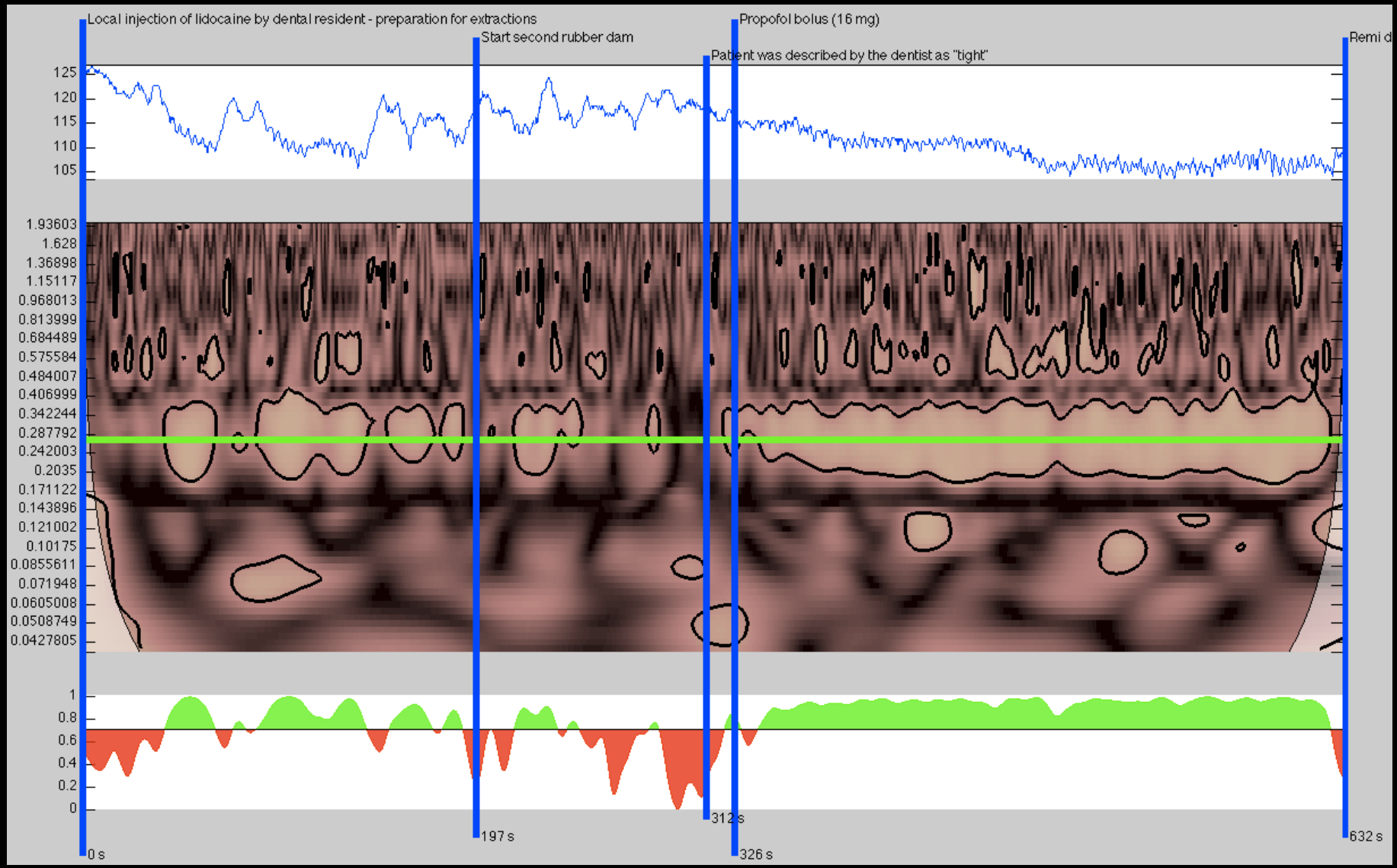
Information from PO

- Heart rate
- Oxygen saturation
- Pulse volume variation
- Respiratory Rate
- **Heart rate variability**

Heart Rate and Blood Pressure Variability



Respiratory Coherence



Information from PO

- Heart rate
- Oxygen saturation
- Pulse volume variation
- Respiratory rate
- Heart rate variability
- **Capillary refill time**

Walter Karlen

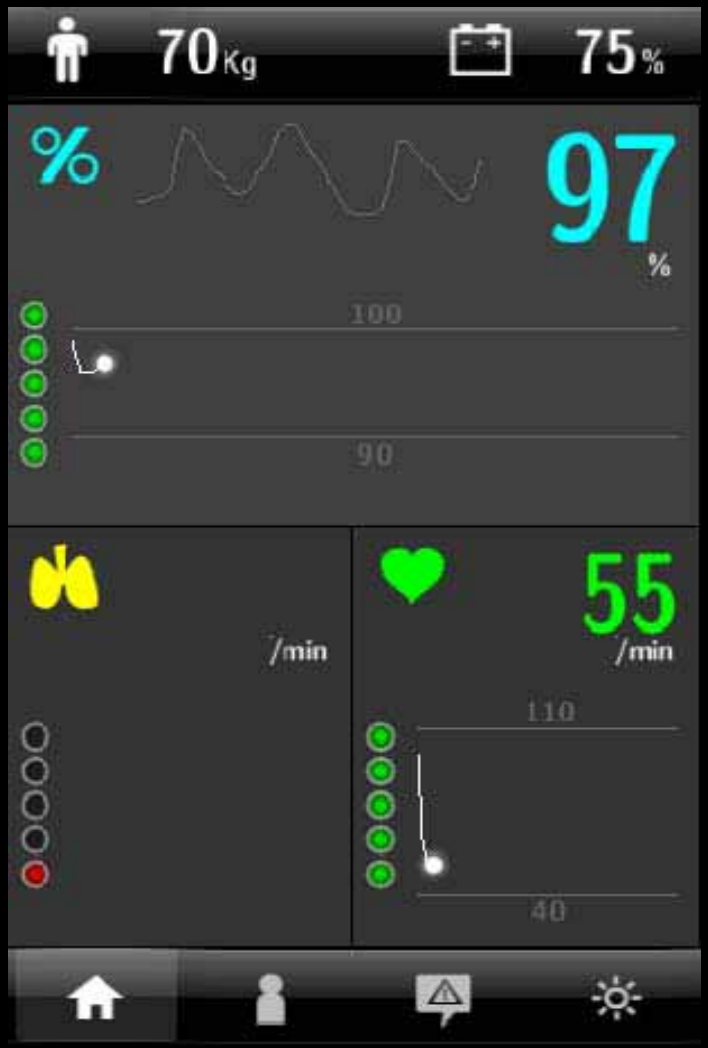
Oximeter software interface

Design goals:

- Uncluttered view of pertinent information
- Greatly simplified operation over conventional oximeters
- Decision support to provide diagnostic information (e.g. syndrome classification?)
- Treatment suggestions?
- Remote communications
- Data storage

Jacqui Hudson

Usability


70 Kg
75 %
%
97
%
100
90
/min
55
/min
110
40


Settings
69
70
71
Kg
%
99
100
%
89
90
91
109
110
111
/min
39
40
41
59
60
/min
6
7
9
10
11
min

PO will change the world!

- **Acute Lower Respiratory Infection (ALRI)**
  - Leading cause of death in <5y
  - 20% of 10 million deaths a year
  - 35% death reduction with oxygen alone
- Impact
  - Early diagnosis (screening)
  - Lay health worker diagnosis
  - Follow response to antibiotics
  - Reduced antibiotic use
  - Early referral
  - Manage oxygen therapy

Other Applications of PO

- Infant mortality
  - Pneumonia
  - Diarrhoea and vomiting
  - Malaria
- Newborn screening
  - Lung disease
  - Heart disease
  - **Sepsis**
- Adults

Sepsis – the final common pathway

The Problem…


5 Kg
100 %
%
99
%
27
/min
100
/min

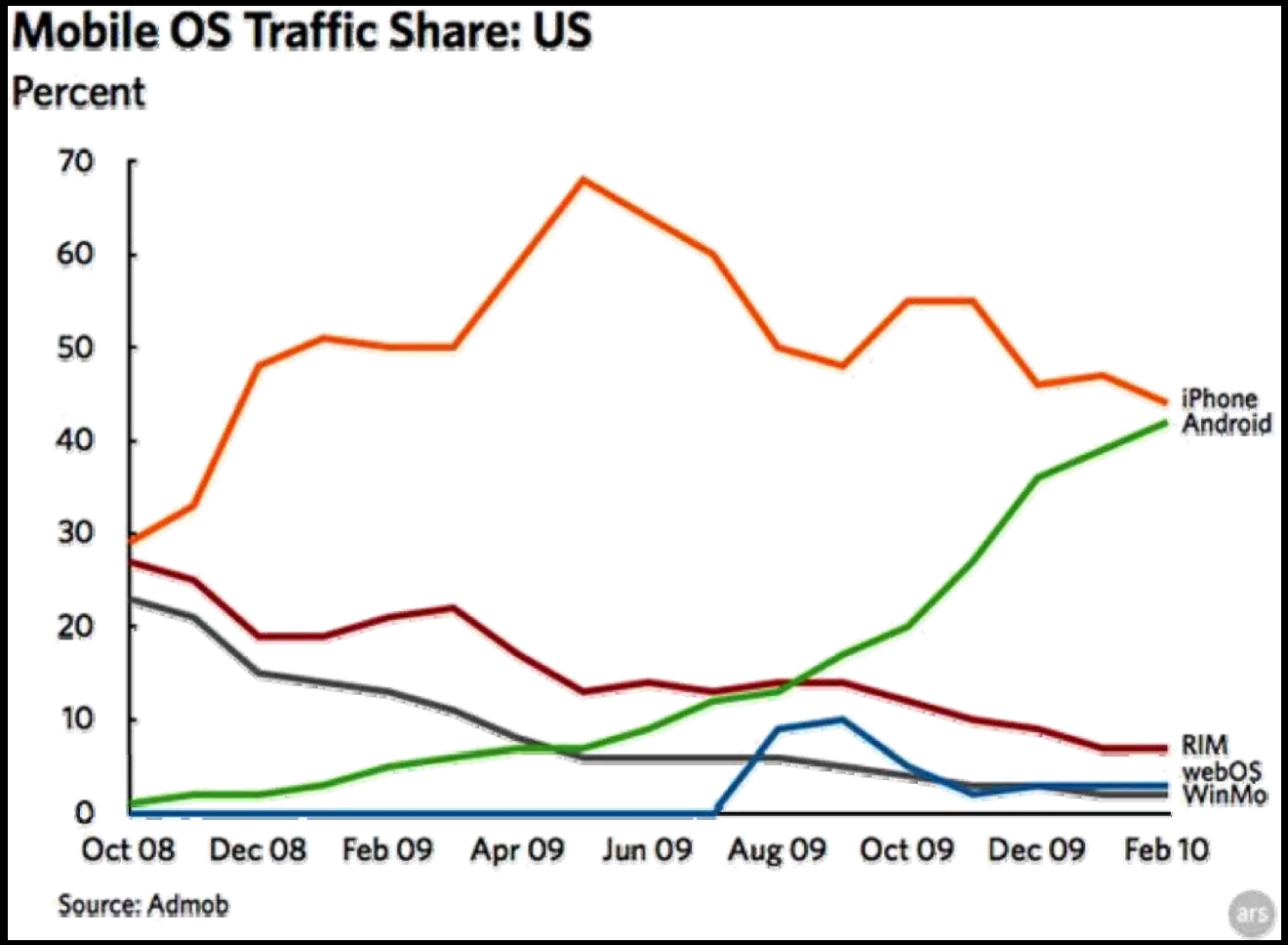
?


NOKIA
SAT:98%
HR:75bpm
RR:12/min
NO_SYNDROME

$$$$

$

Will it be Apples or Androids?



Morgan Stanley: Smartphones will out-ship global PC market by 2012

What is needed?

- Cheap sensor
- Easily cleaned
- Low power
- Robust
- Cheap display (cell phone or laptop)
- Intelligent interpretation
- Low learning overhead (AED)

Thanks for listening….

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