6.873/HST.951 Medical Decision Support
Fall 2005

Biomedical Decision Support

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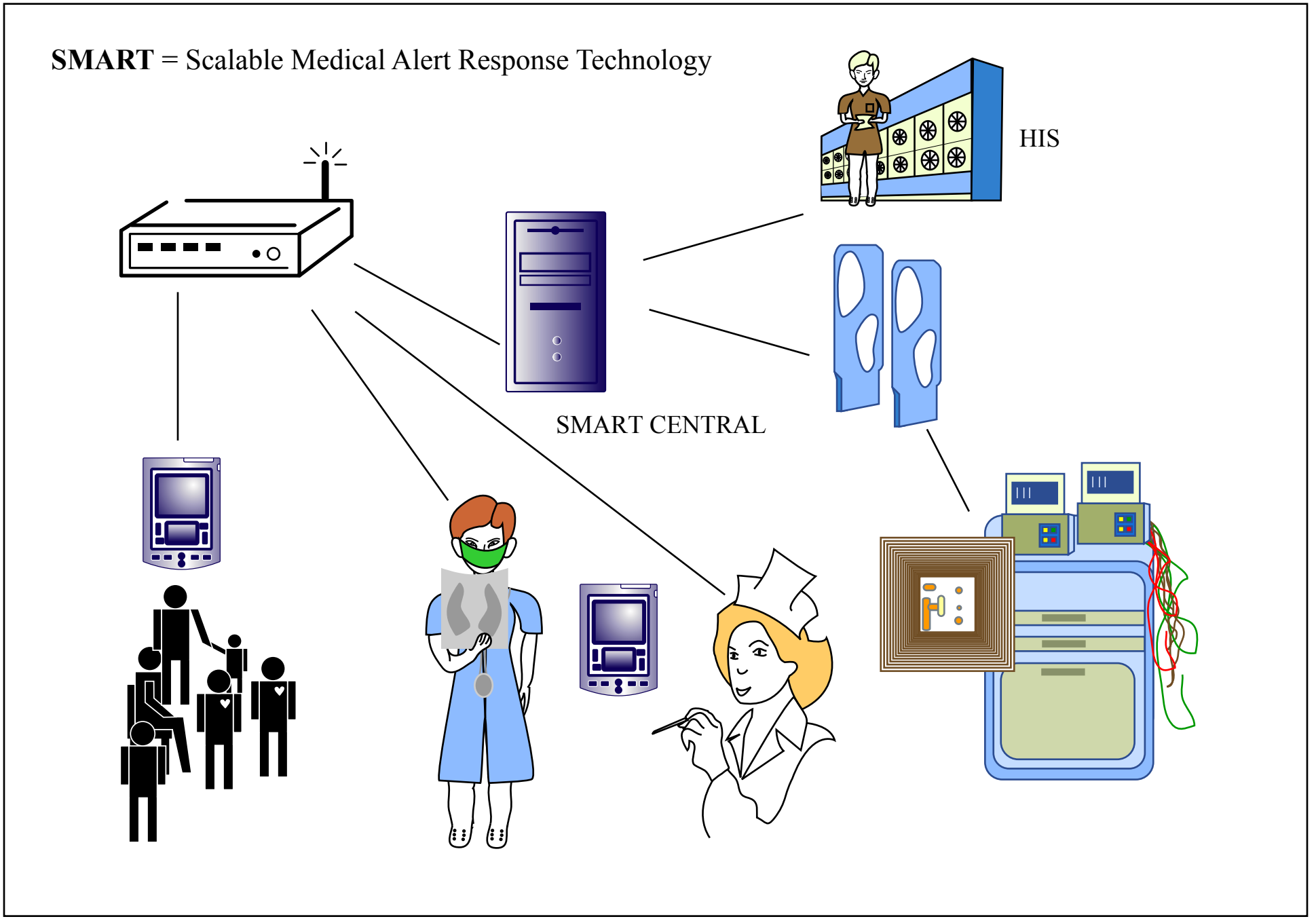
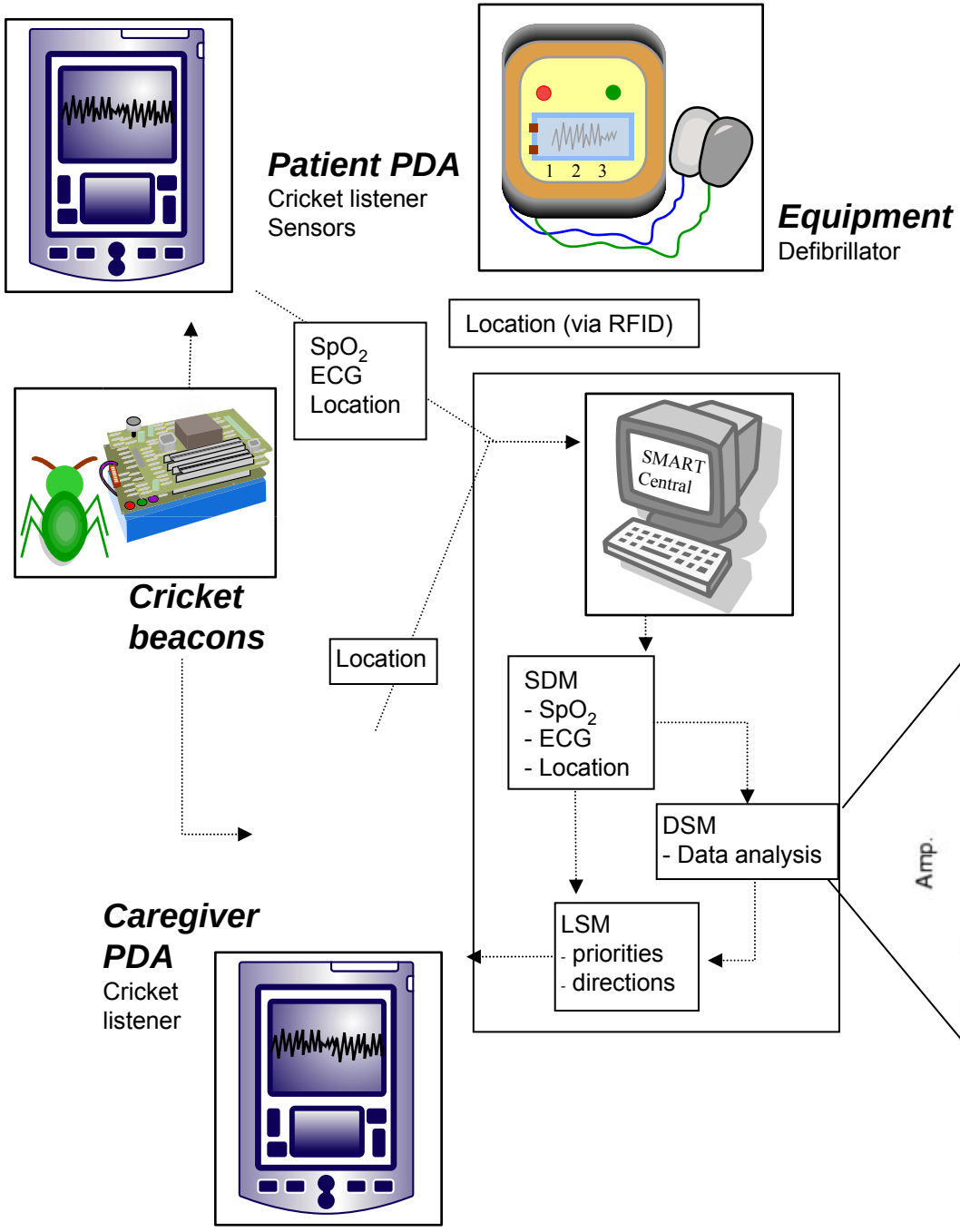
Medical decisions

Maximize value:

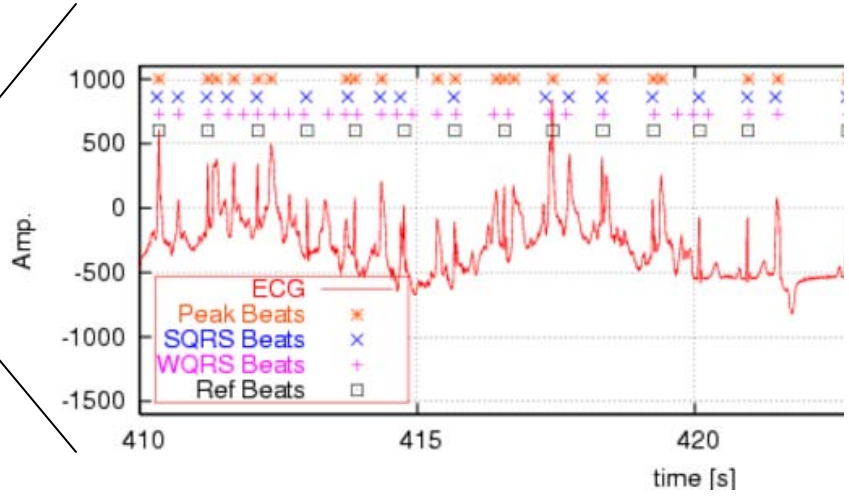
- Prolong life
- Increase quality of life
- Minimize pain
- Minimize cost
- Match available resources



Figures by MIT OCW.

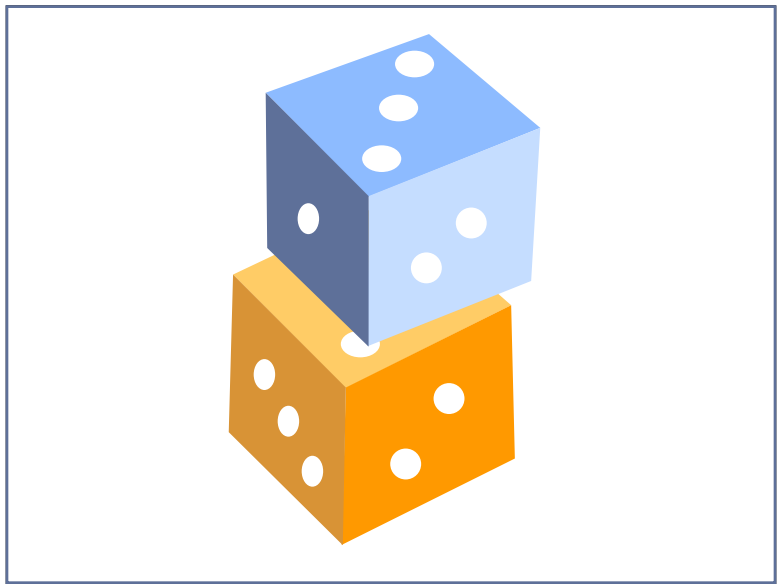


Pattern Recognition



Decision Theory

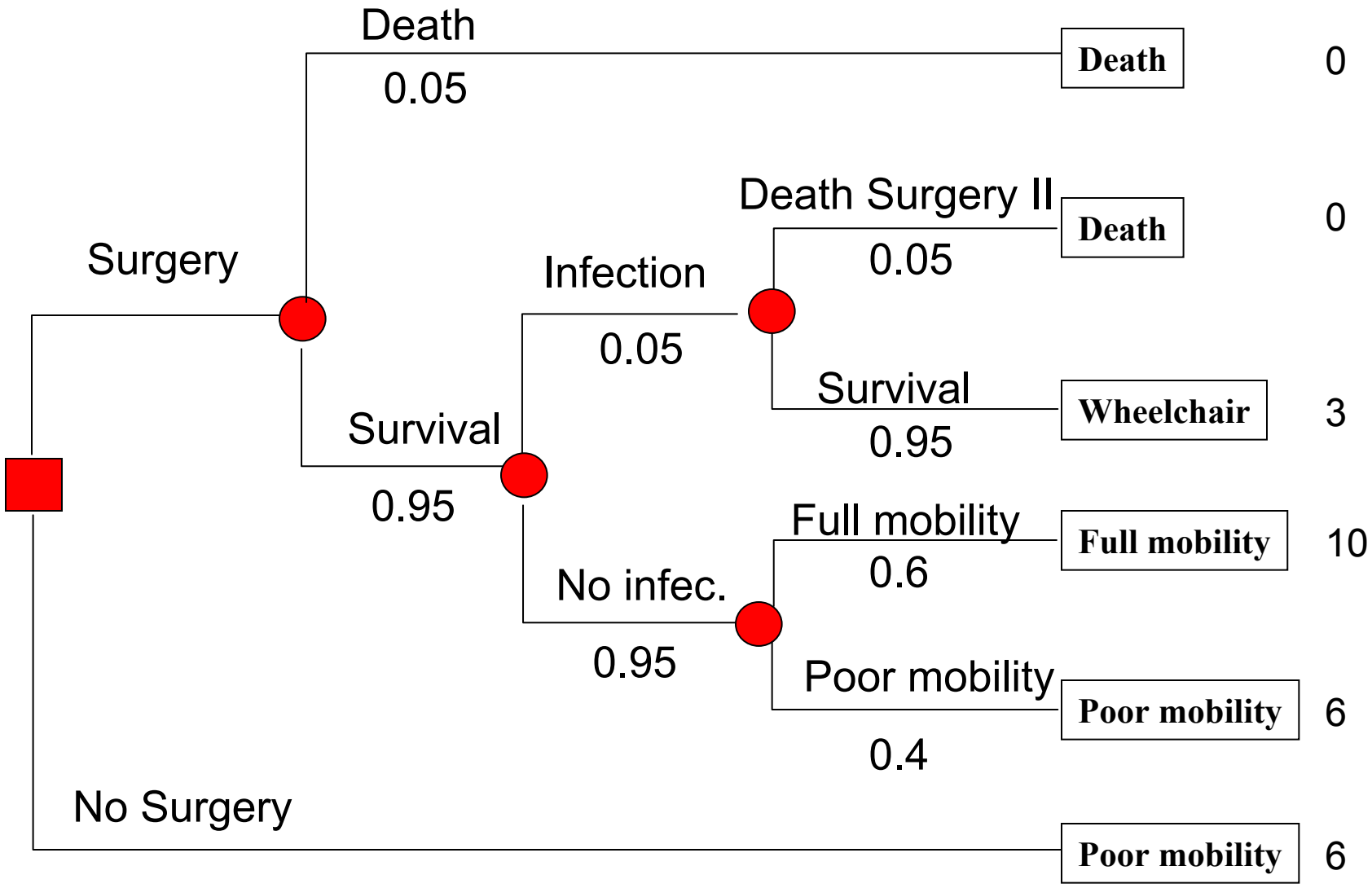
- Game theory
  - Statistics
  - Operations research
- Maximize utility
  - In many domains, this means maximize $$$



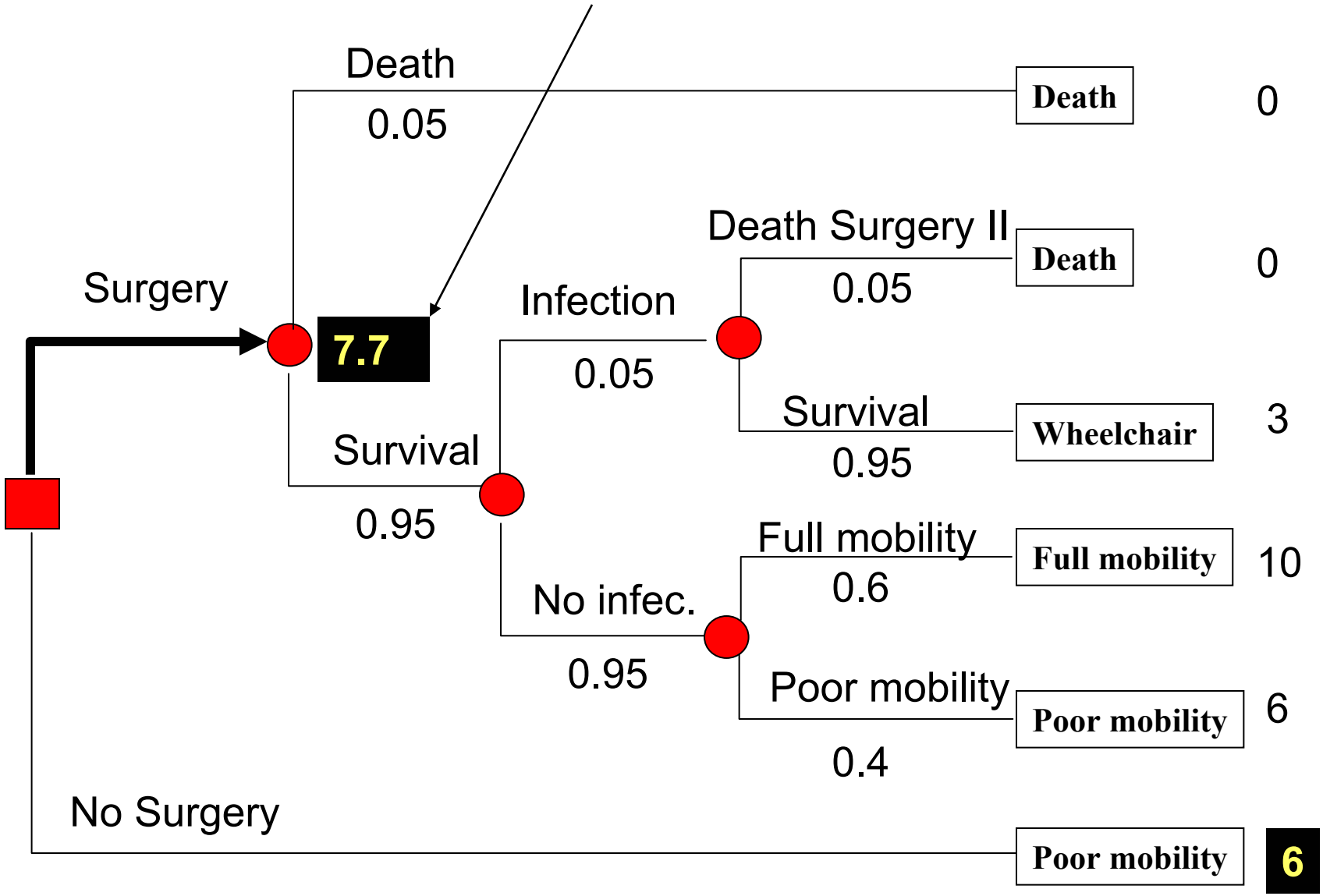
Example of a Decision Problem

- College athlete considering knee surgery
- Uncertainties:
  - success in recovering perfect mobility
  - infection in surgery (if so, needs another surgery and may loose more mobility)
  - survive surgery

Knee Surgery

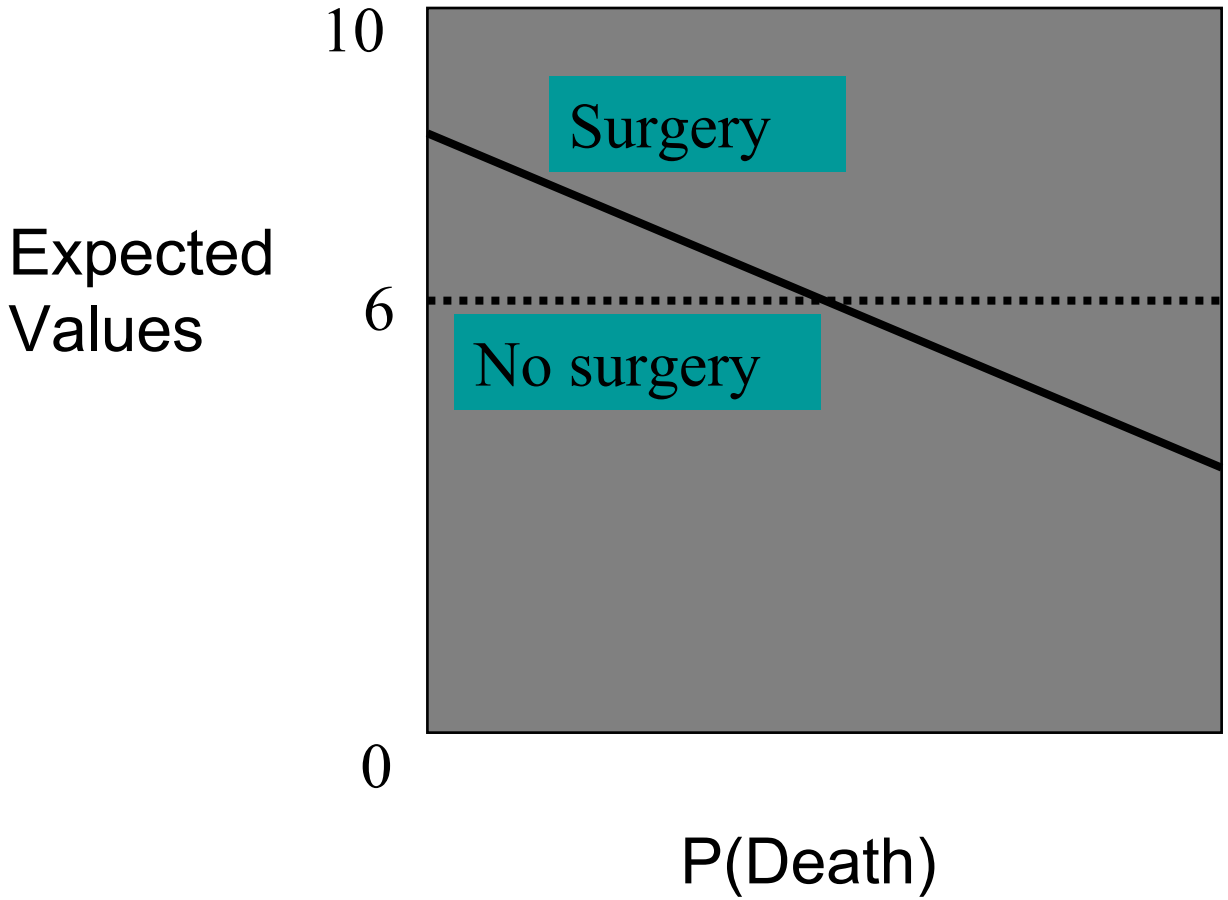


Expected Value of Surgery



Sensitivity Analysis

- Effect of probabilities in the decision



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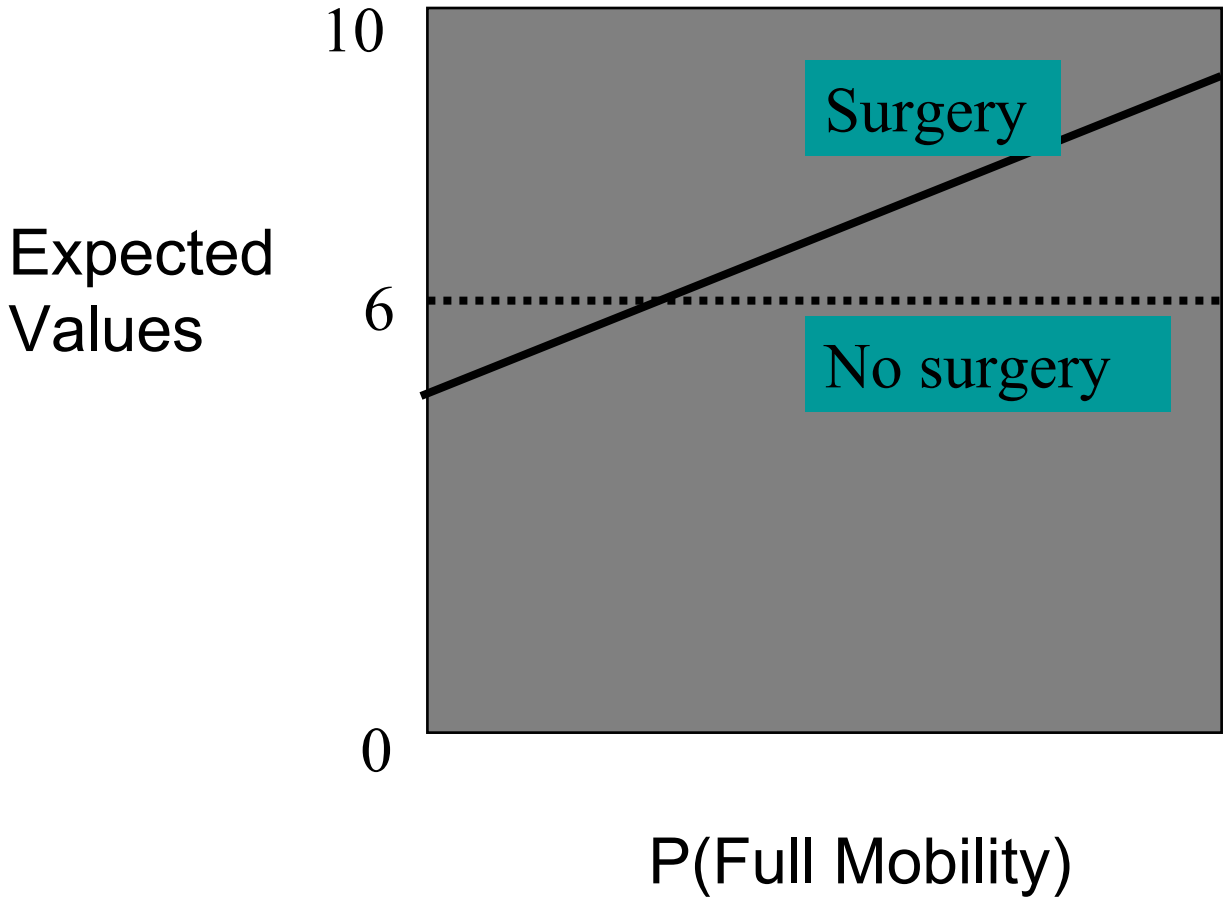
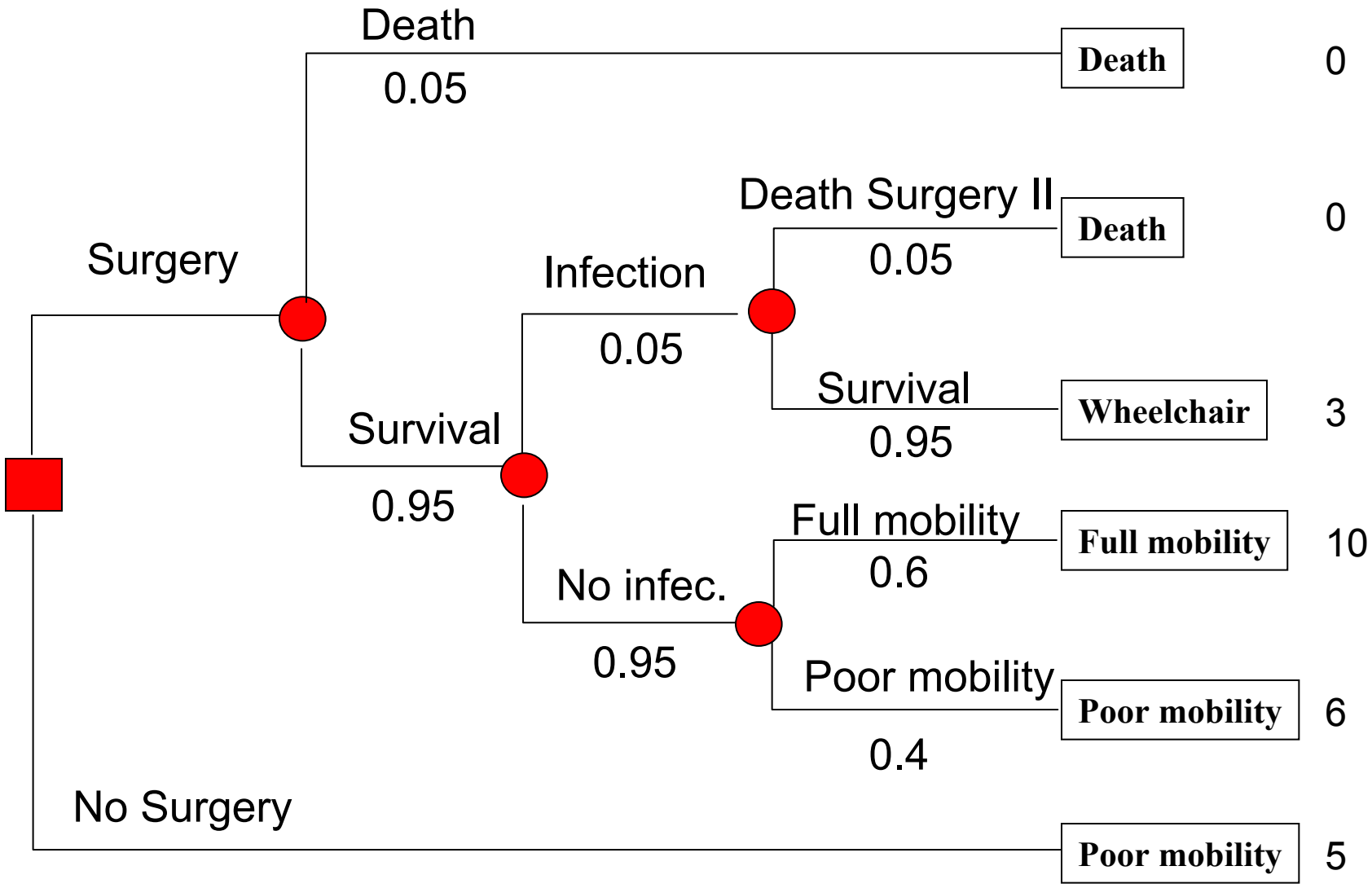
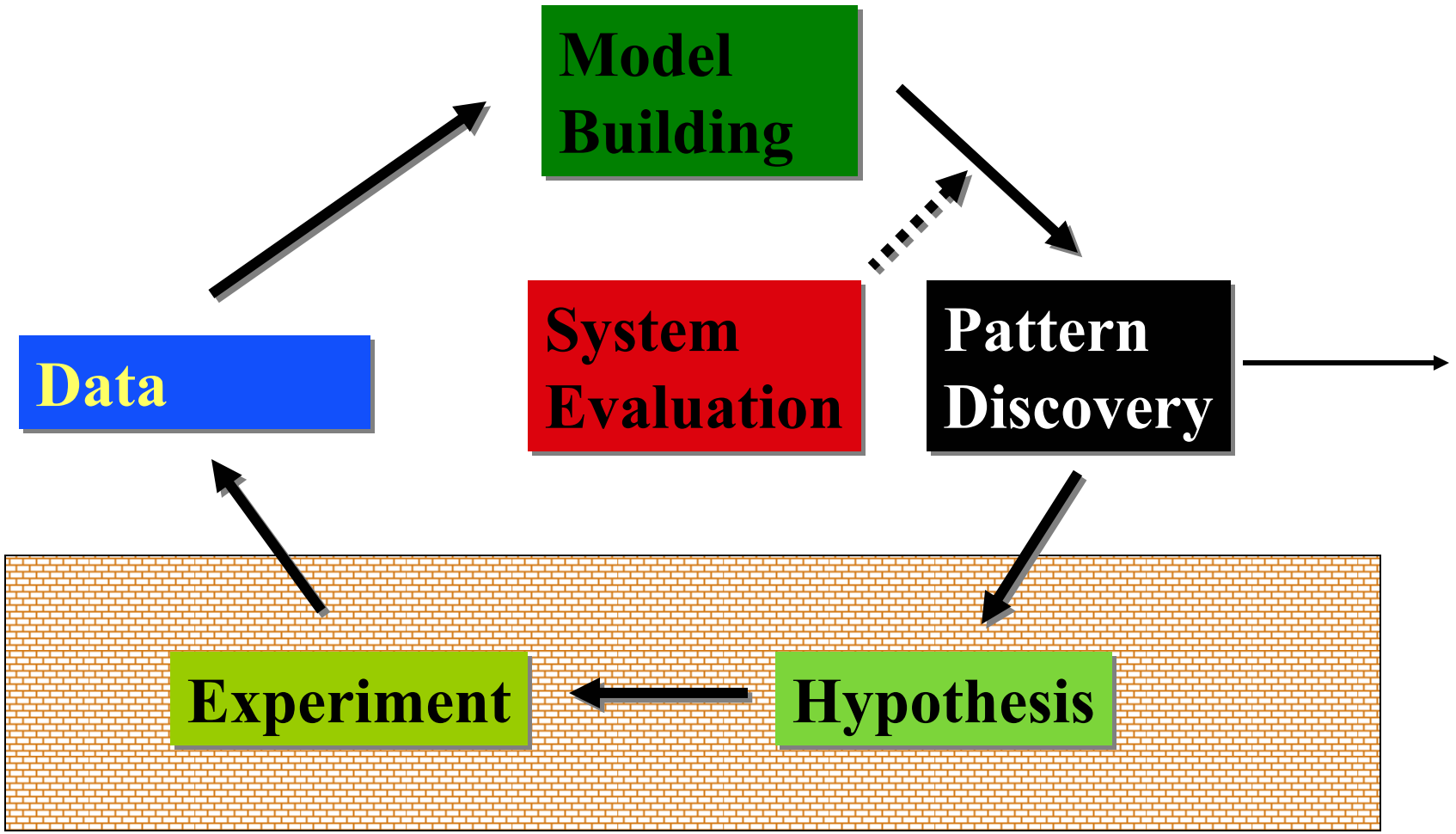


Knee Surgery



Predictive Models



Objectives

- Build models from existing data
  - Pattern recognition
- Apply model to new data to predict an unknown feature such as:
  - Diagnosis
  - Prognosis (outcome)

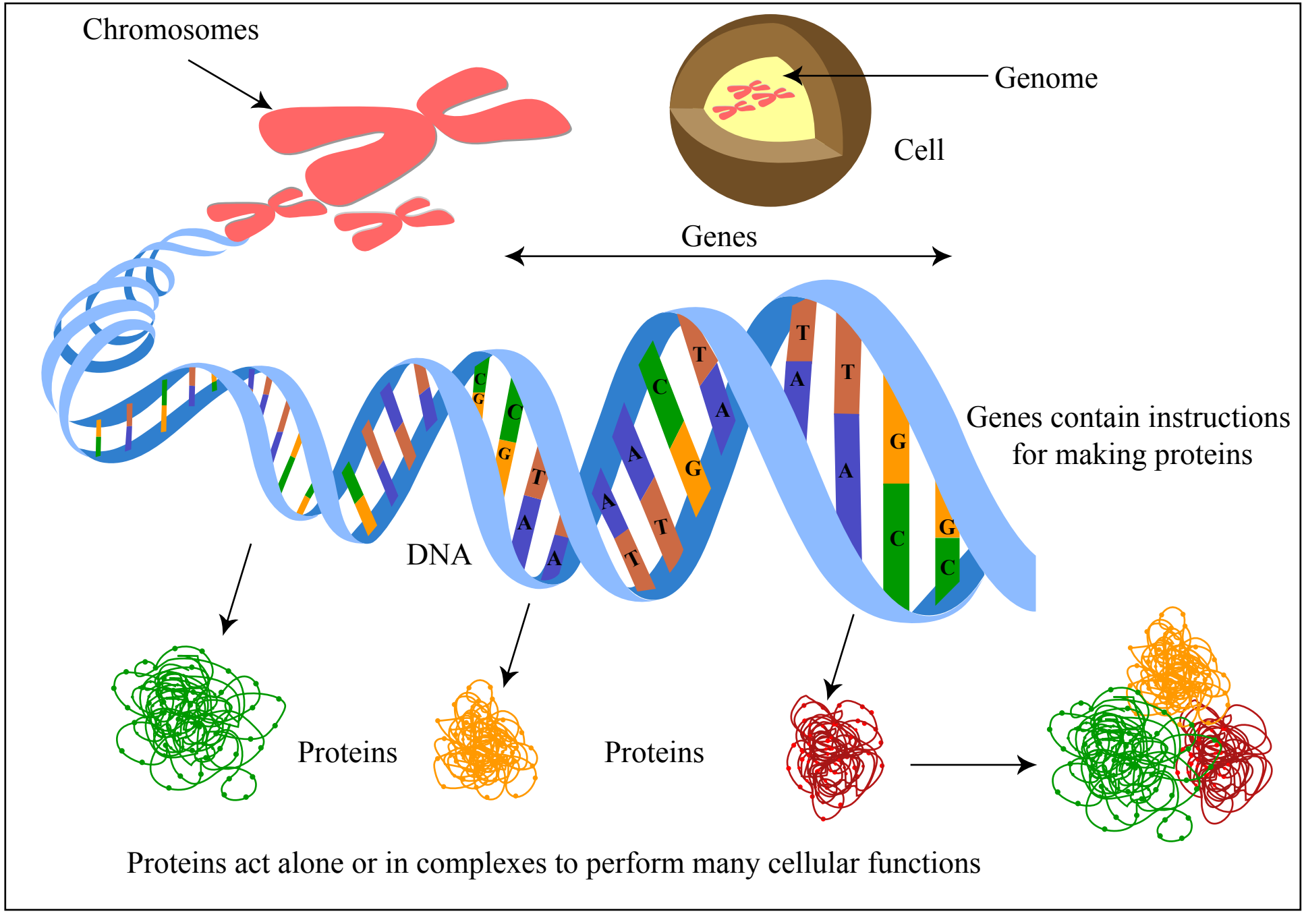


Figure by MIT OCW.

What kind of data?

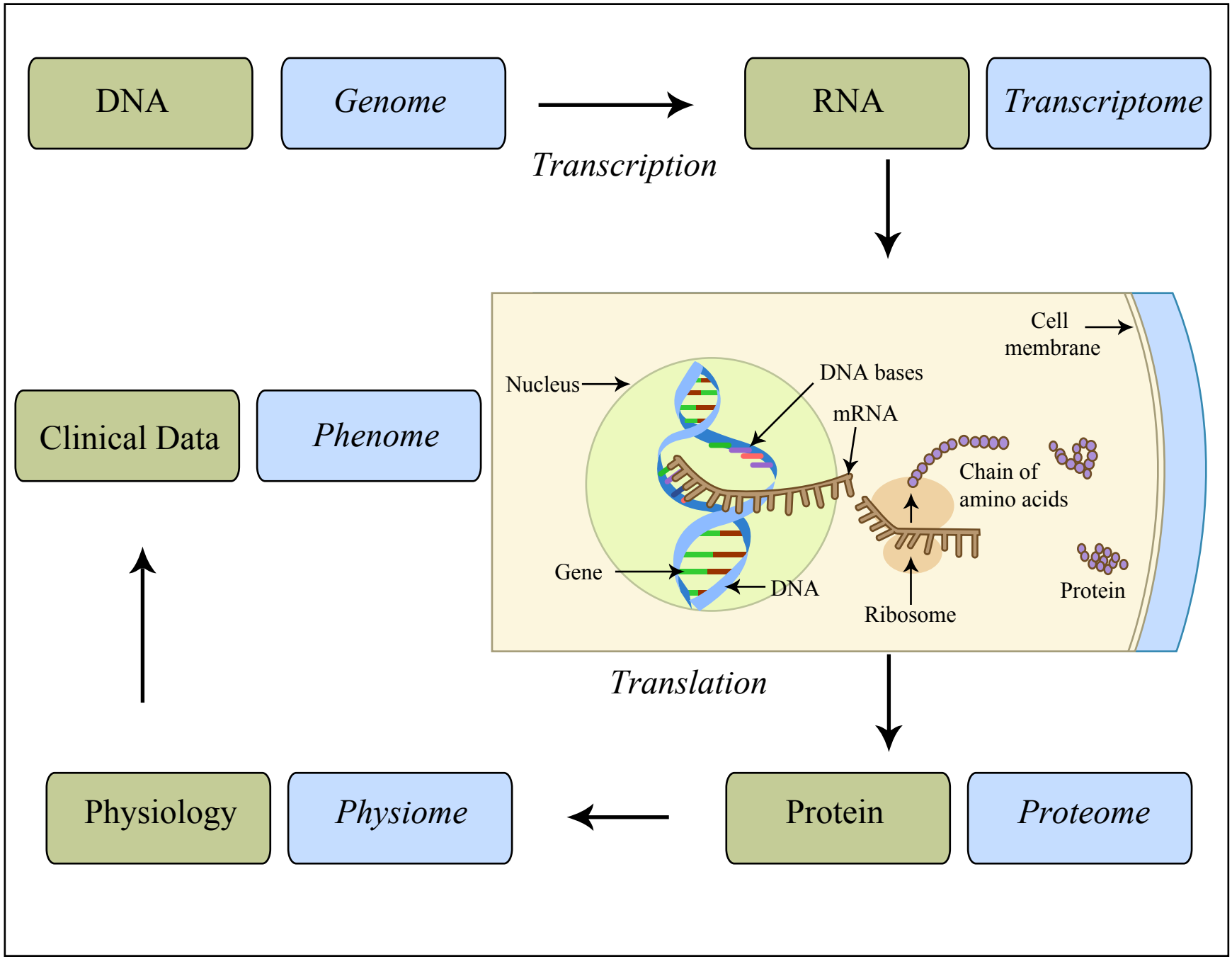
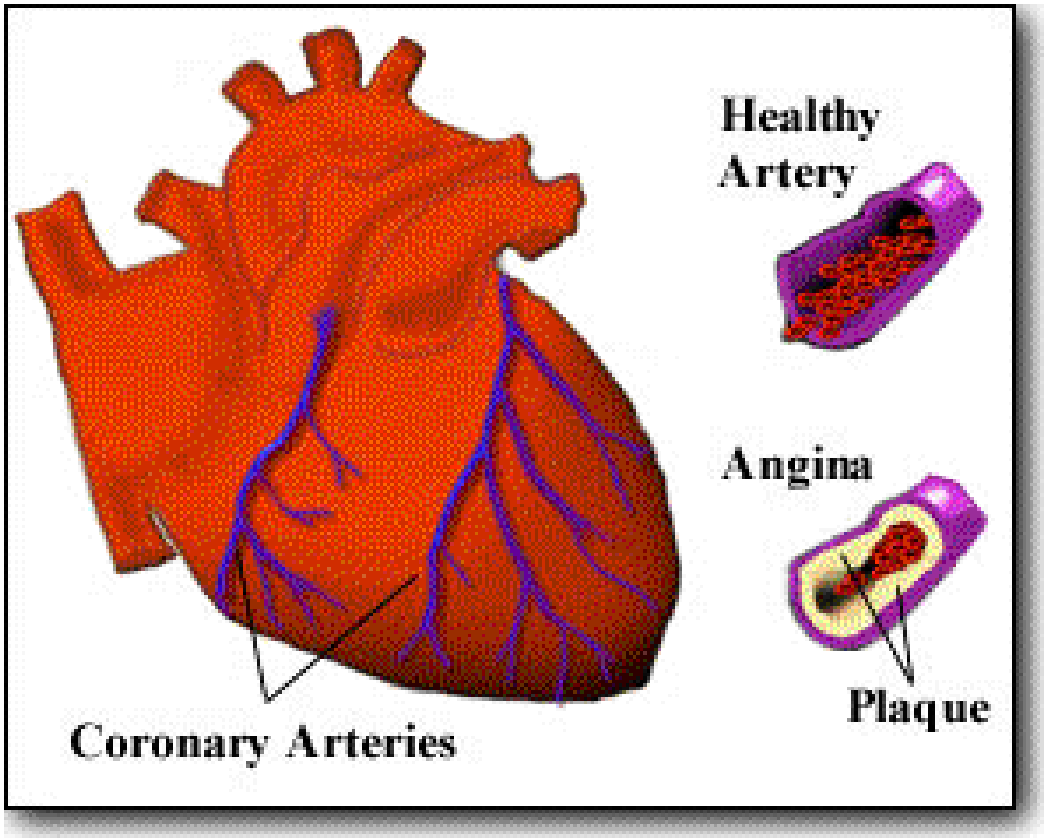
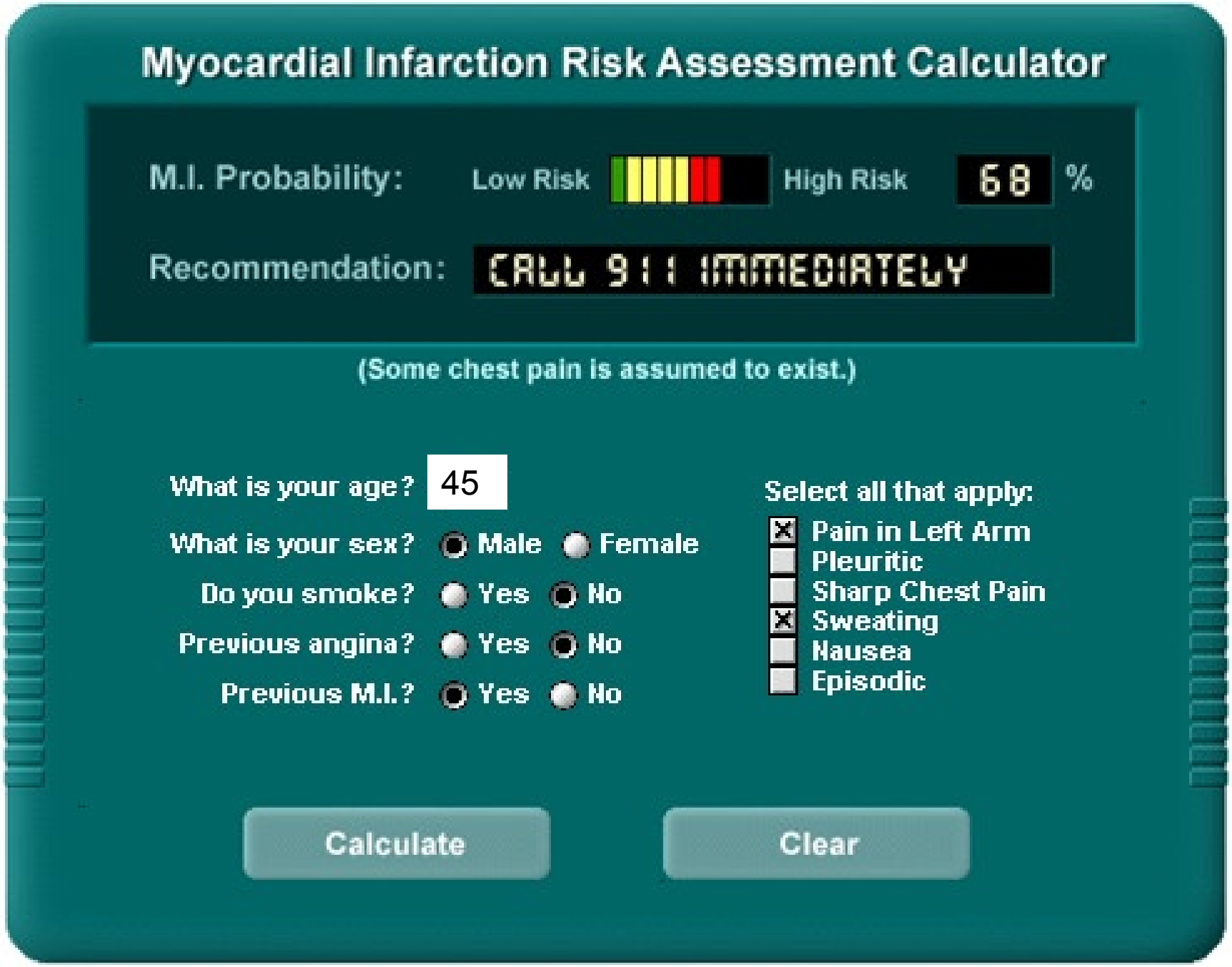


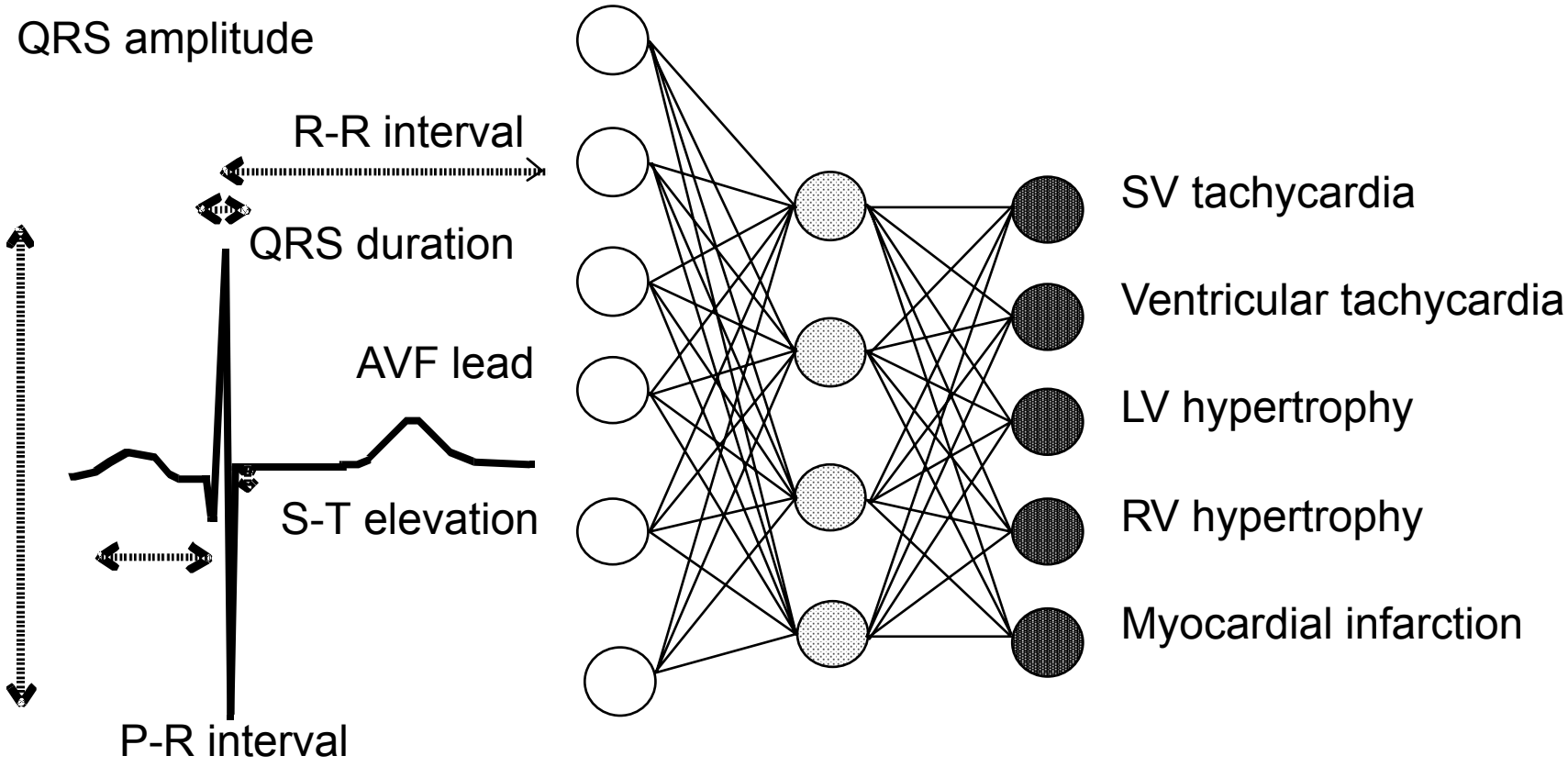
Figure by MIT OCW.

Coronary Disease



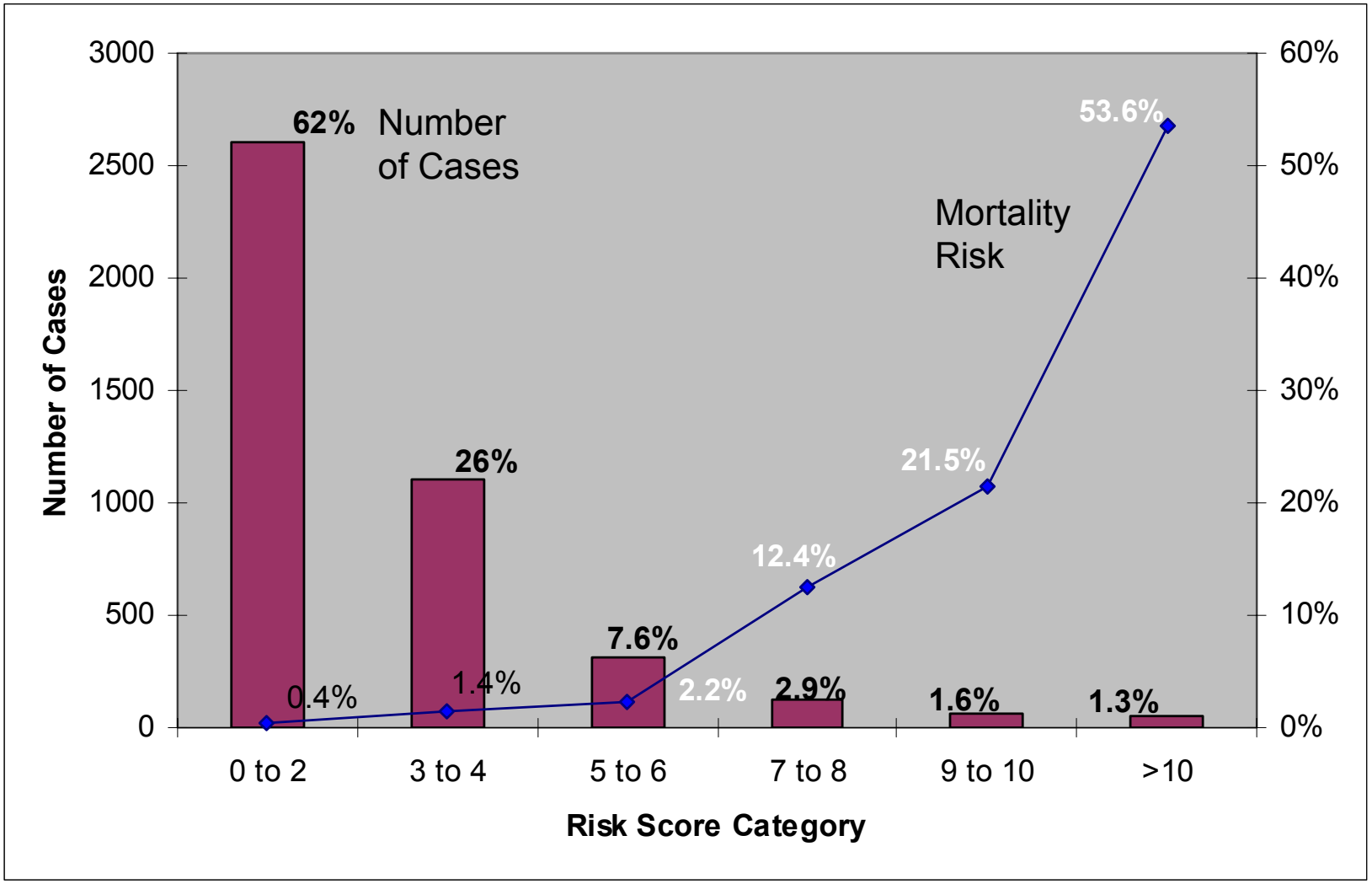

Myocardial Infarction Risk Assessment Calculator
M.I. Probability:
Low Risk
High Risk
68
%
Recommendation:
CALL 911 IMMEDIATELY
(Some chest pain is assumed to exist.)
What is your age?
45
What is your sex?
Male
Female
Do you smoke?
Yes
No
Previous angina?
Yes
No
Previous M.I.?
Yes
No
Select all that apply:
Pain in Left Arm
Pleuritic
Sharp Chest Pain
Sweating
Nausea
Episodic
Calculate
Clear

ECG Interpretation



Risk Score of Death from Angioplasty

Unadjusted Overall Mortality Rate = 2.1%



Predicting Individual Outcome in Coronary Intervention

	Logistic Regression Model		Prognostic Risk Score Model	
	Odds Ratio	p-value	beta coefficient	Risk Value
Age > 74yrs	2.51	0.02	0.921	2
B2/C Lesion	2.12	0.05	0.752	1
Acute MI	2.06	0.13	0.724	1
Class 3/4 CHF	8.41	0.00	2.129	4
Left main PCI	5.93	0.03	1.779	3
IIb/IIIa Use	0.57	0.20	-0.554	-1
Stent Use	0.53	0.12	-0.626	-1
Cardiogenic Shock	7.53	0.00	2.019	4
Unstable Angina	1.70	0.17	0.531	1
Tachycardic	2.78	0.04	1.022	2
Chronic Renal Insuf.	2.58	0.06	0.948	2

Informed consent

"Informed consent and good clinical practice require a discussion of these risks and benefits, but there is very little data on the degree to which patients comprehend the specifics of this information,"

The researchers found that, of the patients who received angioplasty 42 percent could not identify any risks, and 41 percent could not identify any benefits. For the surgery patients, 45 percent could not identify any risks and 22 percent could not identify any benefits. Furthermore, when asked to quantify the risks of the procedure, 78 percent of the angioplasty and 57 percent of the surgery patients could not.

Alexander et al, 52th ACC meeting

Overview of this Course

Individualized prediction for decision support in medical/biological problems

- ***Theory -- how it works***
- ***Practicality -- when to apply***
- ***Implementation -- how to apply***

Pre-Requisites

6034 -- Intro to AI (Machine Learning)

basic statistics, including linear regression

If needed, we will consider optional refresher recitations:

- basic linear algebra (mostly notation)
- basic statistical tests
- set theory

Course Structure

- Homeworks, individual (30%)
- Midterm (30%)
- Final Project
- Presentation and write-up – 5 pages plus references, figures, tables on the web (40%)
- No final exam

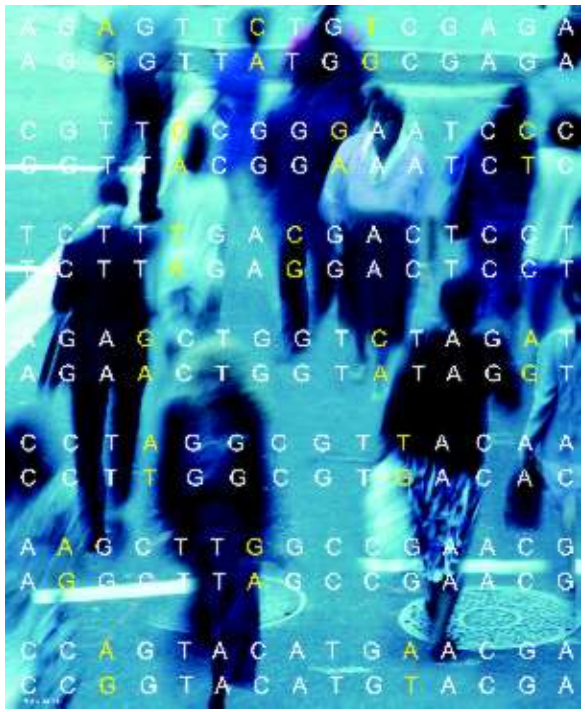
Slides available online.

Office hours by arrangement.

Password protection for posting articles: Username and password.

Intro to Decision Theory and Decision Analysis

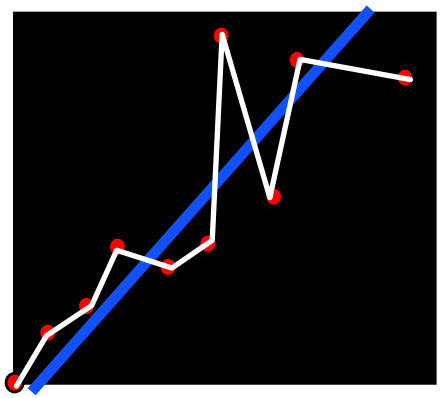
- Optimal classification performance of a model
- Cost functions
- Individualized decisions
  - Confidence in predictions
  - Decision trees



Source: DOE

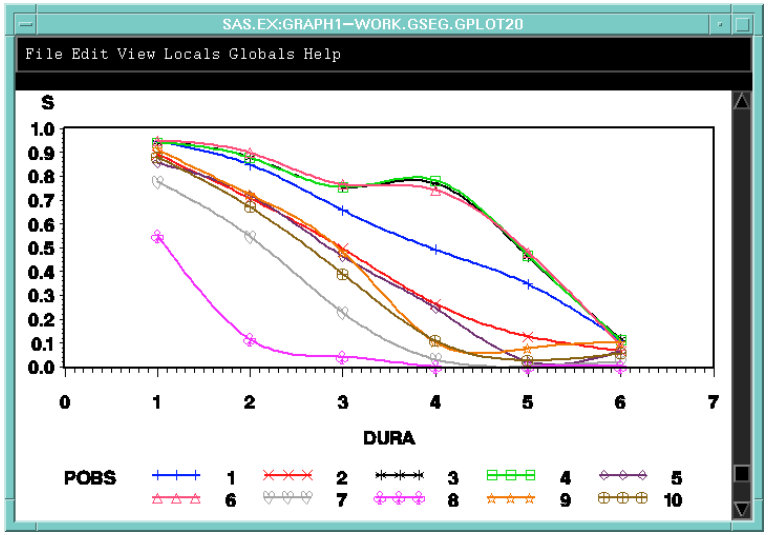
Simple Models

- Artificial Intelligence
  - Nearest neighbors
  - Association rules
  - Learning from experts
- Statistics
  - Linear regression
  - Linear discriminant analysis



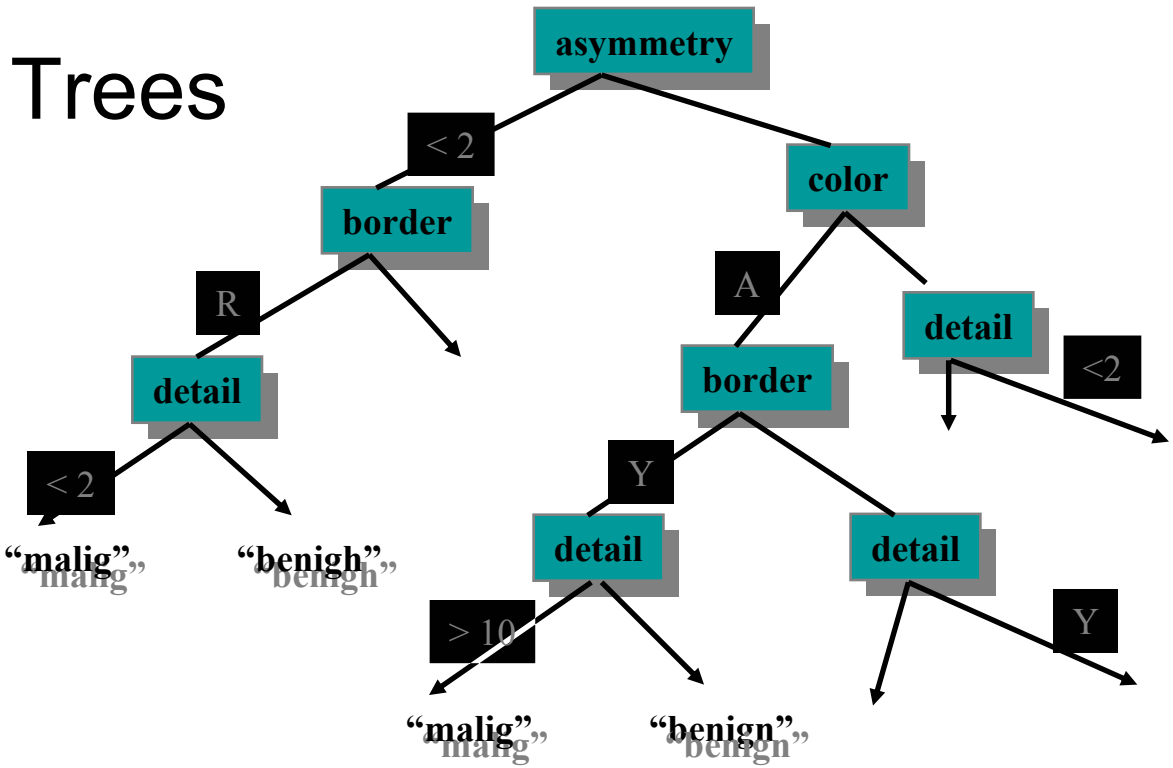
Analysis of Failure Times

- Survival analysis
- Cox model
- Assumptions required for models
- Alternatives



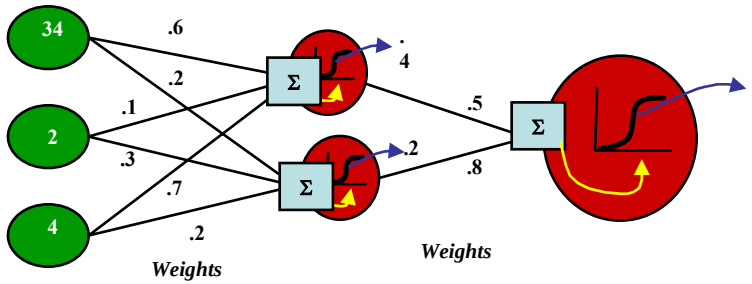
Supervised Methods I

- Logistic Regression
  - interpretation of coefficients
  - limitations
- Classification Trees
  - splitting functions
  - pruning
  - forests



Supervised Methods II

- Neural networks
  - Regularization
  - Mixture of experts
- Support Vector Machines
  - VC dimension
  - Soft margins



Supervised Methods III

- Rule-based approaches
  - Rough sets
  - Fuzzy sets

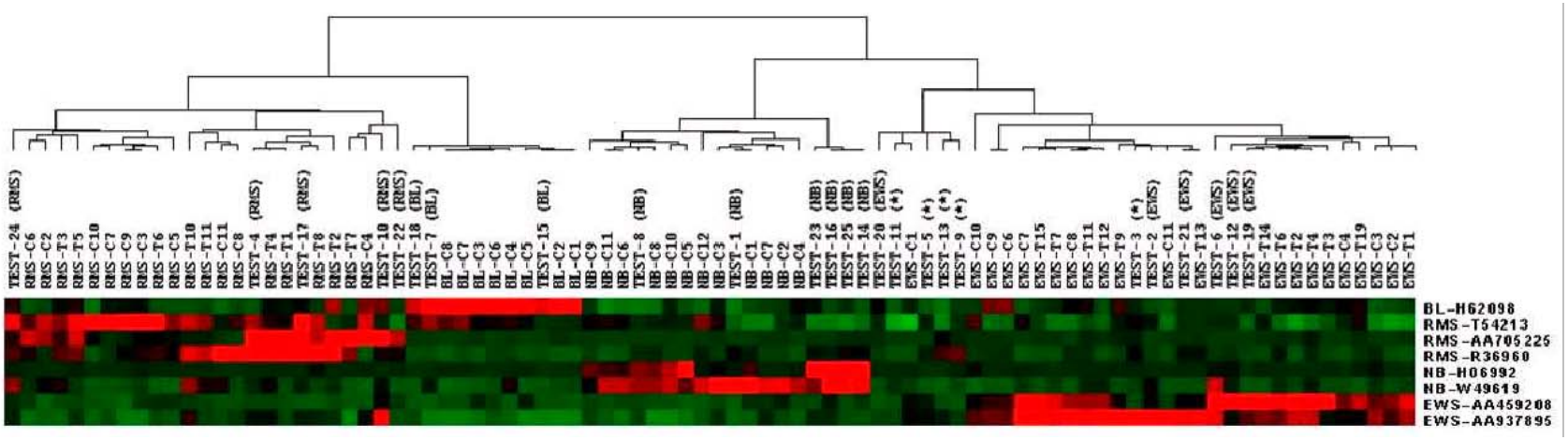
Figures removed due to copyright reasons.

Unsupervised Learning

Clustering

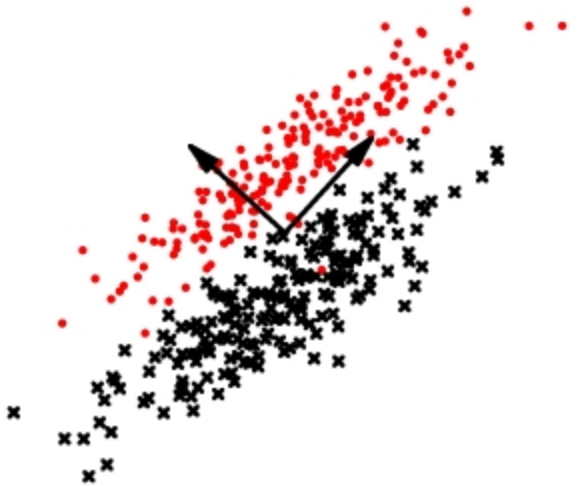
- Agglomerative/divisive
- Hierarchical/nonhierarchical

- K-means, k-medoids
- Multidimensional scaling
- Visualization



Dimensionality Reduction

- Pre-processing
  - Discretization algorithms
  - Filtering, cleaning
- Compression
  - Principal components analysis
  - Partial least squares
- Variable/Model Selection
  - Multivariate strategies
  - Interpretation

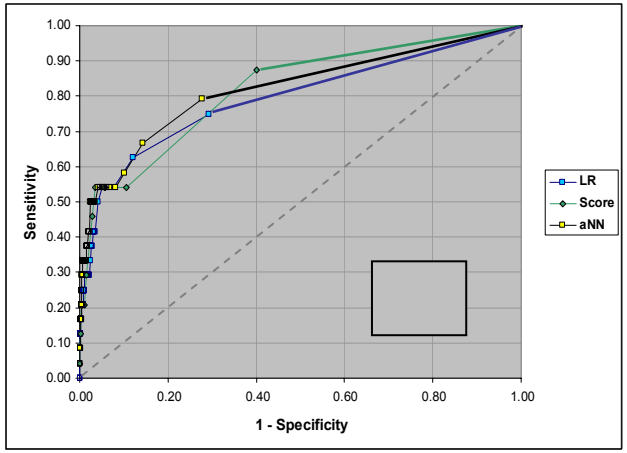


Stochastic Search

- Approximate solution strategies
  - Greedy
  - Annealing
  - Genetic algorithms
  - Ant colony optimization
  - Other evolutionary approaches

Evaluation

- How good is the prediction?
  - Calibration
  - Discrimination
  - Bias and variance
- Strategies for evaluation when number of cases is small
  - Cross-validation
  - Jackknife
  - Bootstrap



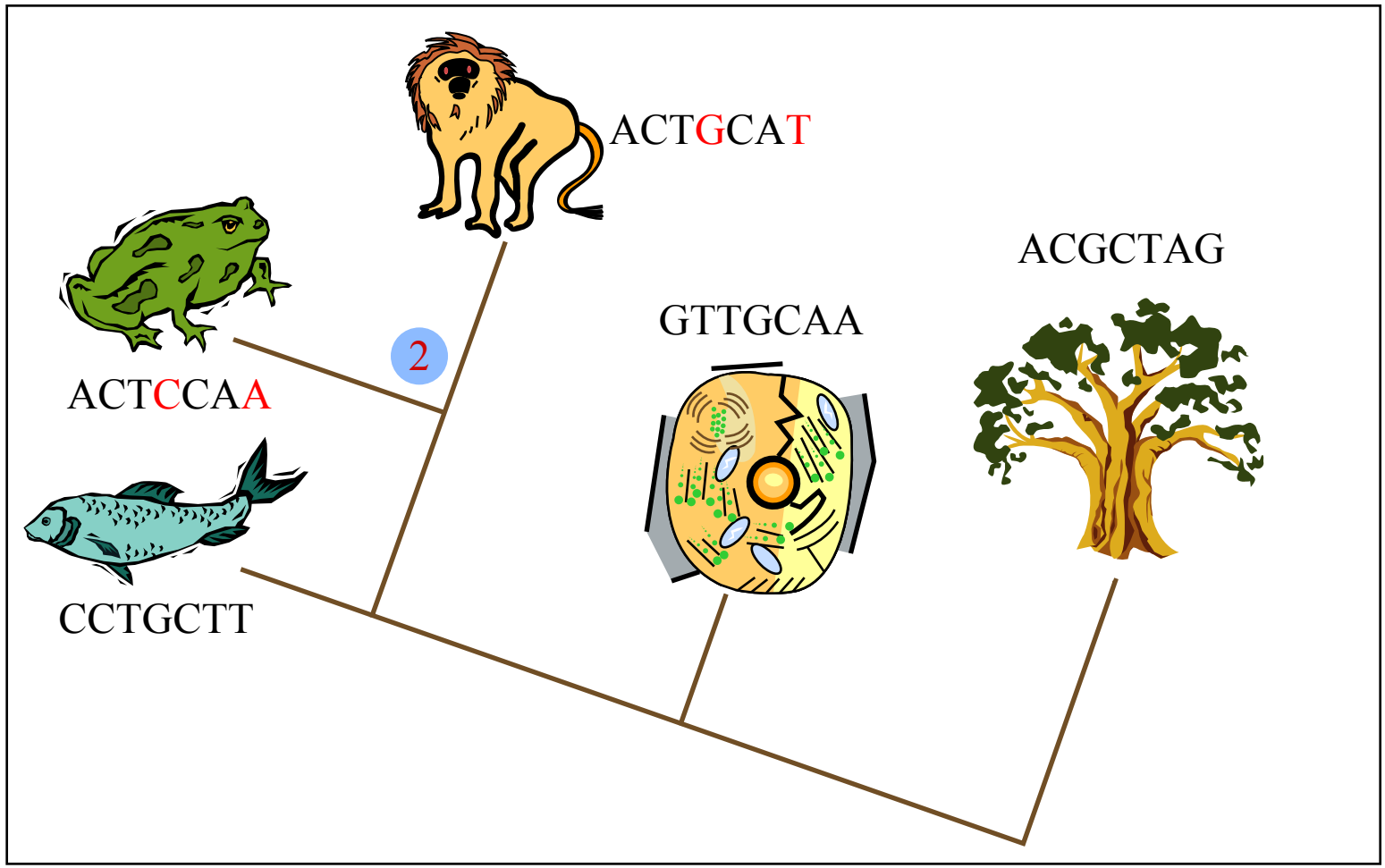
Improving Performance

Combining Models/Ensembles

- Boosting
- Bagging
- Stacking

Bioinformatics

- Phylogenetic trees
- Haplotype tagging (SNP patterns)



Figures by MIT OCW.

Sugested General Books

- Duda R, Hart P, Stork D.
  Pattern Classification
  Wiley Interscience ($103)

Duda, Richard O., Peter E. Hart, and David G. Stork. *Pattern Classification*. 2nd ed. New York, NY: Wiley, 2001. ISBN: 0471056693.

- Hastie T, Tibshirani R, Friedman J.
  The Elements of Statistical Learning
  Springer ($67)

Hastie, Trevor, Robert Tibshirani, and Jerome Friedman. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. New York, NY: Springer, 2001. ISBN: 0387952845.

Decision Analysis Module

- Chernoff and Moses

  Elementary Decision Theory. Dover ($12)

Chernoff, Herman and Lincoln E. Moses. *Elementary Decision Theory*. New York, NY: Dover Publications, 1986, c1959. ISBN: 0486652181.

- Hunink et al

  Decision Making in Health and Medicine: Integrating Evidence and Values. ($65)

Hunink, M.G. Myriam and et. al. *Decision Making in Health and Medicine: Integrating Evidence and Values*. Cambridge, UK: Cambridge University Press, 2001. ISBN: 0521770297.