Welcome to STAT 547C, *Topics in Probability*

Instructor: Alexandre Bouchard
Fall 2014

Plan for today:

- Logistics.
- Why you should care about probability.
- First definitions.

Logistics

Contact & other logistic issues

- Web site: always check first! http://www.stat.ubc.ca/~bouchard/courses/stat547c-fa2013-14/index.html
    - Textbook and other readings
    - Hints and updates for assignments
- Office Hours: TBA, fill Doodle
- Contact:
  1. Piazza
  2. bouchard@stat.ubc.ca

Teaching assistant

- Seong-Hwan Jun
- Contact email: s2jun.uw@gmail.com
- Office hours: TBA, fill Doodle

Homeworks (40%)

- Four main assignments (25%)
- ‘Exercises/Participation’ (15%): doing the short exercises, interacting in class, coming at office hours

Exams

- In class midterm (20%)
- Finals:
  - Last day of class: 'Essay: what I have learned in the course' (10%)
  - Take home final/project (30%)

Why this topic is important

- Fundamental tool in statistics and computer science
    - Probability is arguably the best tool to model reality
    - Computational power of randomness
- New foundations of Science (‘Dawning of the age of stochasticity’, D. Mumford)
- A very good investment for researchers

Killer apps

- Probabilistic machine learning: Siri, autonomous cars, machine translation
- Physics: Determining the shape and ultimate fate of the Universe ('random fields'), quantum, stat. mech.
- Biology: Tree of life, DNA testing, folding@home
- Engineering: Compression for deep space communication ('LDPC'), design of polymers, Google
- But also: atomic bomb ('MC approximations'), financial crisis

Core topics

- Applications of probability in statistics
- Formal treatment of the probability spaces and expectation and their properties (the language of probability)
- The ‘surprising challenges of composing r.v.s’
    - Asymptotics
    - Generating functions
- Conditioning
- Going beyond independence: Markov chains

Additional potential topics

- Poisson processes
- Martingales
- Continuous time Markov chains

Some highlights and examples of applications

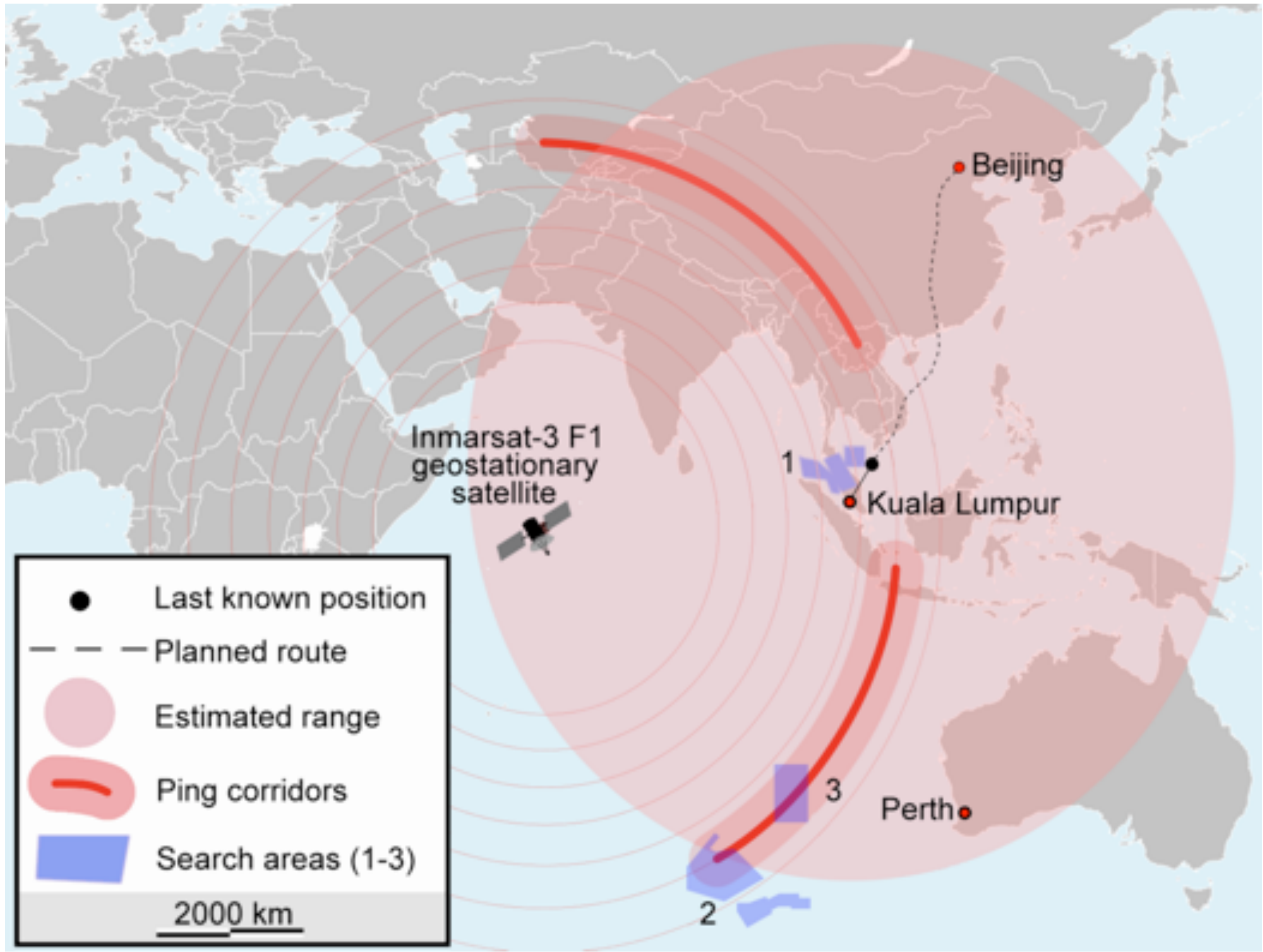
The Search for Malaysia Airlines Flight 370

Goal: finding the location of the crash

Question: how to prioritize search

How to reconcile several sources of partial info:

- Last known position
- Fuel range
- Last satellite ping



http://tinyurl.com/lhzrufa

Bayesian Search

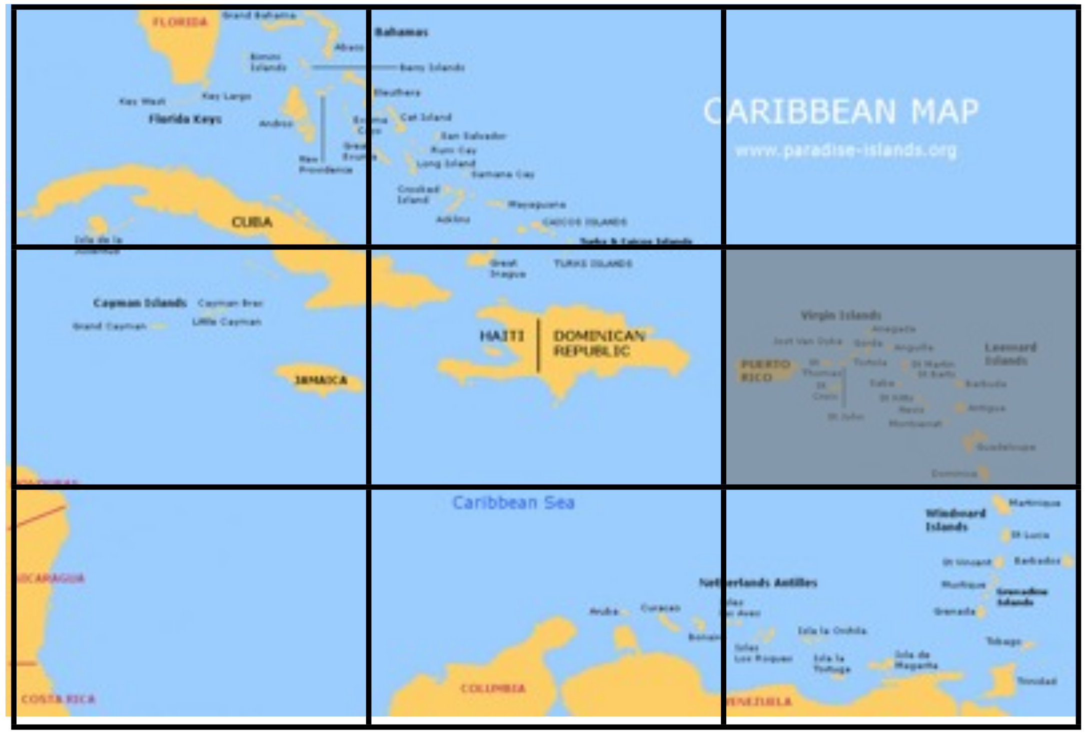
1966: Palomares B-52 crash

Photo # NH 97221-KN Stern section of sunken USS Scorpion, 1986

1968: USS Scorpion disappearance

Conditioning

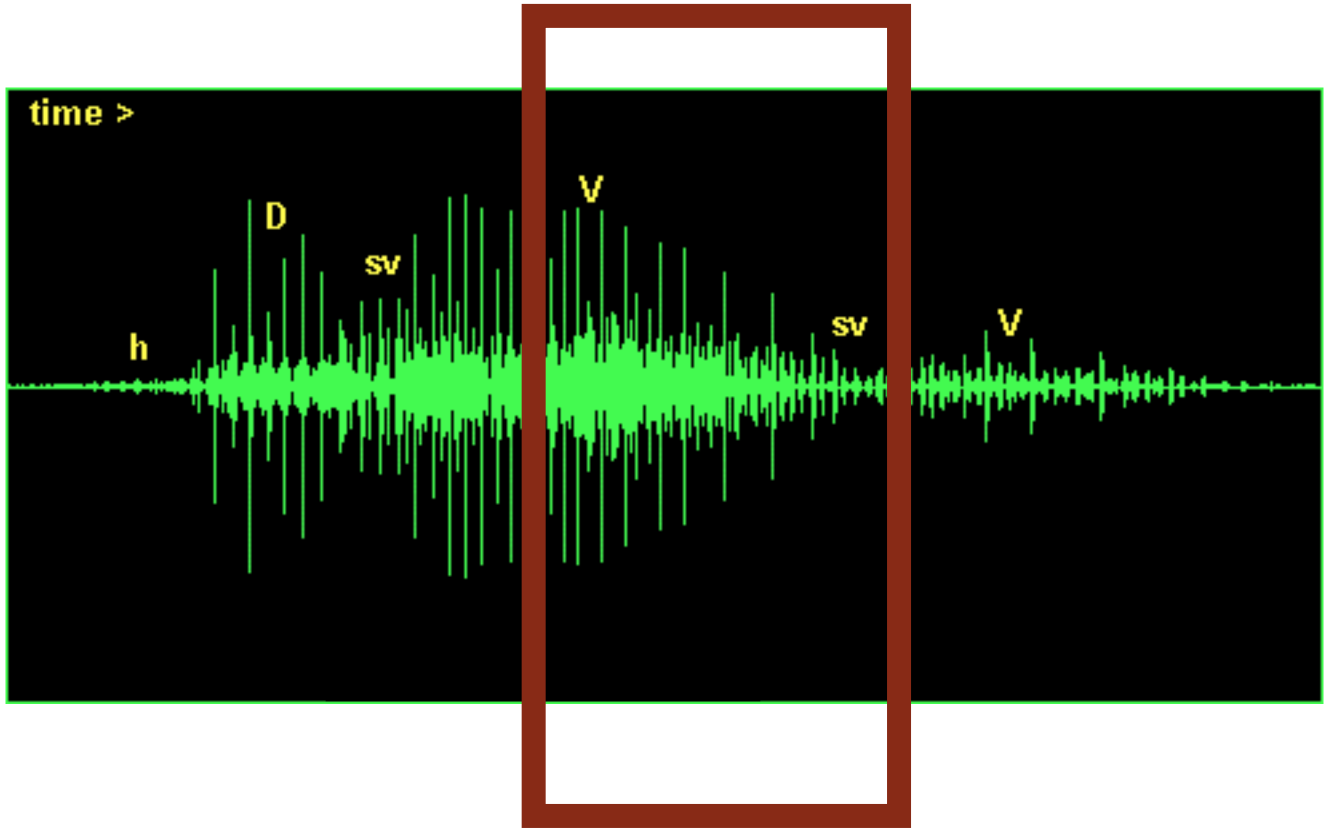
- Say you search in the square of highest success probability
  - You find nothing
  - What should you do next?
    - Note: even if the submarine is there, you might have missed it!
- Probability as a calculus of belief and uncertainty



Bayes theorem (Thomas Bayes), 1763

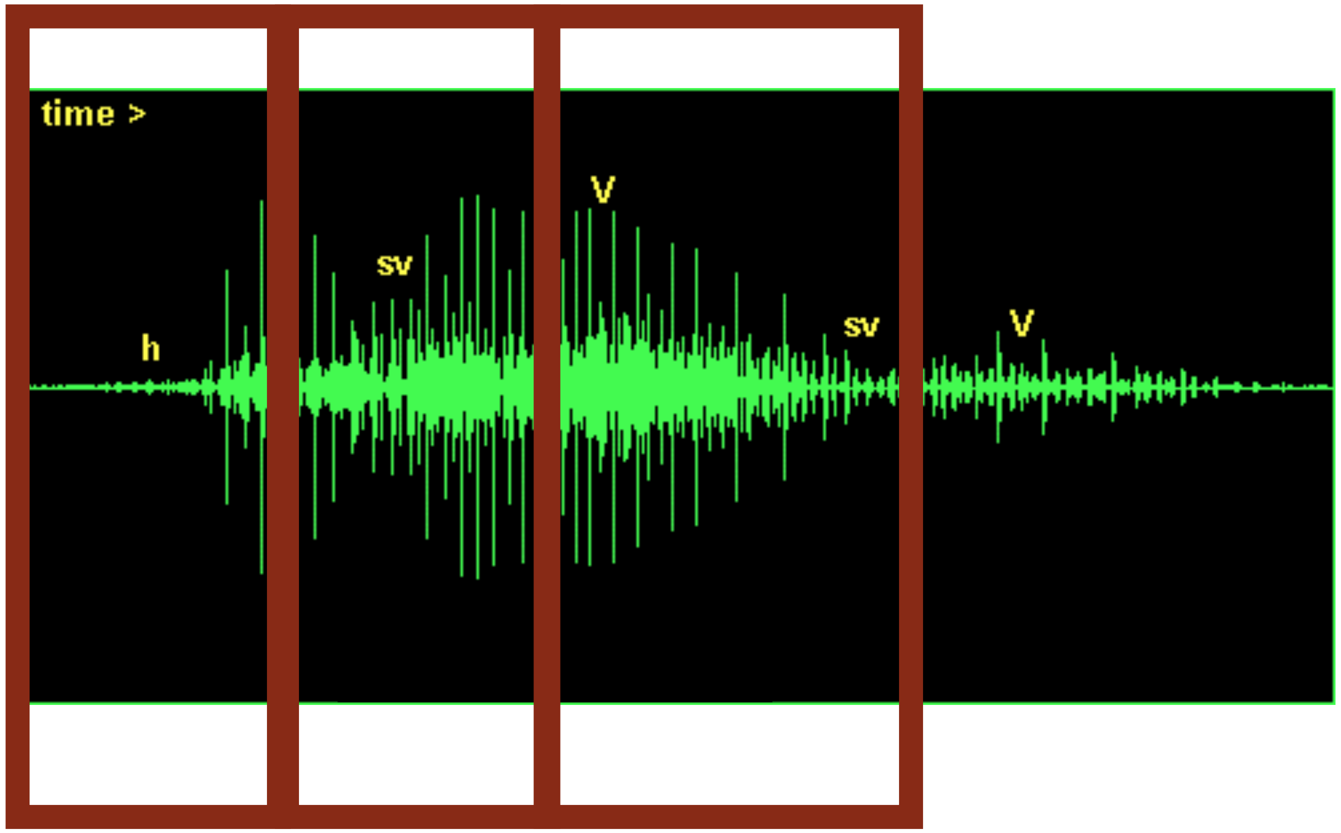
http://tinyurl.com/pcznhml

AI and machine learning: Speech recognition



???

AI and machine learning: Speech recognition



How are ???

Rational behavior and uncertainty

General question: how to **act** when

- we are facing uncertainty
- errors have different costs

Examples:

- fraud detection
- medical diagnosis
- spam classifiers

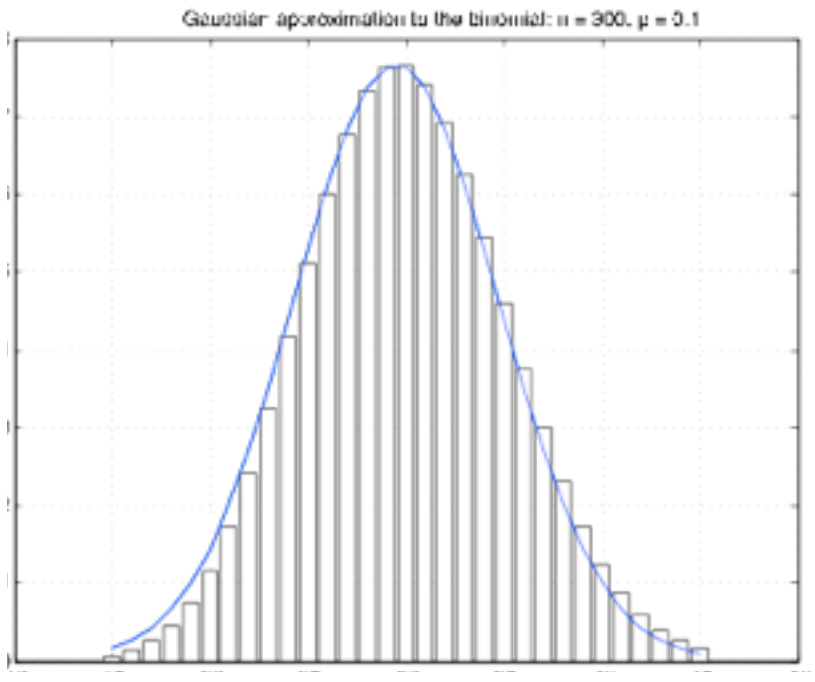
Key tool: *expected value*

Surprising challenge

- Sums of random variables
  - Omnipresent in statistics
  - Taking the sum of variables is easy, so taking the sum of *random* variables should also be easy, right?
  - Not quite... consider for example the problem of computing the probability that the sum of 1000 coins is greater that 500.
    - Would have been hard in the pre-computer era
    - Generalized versions of this problem still hard with computer

Limiting theory to the rescue

- Another surprise: sums of random variables can be approximated by something simple when large number of terms involved
- No matter what each X is!!! (almost)
- Also explains why we spend disproportionate amount of time on some specific types of random variables (normal, Poisson, ...)



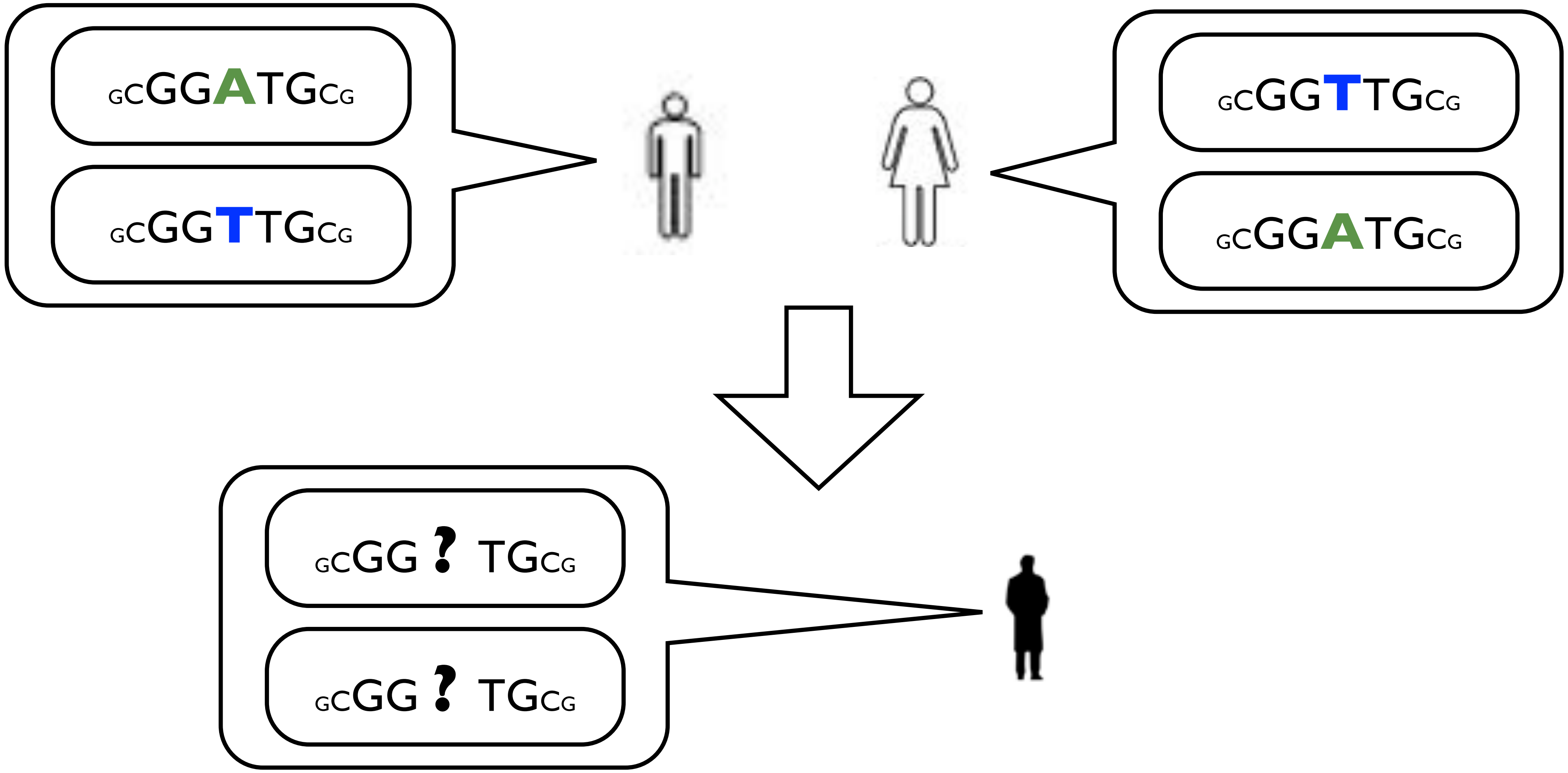
300 coins

Beyond independence

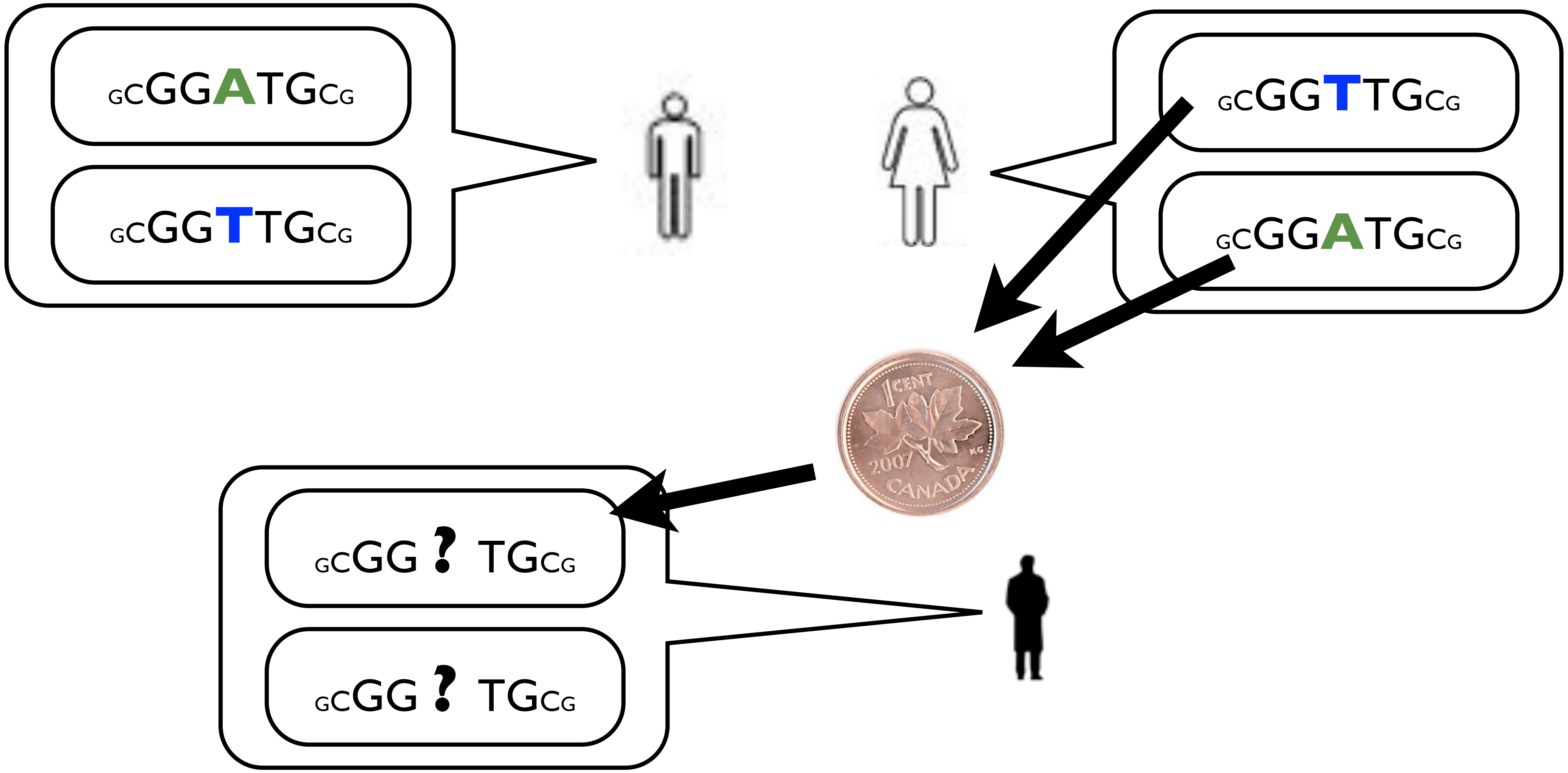
- Markov chain: independence of past and future given present
- Martingale: gambling model

Genetics: inheritable diseases

Randomness in inheritance :

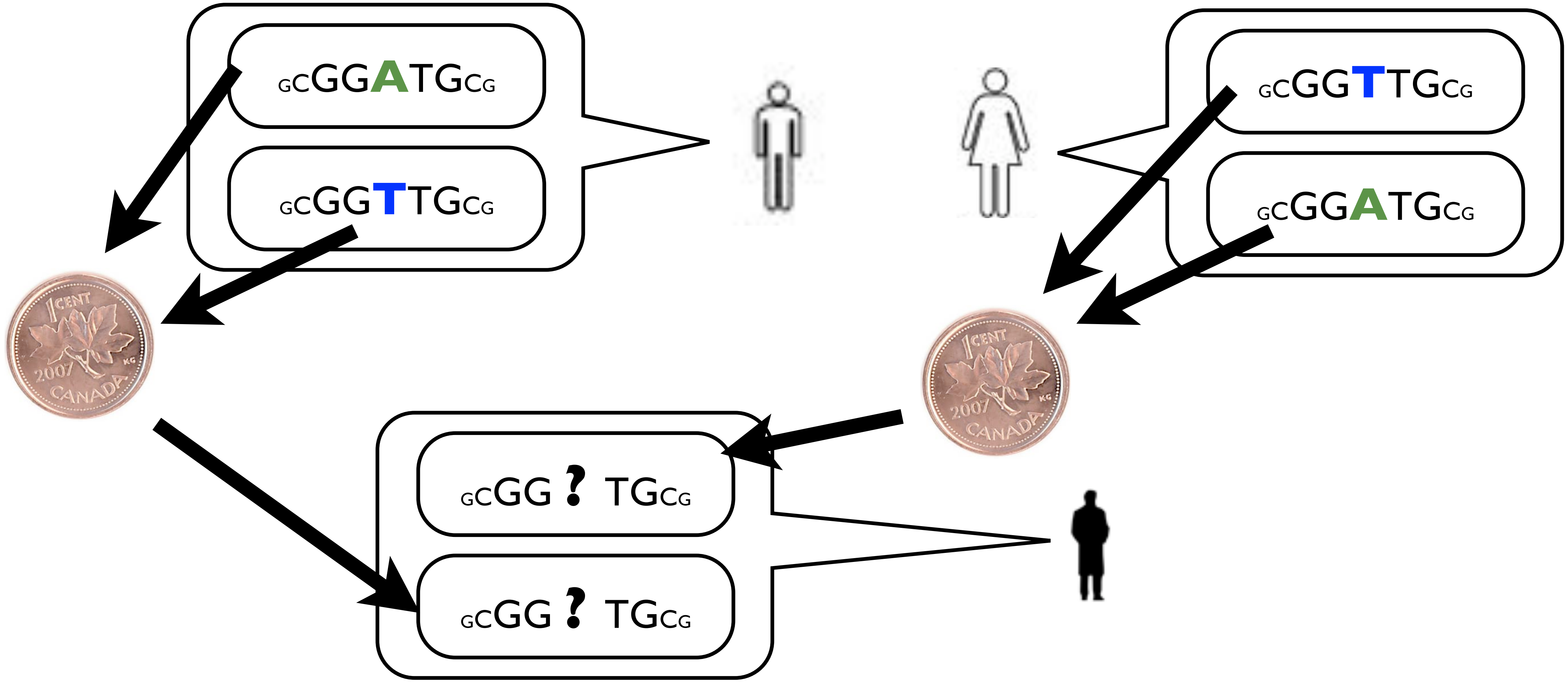


Genotype inheritance



1) Flip a fair coin to decide if you inherit mom's T or A

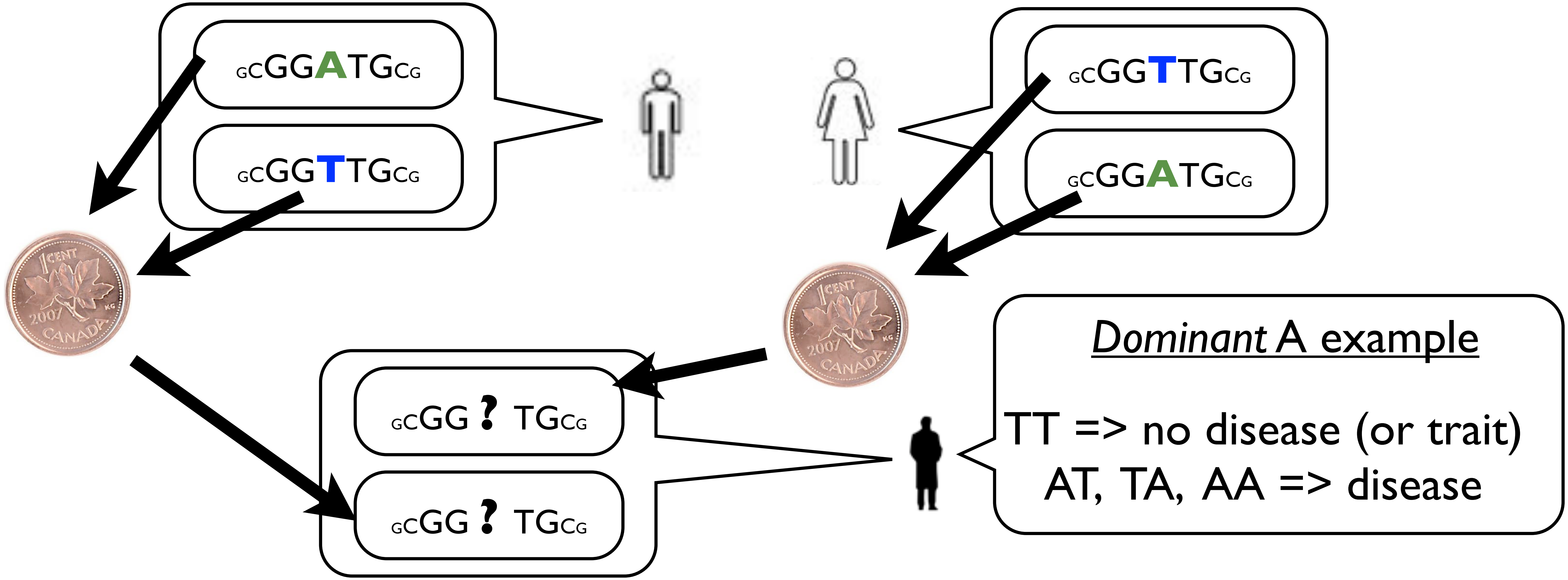
Genotype inheritance



1) Flip a fair coin to decide if you inherit mom's T or A

2) Flip another fair coin to decide if you inherit dad's T or A

Genotype inheritance



Dominant A example

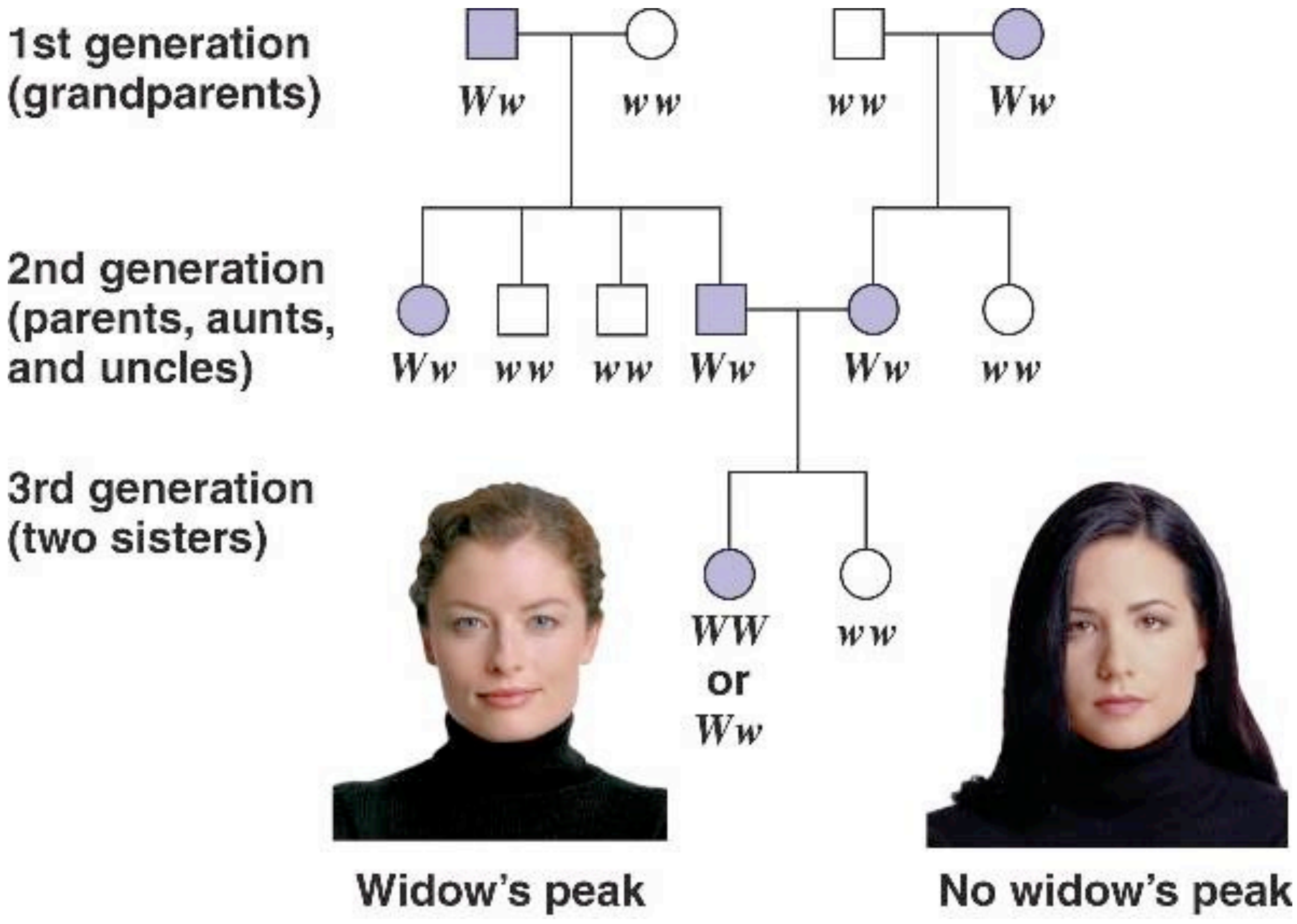
TT => no disease (or trait)
AT, TA, AA => disease

1) Flip a fair coin to decide if you inherit mom's T or A

2) Flip another fair coin to decide if you inherit dad's T or A

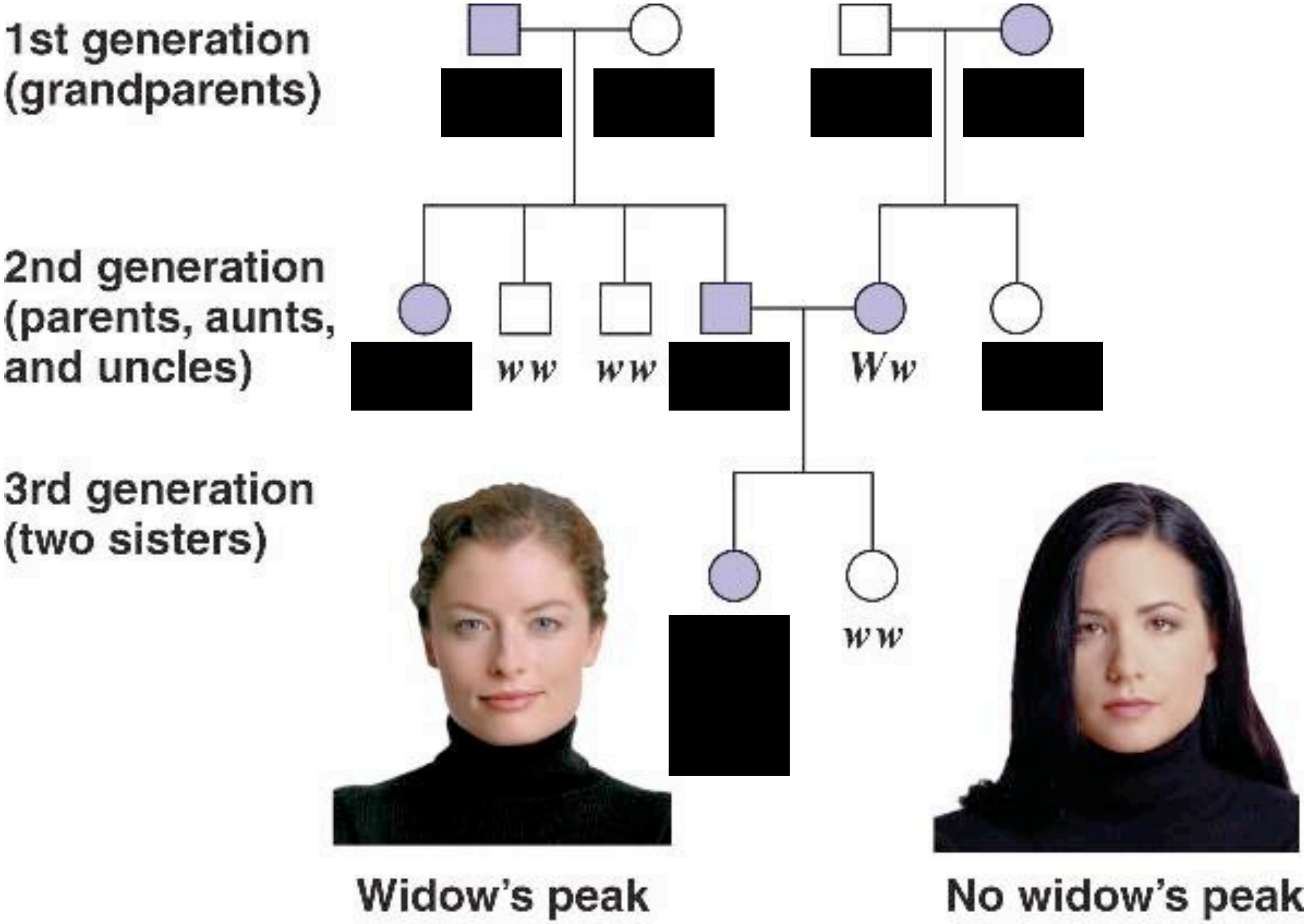
Larger family trees

- A larger example where *W* is dominant over *w*
- Goals:
  - genetic counseling
  - finding genetic factor of diseases / traits
- Complication factor
  - incomplete data


1st generation (grandparents)
Ww
ww
ww
Ww
2nd generation (parents, aunts, and uncles)
Ww
ww
ww
Ww
Ww
ww
3rd generation (two sisters)
WW or Ww
ww
Widow's peak
No widow's peak

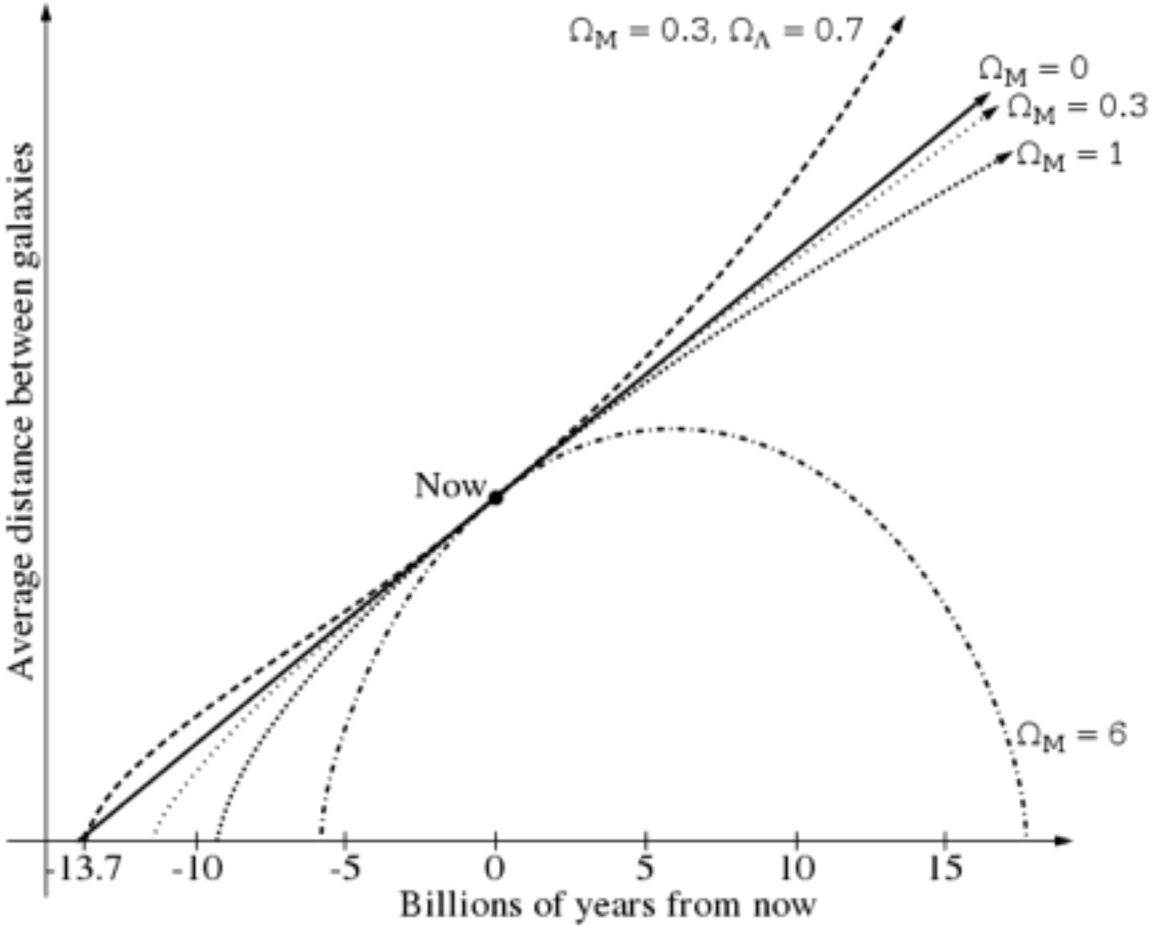
Larger family trees

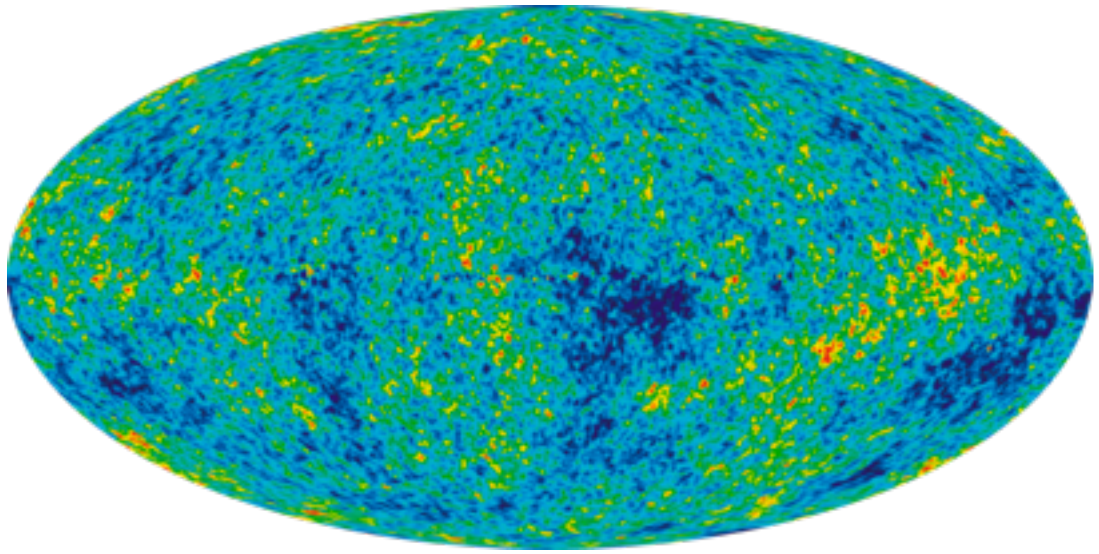
- A larger example where *W* is dominant over *w*
- Goals:
  - genetic counseling
  - finding genetic factor of diseases / traits
- Complication factor
  - incomplete data



Astrophysics: Estimating the age and faith of the Universe

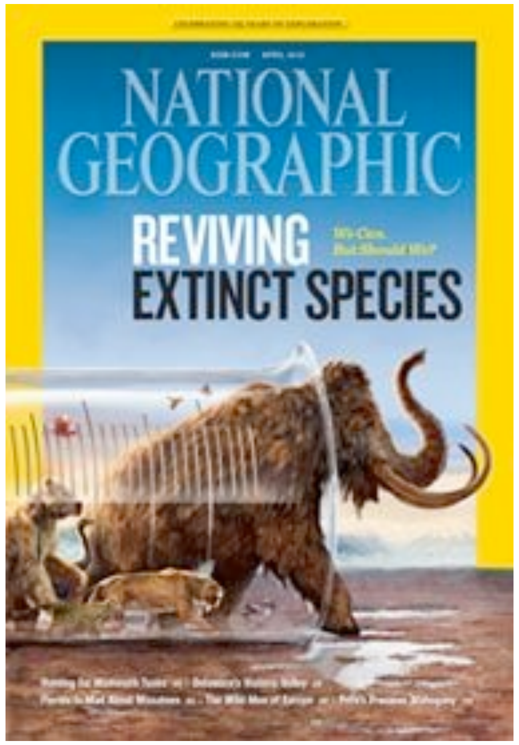
- **Goals**: finding the Universe's
  - age
  - density (=> faith)
- **Data**: Cosmic Microwave Background (CMB): remnants of Big Bang
  - Detailed map from the Planck satellite
- Age, Physical constants => known *distribution* on CMP
- Invert using Bayes' rule





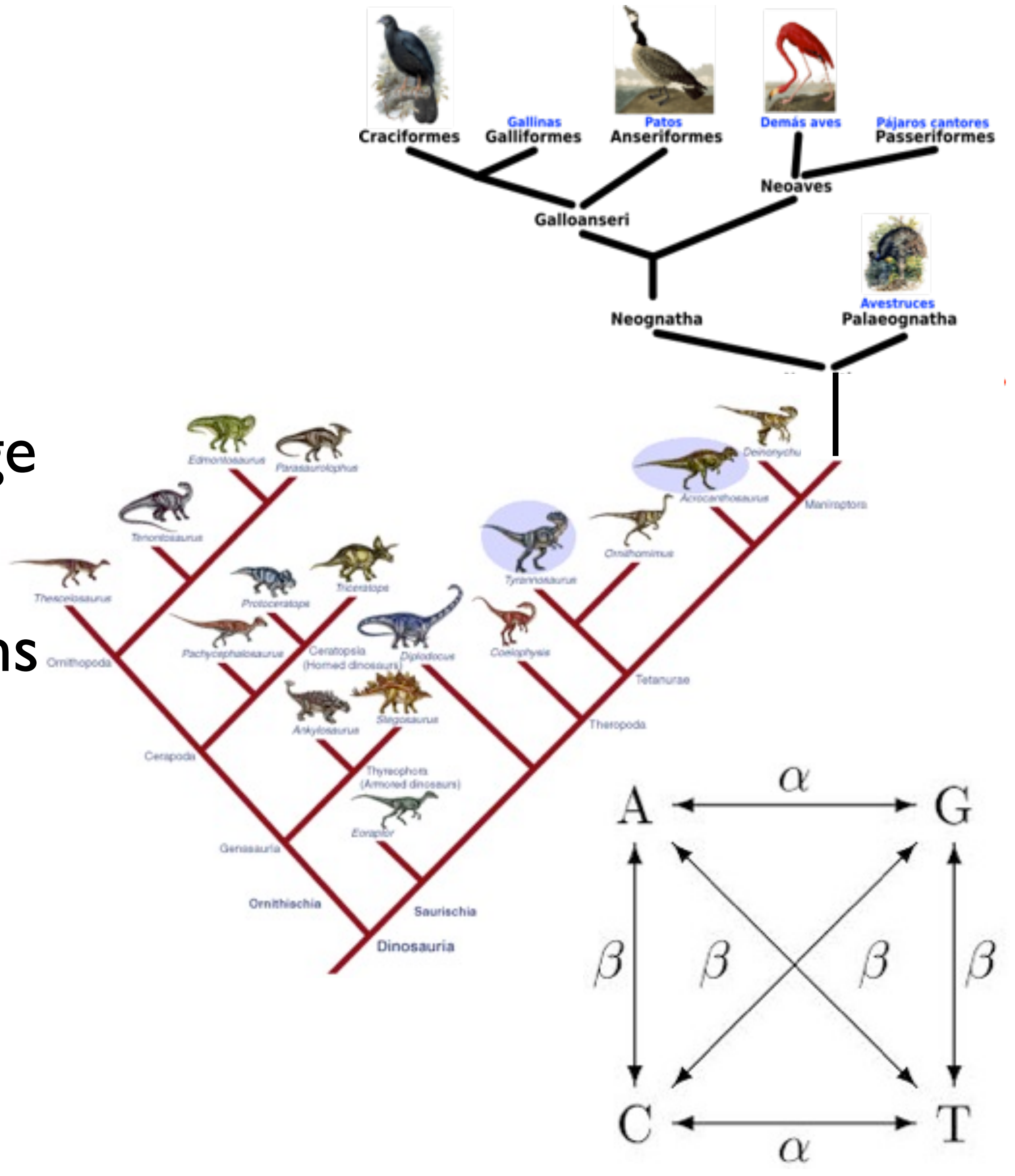
Phylogenetics: Reconstruction of ancient species

- **Goals**:
  - better understand ancient species
  - revive them?
- **Data**: fossil DNA
- Limitation: degrades after few 1000s years
- Are dinosaurs' genomes completely lost?



Phylogenetic tree

- **Idea:** use the genomes from the descendants of dinosaurs (modern birds)
- We know how DNA change over time (probabilistically)
- Marginalization of unknowns (as in family tree example)
- Additional challenge: structure of tree is unknown



Foundations