# Building Watson

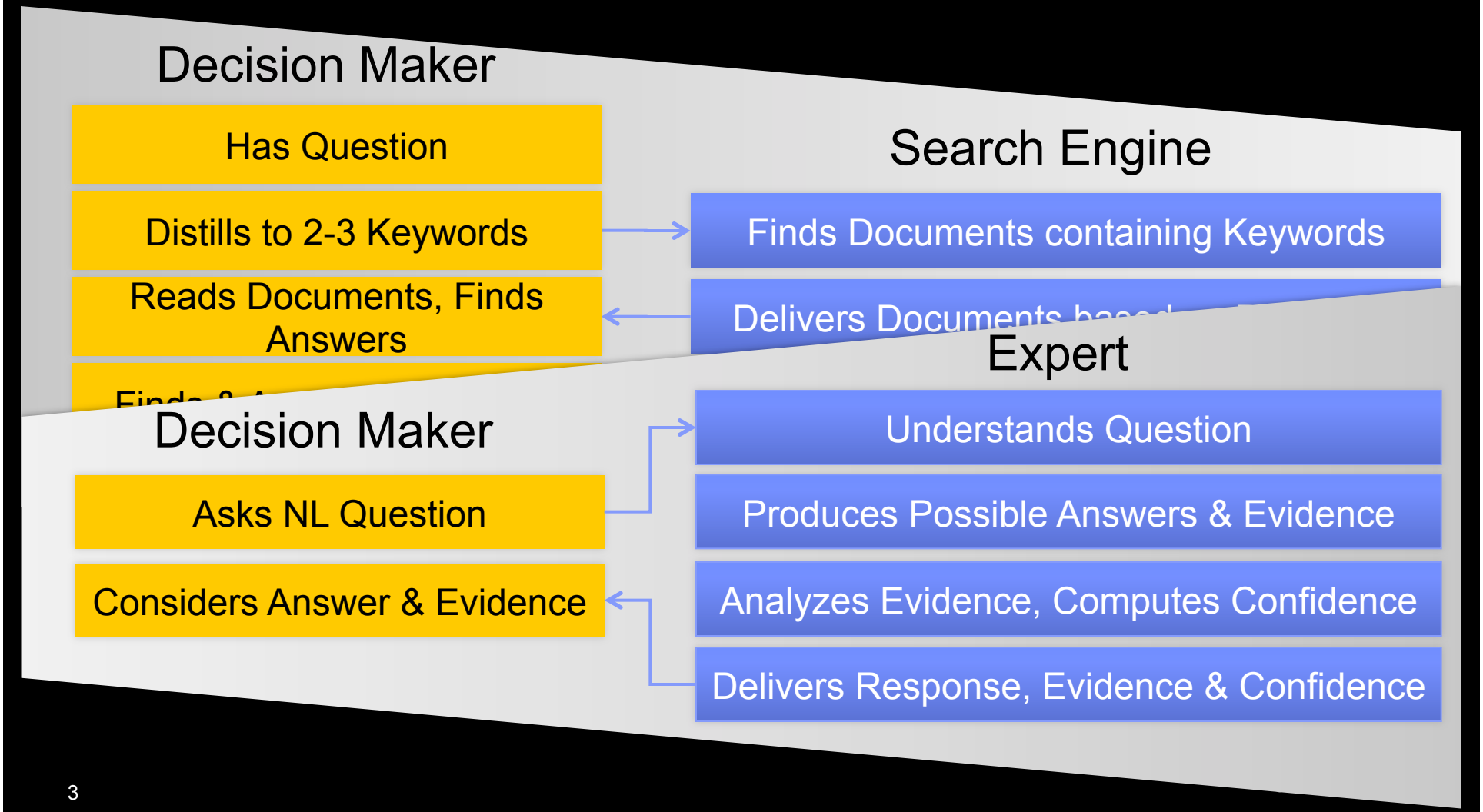
## A Brief Overview of DeepQA, the Jeopardy! Challenge and the future of Watson

David Boloker
CTO Emerging Internet Technology

# Agenda

- What is IBM Watson and why is it important?
- How is IBM putting Watson to work?
- What can we expect in the future?

# Informed Decision Making: Search vs. Expert Q&A



# A Grand Challenge Opportunity


- Capture the imagination
  - The Next Deep Blue

- Engage the scientific community
  - Envision new ways for computers to impact society & science
  - Drive important and measurable scientific advances

- Be Relevant to IBM Customers
  - Enable better, faster decision making over unstructured and structured content
  - Business Intelligence, Knowledge Discovery and Management, Government, Compliance, Publishing, Legal, Healthcare, Business Integrity, Customer Relationship Management, Web Self-Service, Product Support, etc.

# Real Language is Real Hard

- Chess
  - A finite, mathematically well-defined search space
  - Limited number of moves and states
  - Grounded in explicit, unambiguous mathematical rules


- Human Language
  - Ambiguous, contextual and implicit
  - Grounded only in human cognition
  - Seemingly infinite number of ways to express the same meaning

# Automatic Open-Domain Question Answering
## A Long-Standing Challenge in Artificial Intelligence to emulate human expertise

- Given
  - Rich Natural Language Questions
  - Over a Broad Domain of Knowledge

- Deliver
  - Precise Answers: Determine what is being asked & give precise response
    - Accurate Confidences: Determine likelihood answer is correct
      - Consumable Justifications: Explain why the answer is right
      - Fast Response Time: Precision & Confidence in <3 seconds

# What Computers Find Easier (and Hard)

ln((12,546,798 * π) ^ 2) / 34,567.46 = 0.00885

Select Payment where Owner="David Jones" and Type(Product)="Laptop",

| Owner | Serial Number |
|---|---|
| David Jones | 45322190-AK |
| | |

| Serial Number | Type | Invoice # |
|---|---|---|
| 45322190-AK | LapTop | INV10895 |
| | | |

| Invoice # | Vendor | Payment |
|---|---|---|
| INV10895 | MyBuy | $104.56 |
| | | |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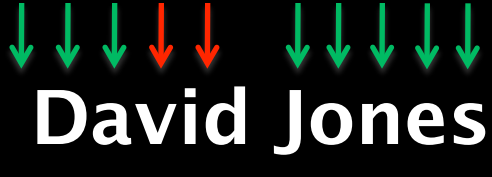


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# What Computers Find Hard

Computer programs are natively explicit, fast and exacting in their calculation over numbers and symbols….But Natural Language is implicit, highly contextual, ambiguous and often imprecise.

| Person | Birth Place |
|---|---|
| A. Einstein | ULM |

Structured

Unstructured

- Where was X born?

  One day, from among his city views of Ulm, Otto chose a water color to send to Albert Einstein as a remembrance of Einstein´s birthplace.

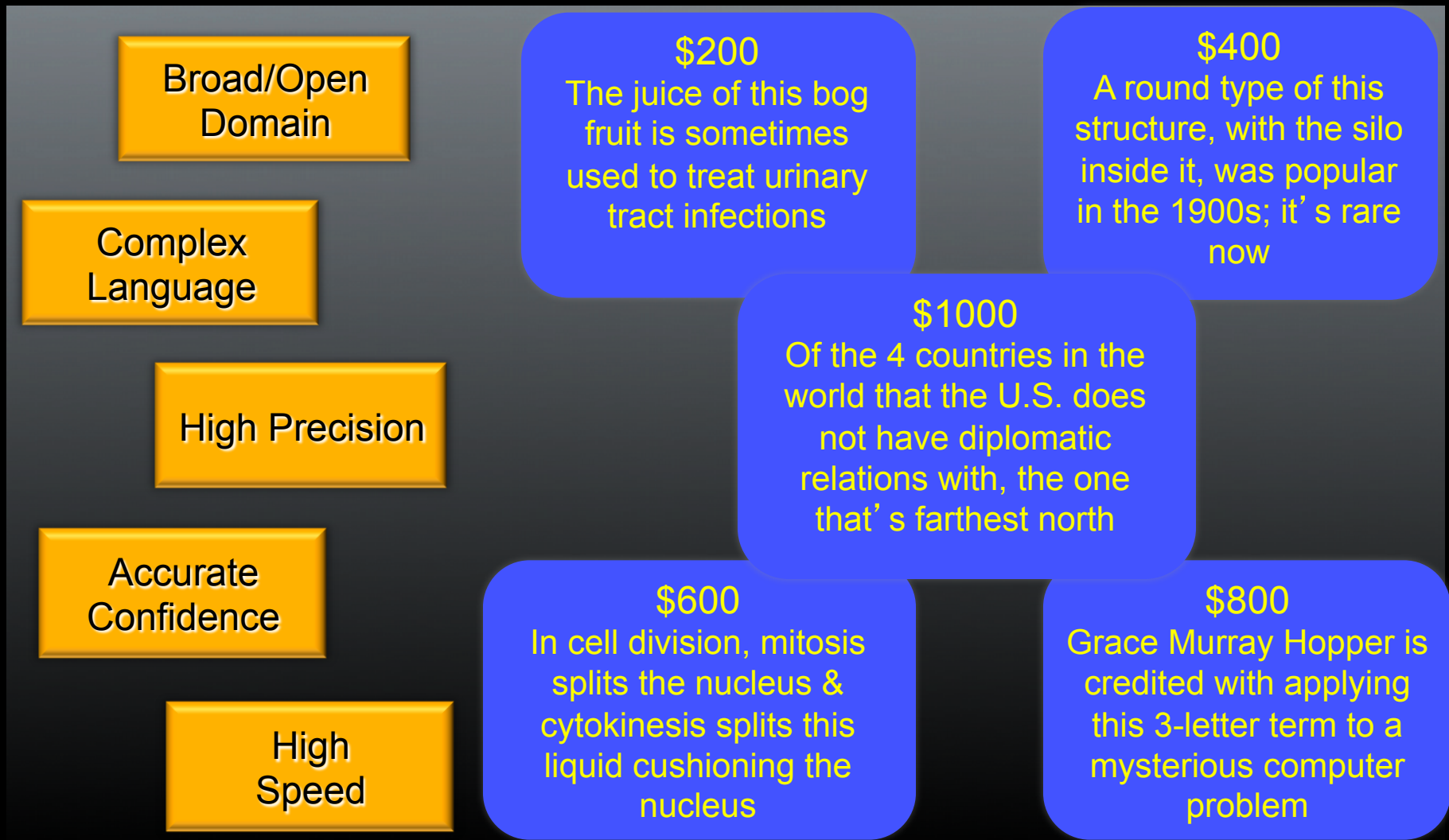
| Person | Organization |
|---|---|
| J. Welch | GE |

- X ran this?

  If leadership is an art then surely Jack Welch has proved himself a master painter during his tenure at GE.

# The Jeopardy! Challenge

## A palpable, compelling and notable way to drive the technology of Question Answering along Key Dimensions



# Some Basic Jeopardy! Clues

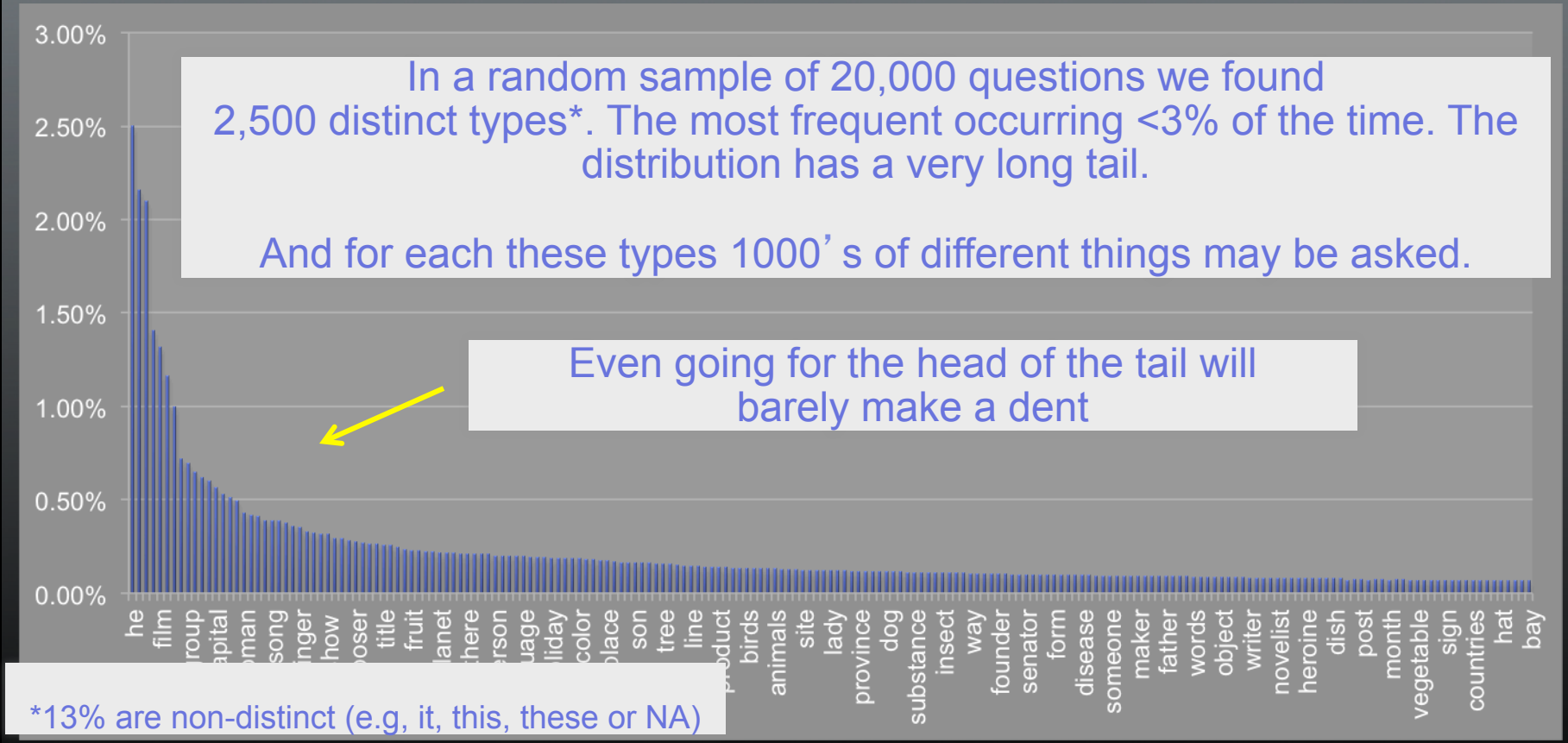
The type of thing being asked for is often indicated but can go from specific to very vague

- This fish was thought to be extinct millions of years ago until one was found off South Africa in 1938
  - Category: ENDS IN "TH"
  - Answer: coelacanth
- When hit by electrons, a phosphor gives off electromagnetic energy in this form
  - Category: General Science
  - Answer: light (or photons)
- Secy. Chase just submitted this to me for the third time--guess what, pal. This time I'm accepting it
  - Category: Lincoln Blogs
  - Answer: his resignation

# Broad Domain

We do NOT attempt to anticipate all questions and build databases.

We do NOT try to build a formal model of the world



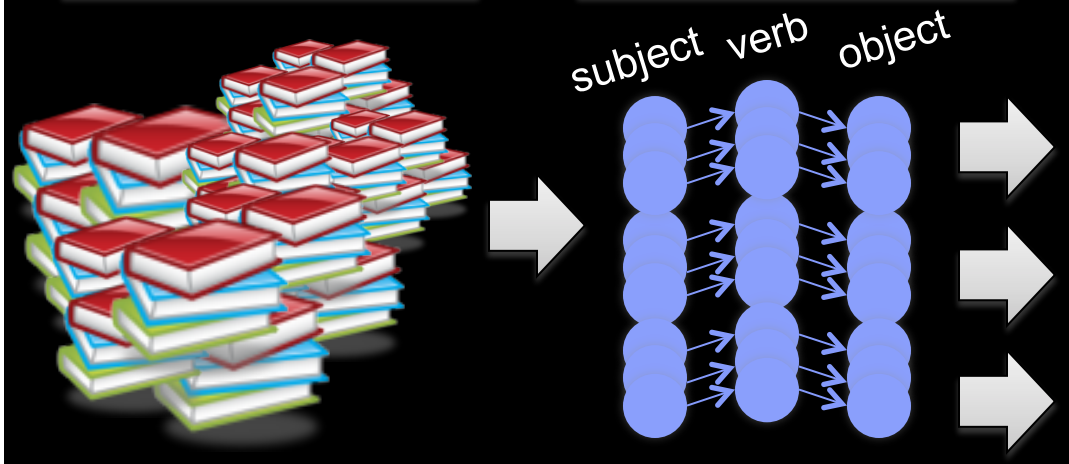

Our Focus is on reusable NLP technology for analyzing vast volumes of as-is text.
Structured sources (DBs and KBs) provide background knowledge for interpreting the text.

# Automatic Learning for “Reading”

Sentence Parsing

Generalization & Statistical Aggregation

Volumes of Text → Syntactic Frames → Semantic Frames




Inventors patent inventions (.8)

Officials Submit Resignations (.7)
People earn degrees at schools (0.9

Fluid is a liquid (.6)
Liquid is a fluid (.5)

Vessels Sink (0.7)
People sink 8-balls (0.5) (in pool/0.8)

# Evaluating Possibilities and Their Evidence

In cell division, mitosis splits the nucleus & cytokinesis splits this liquid cushioning the nucleus.

- *Organelle*
- *Vacuole*
- *Cytoplasm*
- *Plasma*
- *Mitochondria*
- *Blood …*

- Many candidate answers (CAs) are generated from many different searches
- Each possibility is evaluated according to different dimensions of evidence.
- Just One piece of evidence is if the CA is of the right type. In this case a "liquid".

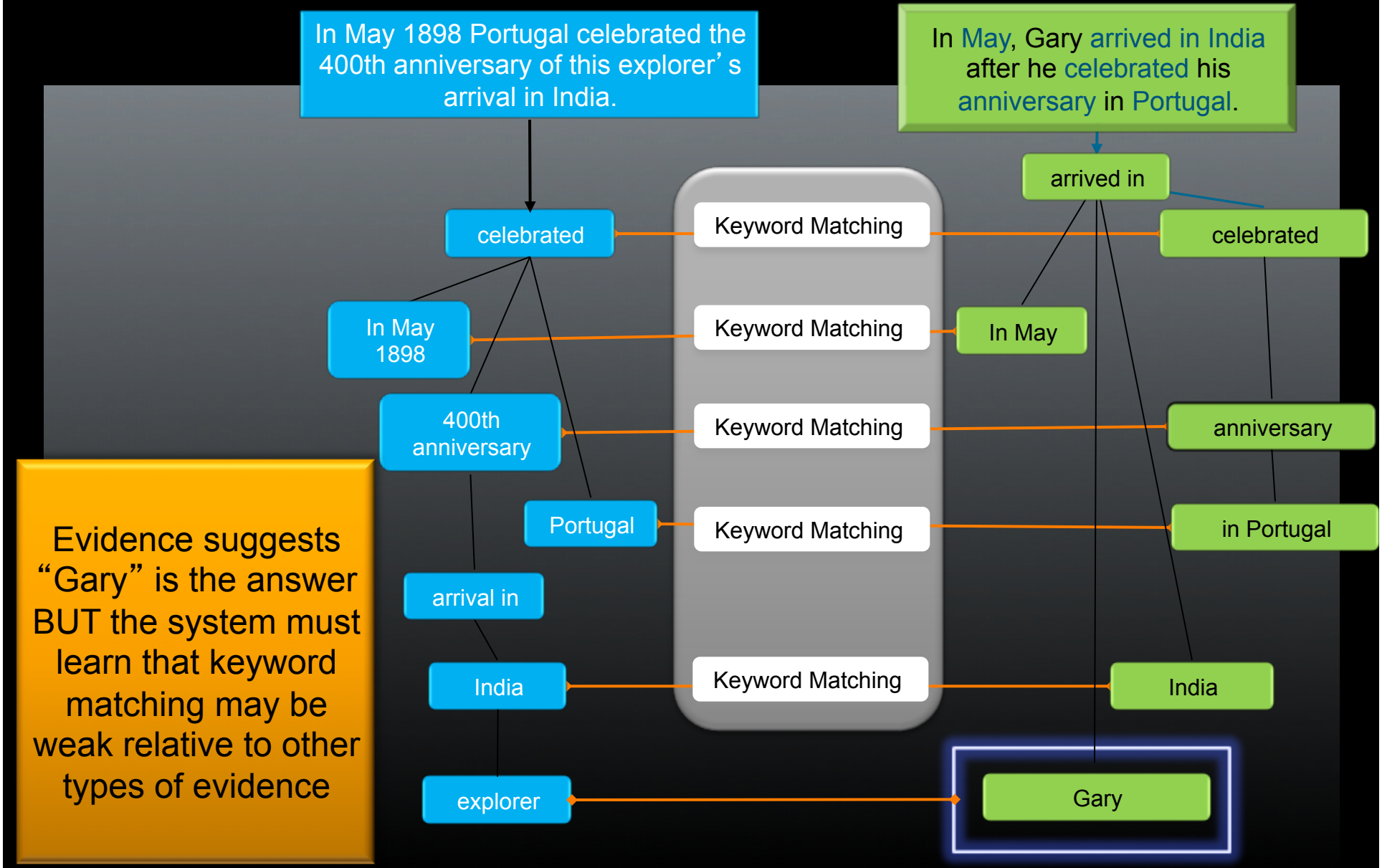
Is("Cytoplasm", "liquid") = 0.2
Is("organelle", "liquid") = 0.1
Is("vacuole", "liquid") = 0.2
Is("plasma", "liquid") = 0.7

"Cytoplasm is a fluid *surrounding* the nucleus…"

Wordnet → Is_a(Fluid, Liquid) → ?

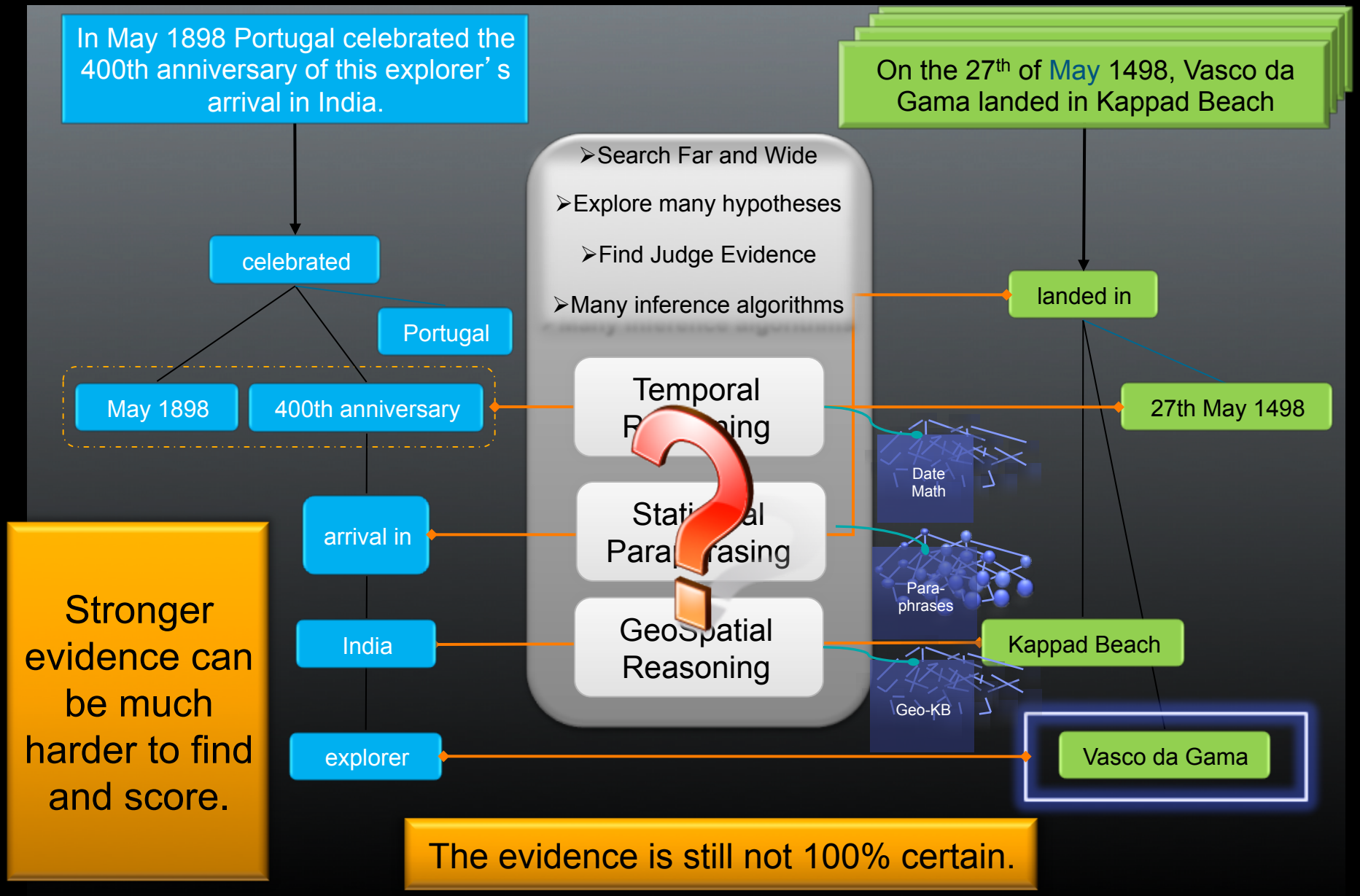
Learned → Is_a(Fluid, Liquid) → yes.

# Different Types of Evidence: Keyword Evidence



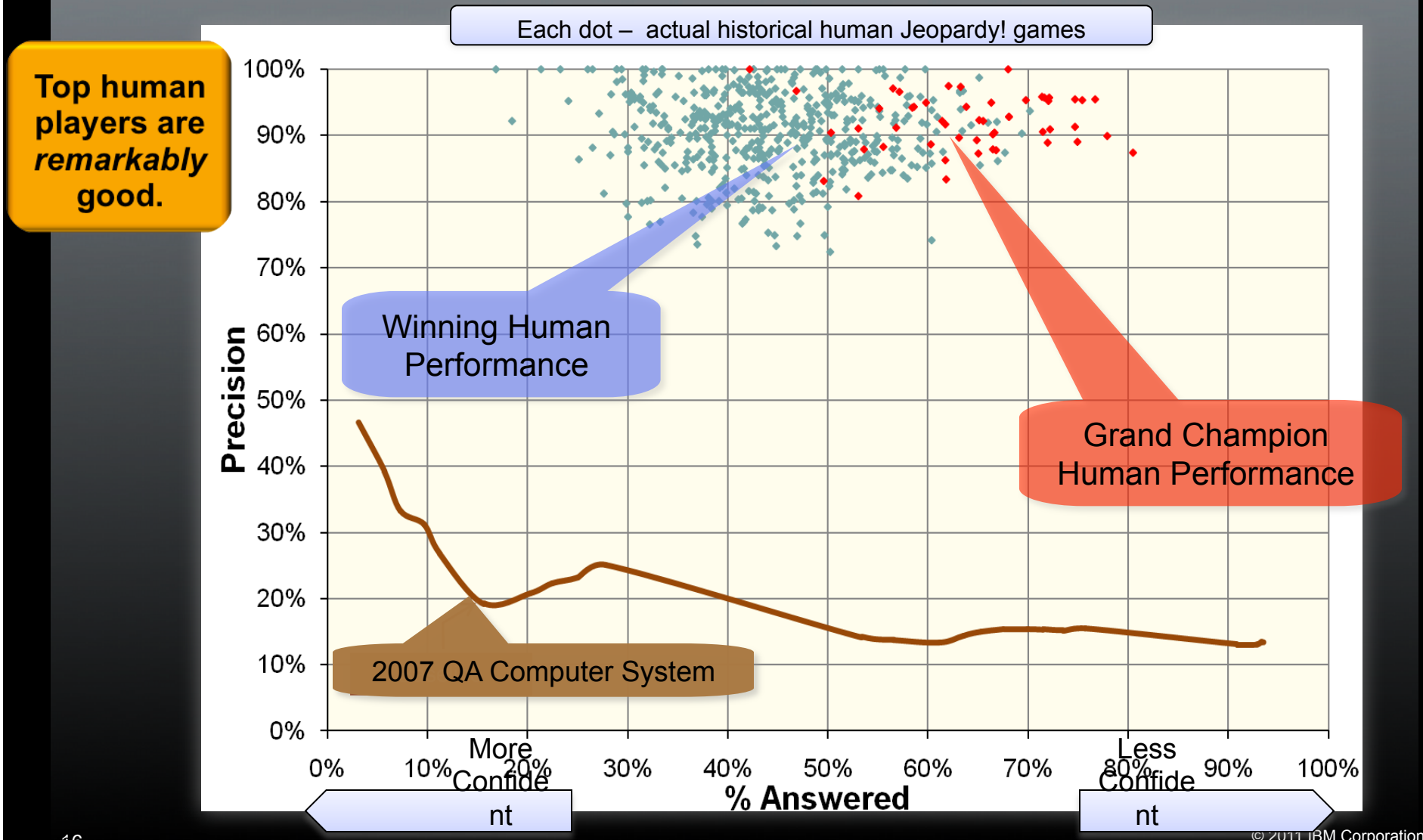

Evidence suggests "Gary" is the answer BUT the system must learn that keyword matching may be weak relative to other types of evidence

# Different Types of Evidence: Deeper Evidence



# What It Takes to compete against Top Human Jeopardy! Players

## Our Analysis Reveals the Winner's Cloud



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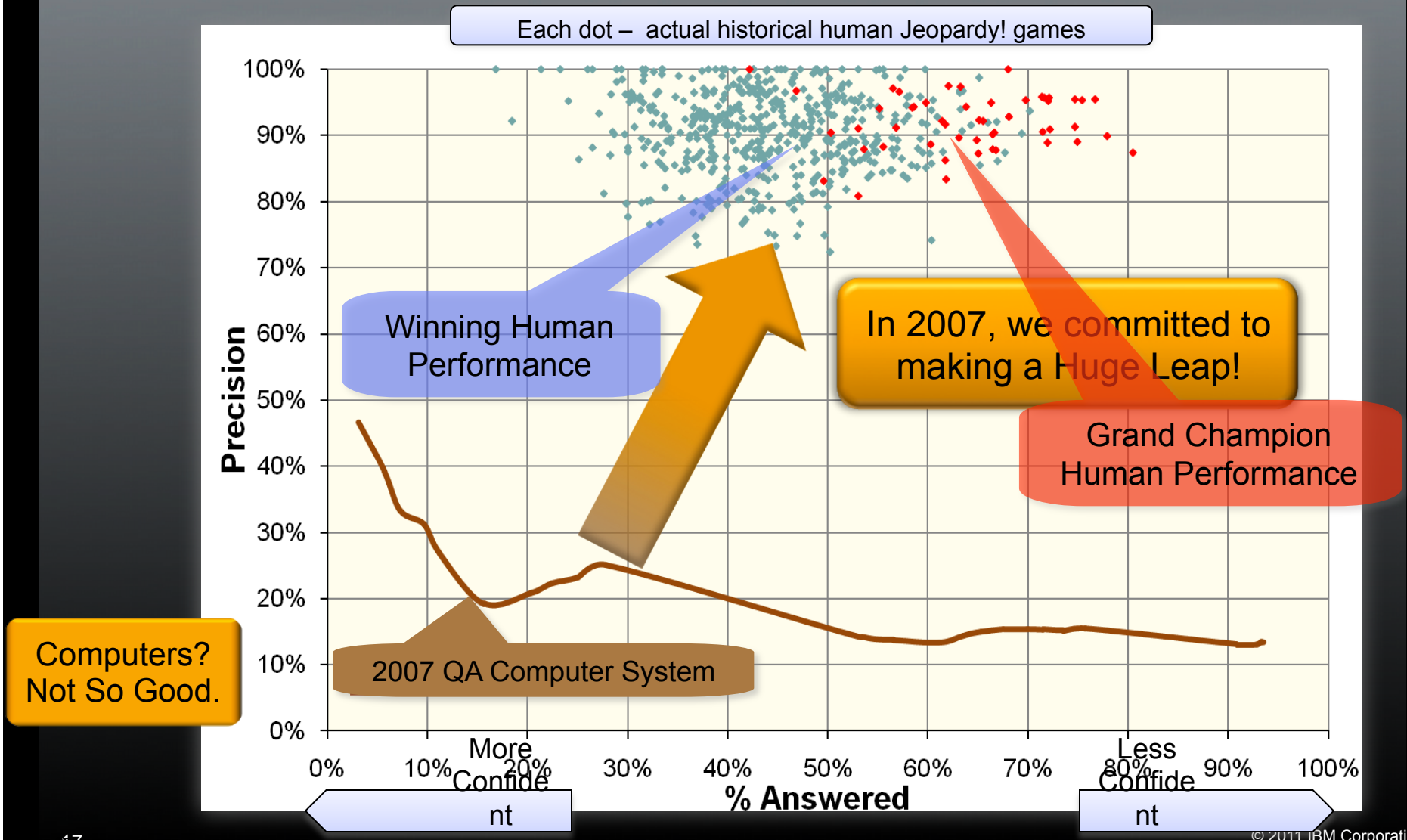
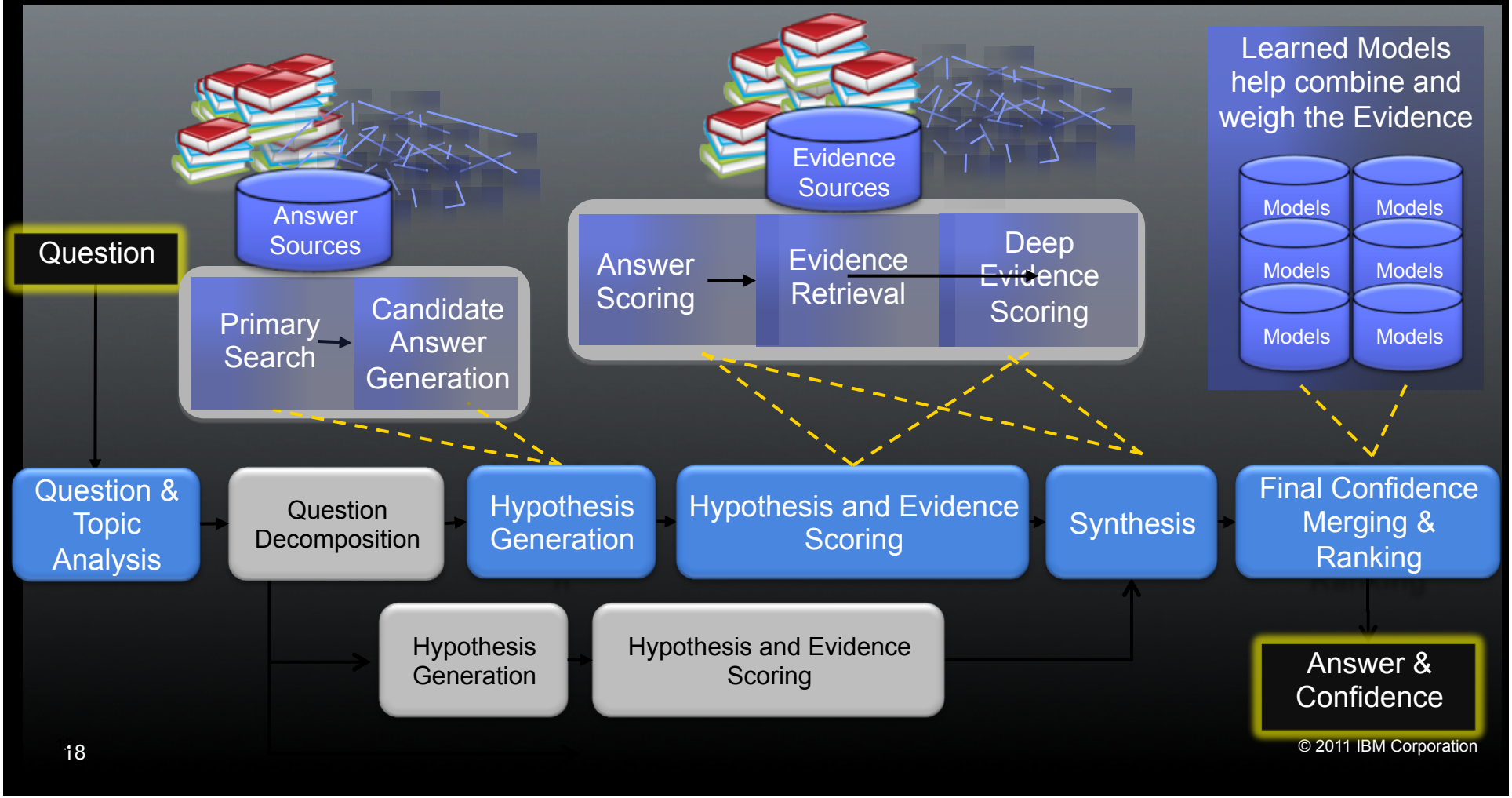
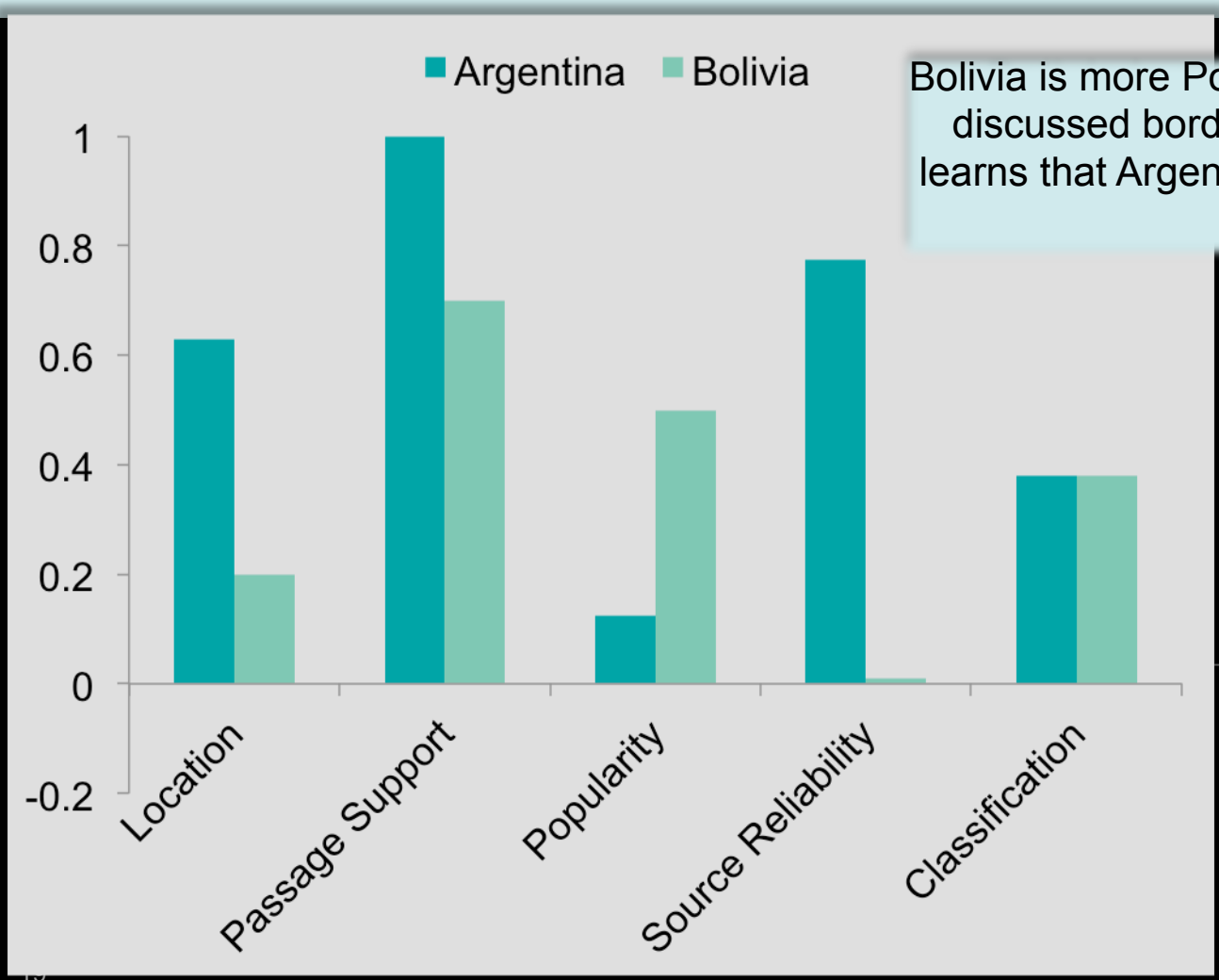


# DeepQA: The Technology Behind Watson
## Massively Parallel Probabilistic Evidence-Based Architecture



# Grouping features to produce Evidence Profiles

Clue: Chile shares its longest land border with this country.



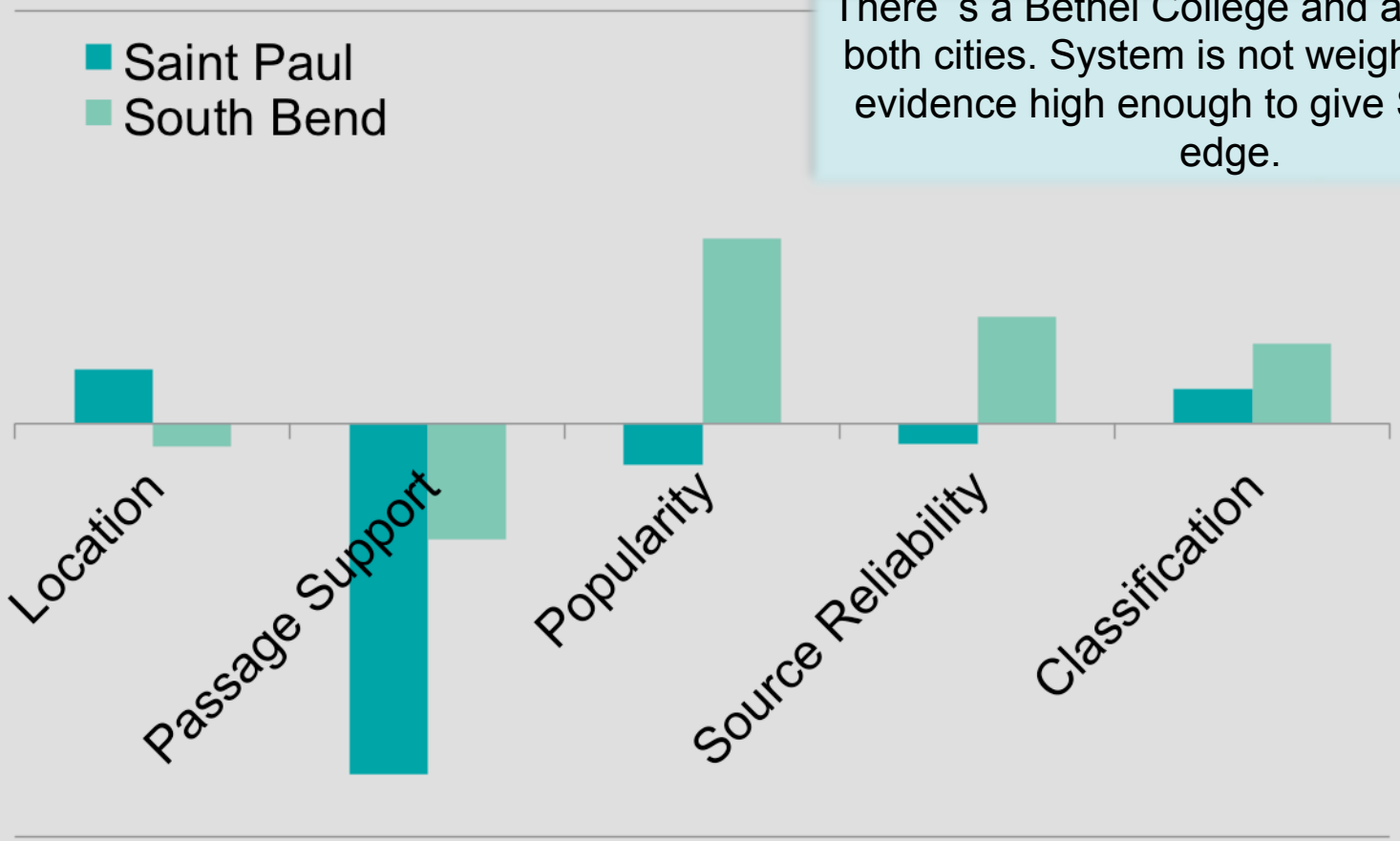

Bolivia is more Popular due to a commonly discussed border dispute. But Watson learns that Argentina has better evidence.

Positive Evidence

Negative Evidence

# Evidence: Time, Space, Source, Type etc.

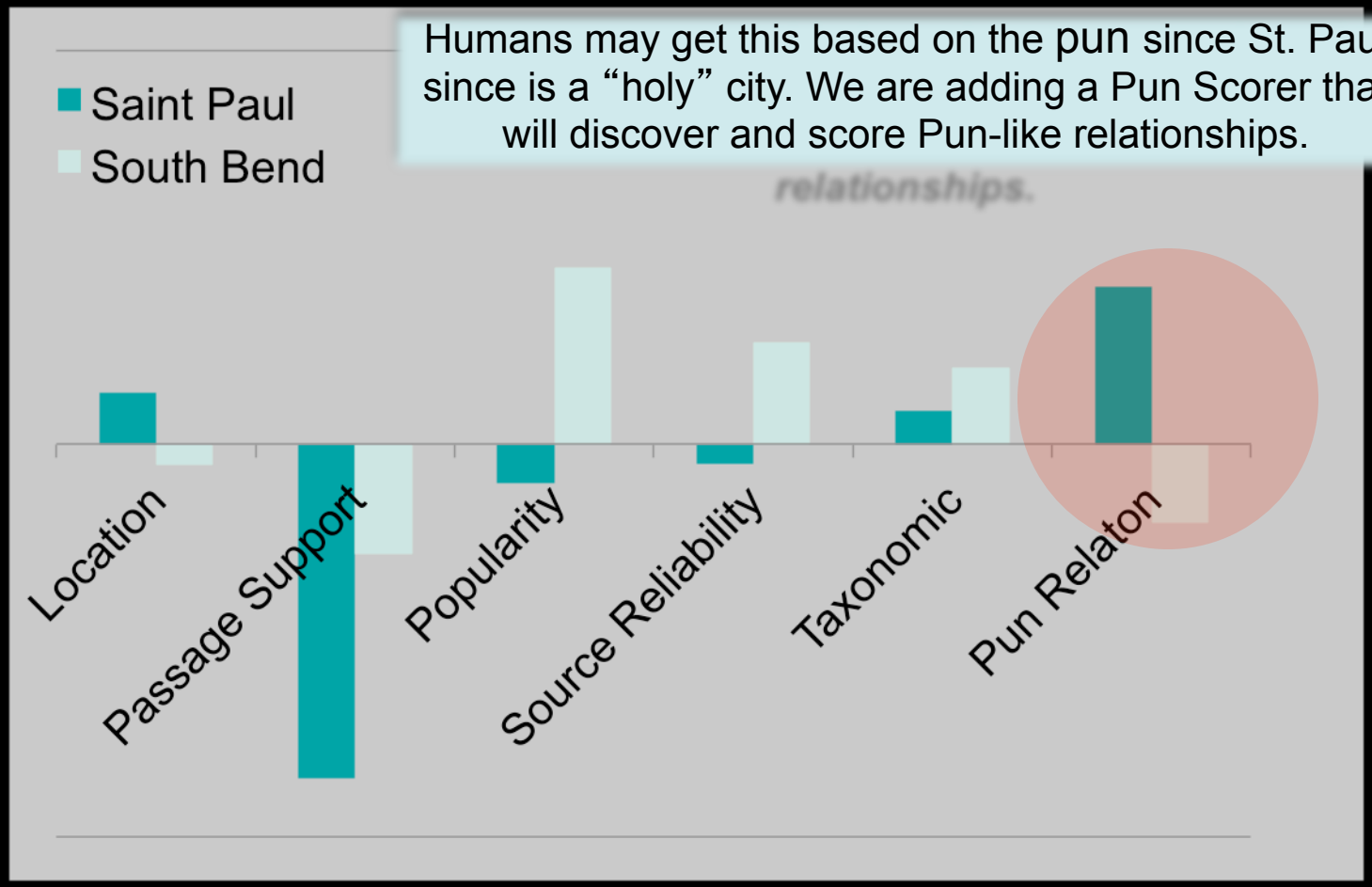
Clue: You'll find Bethel College and a Seminary in this "holy" Minnesota city.




There's a Bethel College and a Seminary in both cities. System is not weighing location evidence high enough to give St. Paul the edge.

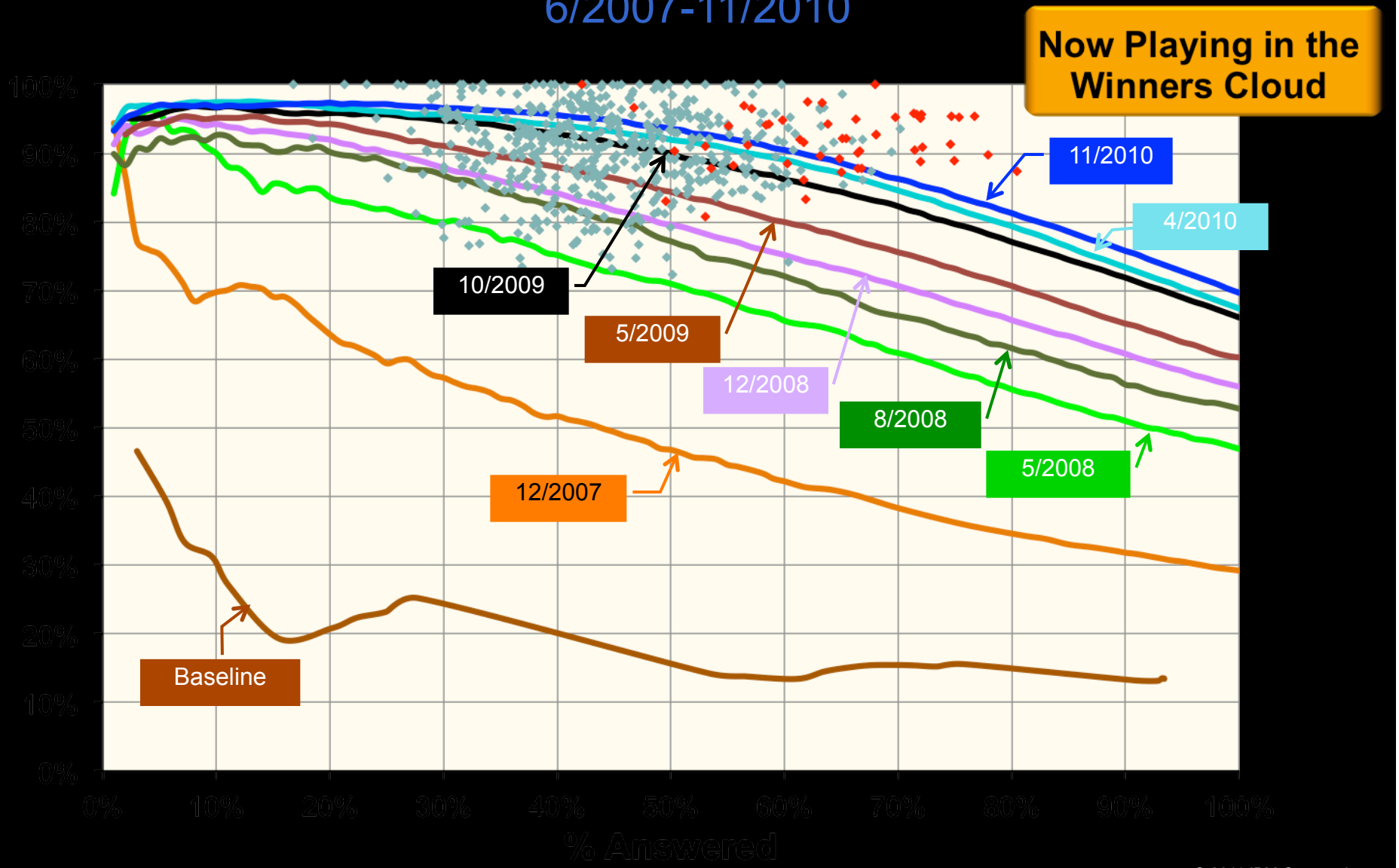
# Evidence: Puns

Clue: You'll find Bethel College and a Seminary in this "holy" Minnesota city.

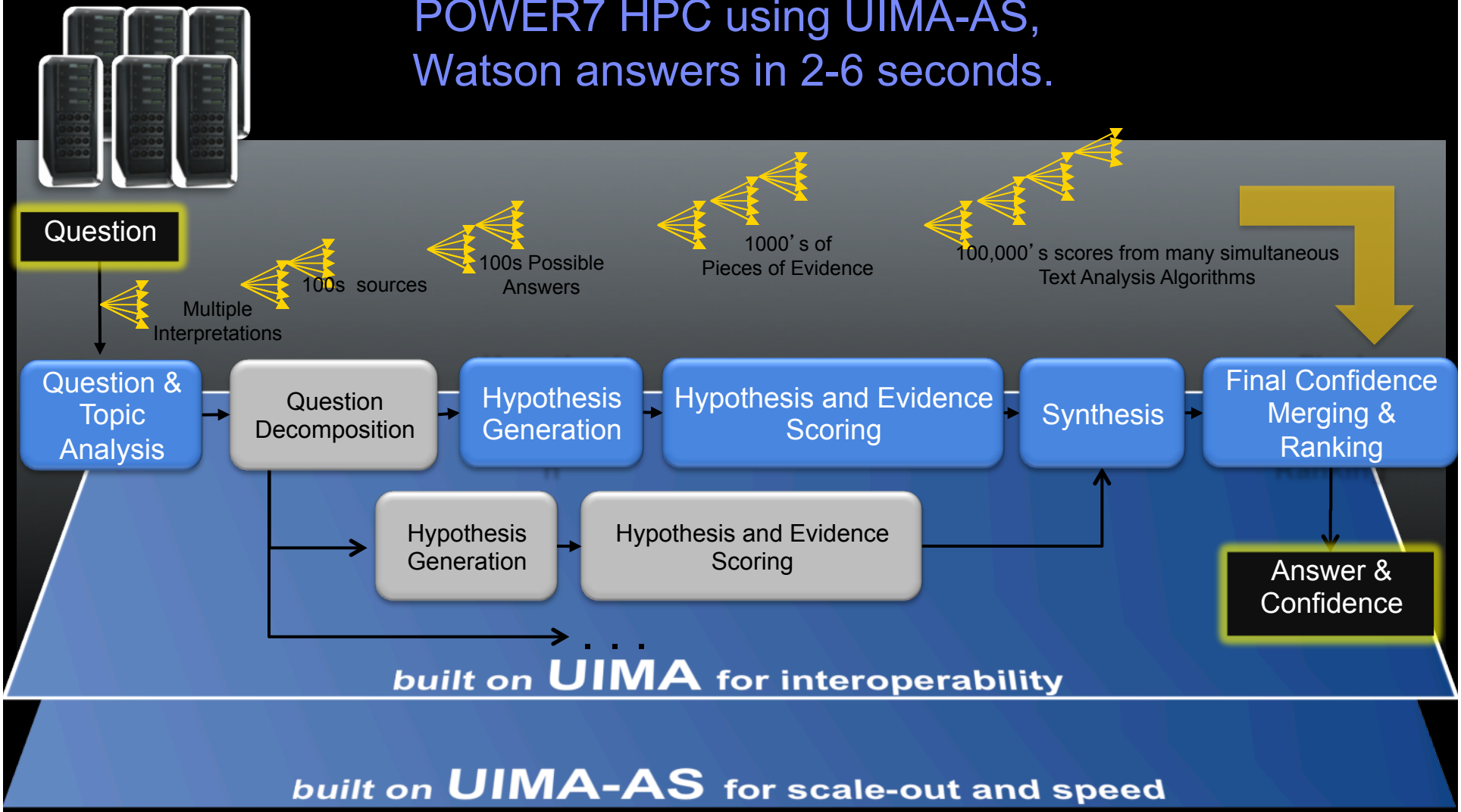



Humans may get this based on the pun since St. Paul since is a "holy" city. We are adding a Pun Scorer that will discover and score Pun-like relationships.

# Deep QA: Incremental Progress in Precision and Confidence 6/2007-11/2010



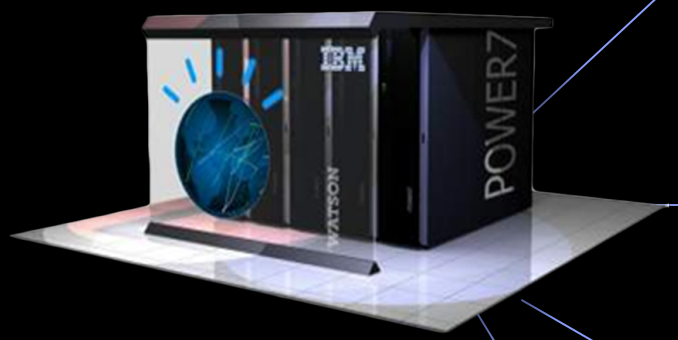
# One Jeopardy! question can take 2 hours on a single 2.6Ghz Core Optimized & Scaled out on 2880-Core IBM workload optimized POWER7 HPC using UIMA-AS, Watson answers in 2-6 seconds.



# IBM Watson a look behind the scenes

## System Specifications

- 2880 Processing Cores
- 90 IBM P750 Servers
- 16 Terabytes Memory (RAM) – 20TB Disk
- 80 Teraflops Computing Power
- Workload Optimized Systems




## IBM Technology Depth

- Content Analytics
- Business Analytics
- Big Data
- Databases / Data Warehouses

# Quick Watson Demo

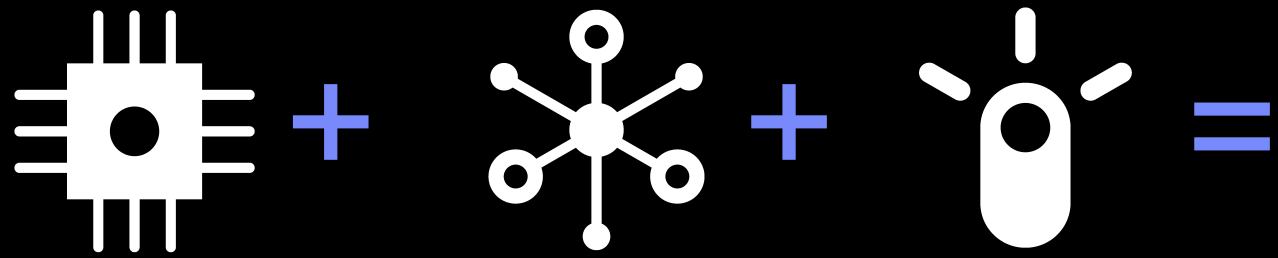
# Agenda

What is IBM Watson and why is it important?

How is IBM putting Watson to work?

What can we expect in the future?

# The World is Getting Smarter



Instrumented Interconnected Intelligent

An opportunity to think and act in new ways—
economically, socially and technically.


27


Unstructured data is proliferating. . .

… 249 B e-mails (2.8M/sec) and 200M Tweets daily

… 220+ B pieces of user generated content on web

In 2005 there were 1.3 billion RFID tags in circulation…

… by 2011 there will be 33 billion.


An estimated 2 billion people will be on the Web by 2011 ...

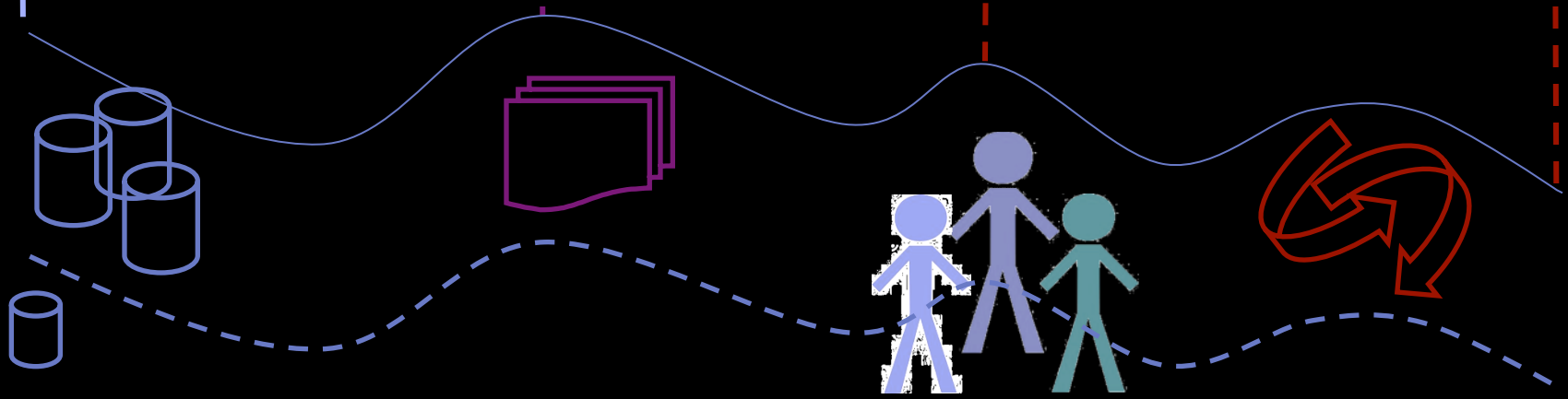
… and a trillion connected objects – cars, appliances, cameras, roadways, pipelines

# Businesses on a Smarter Planet are "dying of thirst in an ocean of data"

90% of the world's data was created in the last two years

80% of the world's data today is unstructured

Traditional technology solutions only leverage 20% of the available information



**1 in 2**

Business leaders don't have access to data they need

**83%**

of CIO's cited BI and analytics as part of their visionary plan

**5.4X**

more likely that top performers use Business analytics

# Today's business challenges are causing organizations to rethink what it will take to get ahead tomorrow

## Traditional IT

- Structured data, local scope
- Deterministic Applications
- Search Oriented
- Small Data
- Machine Language
- Systems of records

## Emerging IT

- Global Structured & unstructured
- Probabilistic Applications
- Discovery Oriented
- Small and Big Data
- Natural Language
- Systems of engagement

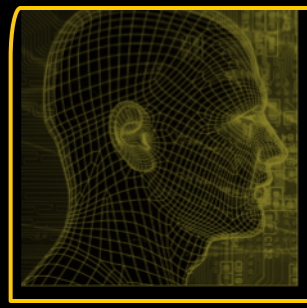
# Healthcare Industry is beset with some of the most complex information challenges we collectively face

- Medical information is doubling every 5 years, much of which is unstructured
- 81% of physicians report spending 5 hours or less per month reading medical journals


"Medicine has become too complex (and only) about 20 percent of the knowledge clinicians use today is evidence-based."

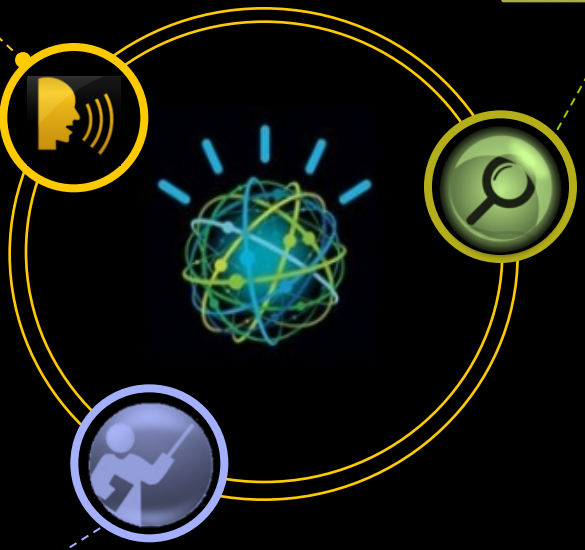
Steven Shapiro, Chief Medical and Scientific Officer, UPMC

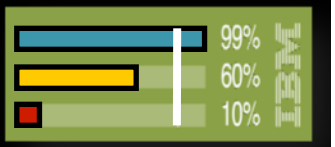
# IBM Watson brings together a set of transformational technologies to drive optimized outcomes



Understands natural language and human speech

Generates and evaluates hypothesis for better outcomes



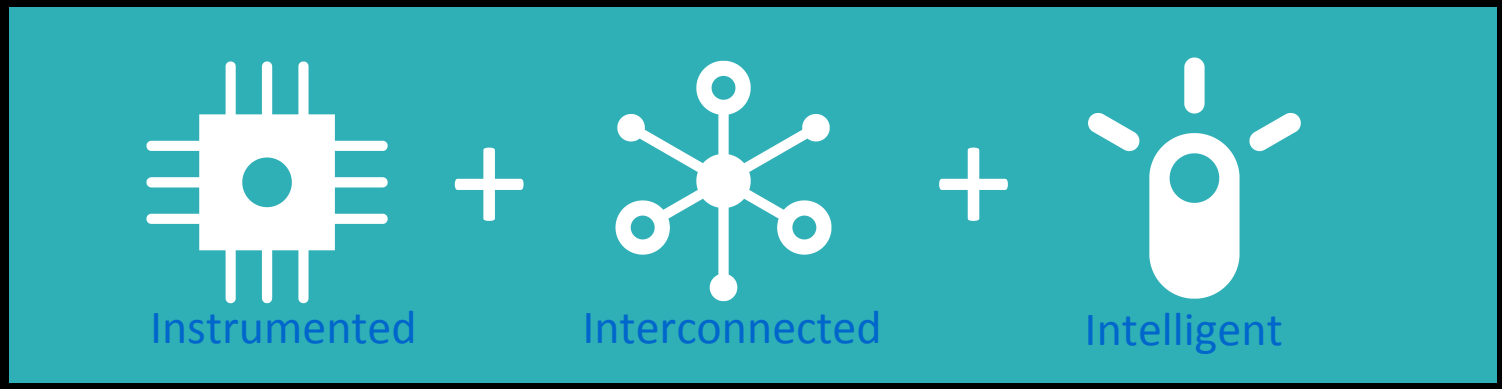



Adapts and Learns from user selections and responses

…built on a massively parallel probabilistic evidence-based architecture

# IBM Smarter Healthcare

A smarter health system improves visibility and collaboration across all health system participants making best use of resources to prevent and treat diseases, reduce overall healthcare costs, and keep people healthy.




Capture accurate, real-time information from devices & systems

Enable seamless information sharing across groups

Use advanced analytics to improve research, diagnosis and treatment

# Why is Watson Technology ideal for Healthcare?

Understands natural language questions →

What condition has red eye, pain, inflammation, blurred vision, floating spots and sensitivity to light?

Analyzes large volumes of unstructured data →

Physician Notes, Medical Journals, Clinical Trials, Pathology Results, Blogs, Wikipedia

Generates and evaluates hypothesis →

| Possible Diagnosis | Confidence |
|---|---|
| Uveitis | 91% |
| Iritis | 48% |
| Keratitis | 29% |

Presents responses with confidence →

Supports iterative dialogue to refine results →

Family History, Patient Interview, Physical Exam, Current Medications

Learns from results over time →

What actions were taken? What treatments were prescribed? What was the outcome?

# IBM and WellPoint are working together to put Watson to work in healthcare

WellPoint
Serving 1 in 9 insured Americans

+

IBM Watson

=

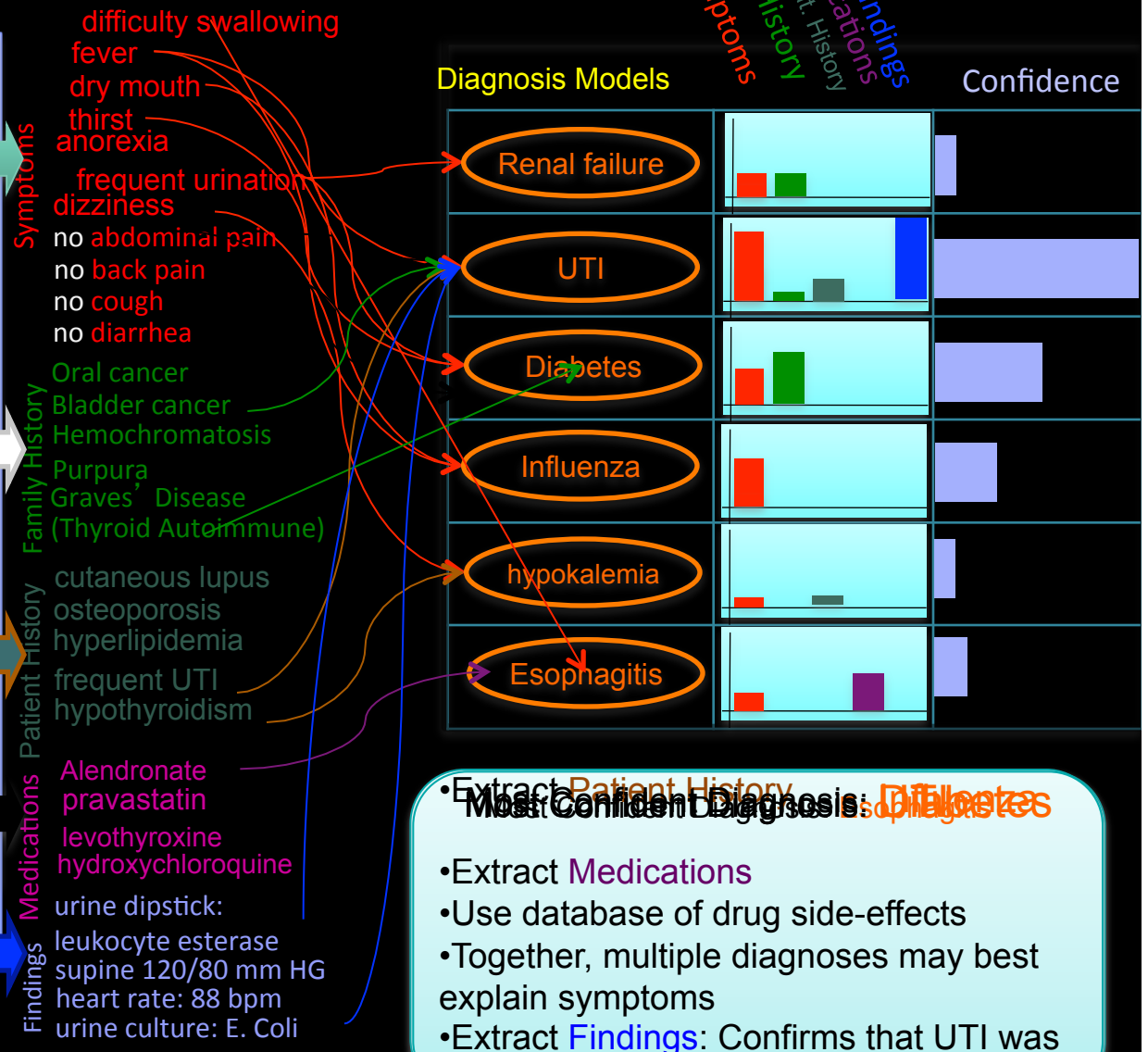
Leverage medical records
TO
diagnose and identify treatment options
TO
enhance the quality of medical care delivered

"Imagine having the ability within three seconds to look through all of that (medical) information….at the moment you're caring for that patient."

Dr. Sam Nussbaum, WellPoint's Chief Medical Officer, WellPoint

# Putting the pieces together at point of impact can be life changing

A 58-year-old woman presented to her primary care physician after several days of dizziness, anorexia, dry mouth, increased thirst, and frequent urination. She had also had a fever and reported that food would "get stuck" when she was swallowing. She reported no pain in her abdomen, back, or flank and no cough, shortness of breath, diarrhea, or dysuria. Her family history included oral and bladder cancer in her mother, Graves' disease in two sisters, hemochromatosis in one sister, and idiopathic thrombocytopenic purpura in one sister. Her history was notable for cutaneous lupus, hyperlipidemia, osteoporosis, frequent urinary tract infections, three uncomplicated cesarean sections, a left oophorectomy for a benign cyst, and primary hypothyroidism, which had been diagnosed a year earlier. Her medications were levothyroxine, hydroxychloroquine, pravastatin, and alendronate. A urine dipstick was positive for leukocyte esterase and nitrites. The patient was given a prescription for ciprofloxacin for a urinary tract infection and was advised to drink plenty of fluids. On a follow-up visit with her physician 3 days later, her fever had resolved, but she reported continued weakness and dizziness despite drinking a lot of fluids. Her supine blood pressure was 120/80 mm Hg, and her pulse was 88 beats per minute; on standing, her systolic blood pressure was 84 mm Hg, and her pulse was 92 beats per minute. A urine specimen obtained at her initial presentation had been cultured and grew more than 100,000 colonies of Escherichia coli, which is sensitive to ciprofloxacin.




- Extract Patient History
- Most Confident Diagnosis: Diabetes
- Extract Medications
- Use database of drug side-effects
- Together, multiple diagnoses may best explain symptoms
- Extract Findings: Confirms that UTI was present

# From battling humans at Jeopardy! to transforming business

## IBM Watson Healthcare

Diagnostic/Treatment Assistance, Evidenced-Based Insights, Collaborative Medicine

## Financial Services


Investment and retirement planning, institutional trading and decision support.

## Tech Support

Contact center support and services. Enterprise knowledge management. Consumer marketing.

## Government

Public Safety, Improved Information Sharing, Security, Fraud and Abuse Prevention

# What's under the Watson Covers?

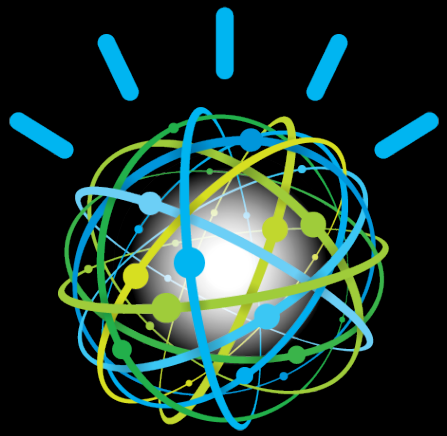
## What's under the Watson Covers?

- Apache UIMA
- Apache Hadoop
- Apache Tomcat
- Apache XMLbeans
- Apache JUL Bridge
- Apache Derby

# References

# Learn more at:

- See Watson in action at an IBM Lab, Briefing Center or Analytics Solution Center



- Learn more at:

www.ibmwatson.com.

www.facebook.com/ibmwatson.

www.twitter.com/ibmwatson (Tweet #ibmwatson )

www.youtube.com/ibm

# And…

- IBM @ http://www.ibm.com/innovation/us/watson/
- Nova @ http://www.pbs.org/wgbh/nova/tech/smartest-machine-on-earth.html
- TED @ http://www.ted.com/webcast/archive/event/ibmwatson

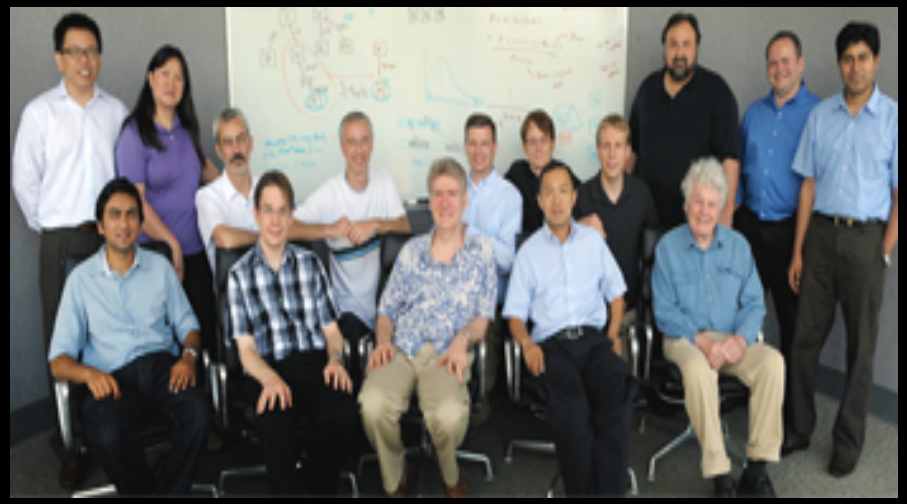
- And References in Print
- "Building Watson: An Overview of the DeepQA Project" in AI Magazine, FALL 2010 59, http://www.stanford.edu/class/cs124/AIMagzine-DeepQA.pdf
- "Building an example application with the Unstructured Information Management Architecture," IBM Systems Journal, Volume 43 Issue 3
- "Final Jeopardy: Man vs Machine and the Quest to Know Everything" by Stephen Baker

# The Complete “Watson” Team

# Organization: Principal Investigator

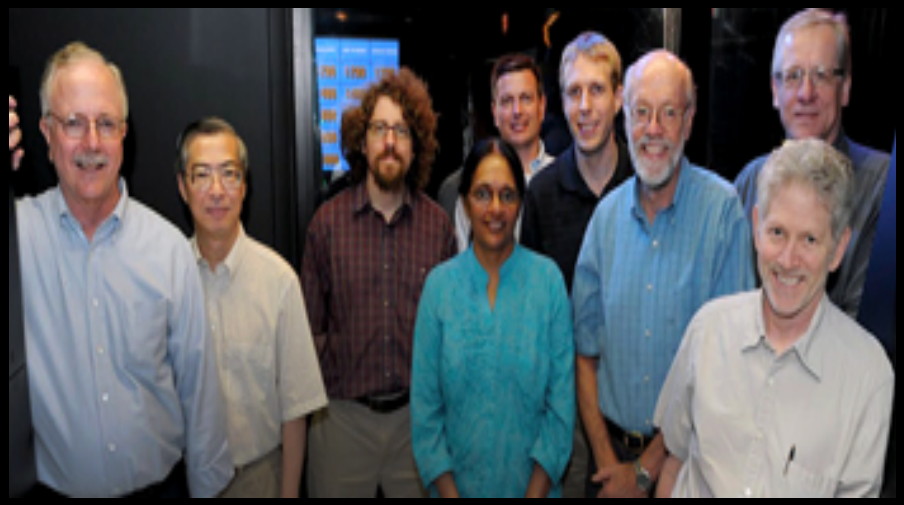
# Organization: Algorithms

- Branimir Boguraev
- Eric Brown
- Jennifer Chu-Carroll
- Bonaventura Coppola
- James Fan
- David Gondek
- Adiyta Kalanpur
- Adam Lally
- Anthony Levas
- Michael McCord
- Bill Murdock
- Siddharth Patwardhan
- John Prager
- Chang Wang



# Organization: Systems

- Eric Brown
- Jaroslaw Cwiklik
- Pablo Duboe
- Edie Epstein
- Tong Fin
- Bhavani Iyer
- Adam Lally
- Burn Lewis
- Marshall Schor



# Organization: Strategy

- James Fan
- David Gondek
- Jon Lenchner
- John Prager
- Gary Tesauro

# Organization: Speech

- Andy Aaron
- Raul Fernandez
- Bhuvana Ramadhadran
- Andrew Rosenberg
- Roberto Sicconi
- Maria Smith

# Organization: Annotations

- Karen Ingraffea
- Matt Mulholland

# Organization: Applications

- Sugato Bagchi
- Mike Barborak
- Anthony Levas
- Erik Mueller
- Wlodek Zadrozny

# Organization: Labs

China
- Lei Zhang
- Yuan Ni
- Yue Pan
- Zhao Ming Qiu

Japan
- Hiroshi Kanayama
- Kohichi Takeda

Haifa
- David Carmel
- Dafna Sheinwald

# Organization: Universities

Carnegie Mellon
- Eric Nyberg
- Nico Schlaefer
- Manas Pathak
- Hideki Shima
- Andy Schlaikier
- Pallika Kanani

Rensselaer Polytechnic
- Barbara Cutler

Massachusetts
- Chang Wang
- James Allen

Southern California
- Ed Hovy
- Rutu Mulkar-Mehta

Texas
- Bruce Porter
- Doo Soon Kim

Trento
- Allesandro Moschitti

MIT
- Boris Katz

# Organization: Universities

Carnegie Mellon
- Source expansion
- Answer scoring

Rensselaer Polytechnic
- Visualization

Massachusetts
- Text search retrieval

Southern California
- Large scale extraction

Texas
- Common sense

Trento
- Machine learning

MIT
- Questions to sub questions
- Object-property-value data model

# Organization: Project Management

- David Shepler
- Jim De Painte