Health Care in the Era of Machine Learning and Cognitive Computing

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Key Challenges in Healthcare & Life Sciences Industry

Information deluge

Medical literature doubling every few years [1]

Approximately 700 K new scientific articles per year

Explosion of patient data (EHR, Fitbits, etc)

1. Densen P. Challenges and Opportunities Facing Medical Education. *Transactions of the American Clinical and Climatological Association*. 2011;122:48-58.

Demand outstripping supply

American Society of Clinical Oncology suggests that by 2025, overall demand for medical oncology services will grow 42 % [2]

At the same time, supply of hematologists/ oncologists is projected to grow only 28 % [2]

2. The State of Cancer Care in America, 2014: A Report by the American Society of Clinical Oncology

Patients not being offered all treatment options

<20% of cancer patients are offered clinical trials as a treatment option [3]
About 20% of cancer patients are eligible for a clinical trial; yet, trial participation is at about 3%
Takes up to 15 years for latest evidence to be fully adopted

3 . Madsen LT, Kuban DA, Choi S, et al. *Journal of the National Comprehensive Cancer Network : JNCCN*. 2014;12(7):993-998.

Patients expect to participate in decision making around their care

Fewer than half of patients receive clear information on the trade-offs for their treatments and are satisfied with their level of control in medical decisions [4]

4. Vahdat S, Hamzehgardeshi L, Hessam S, Hamzehgardeshi Z. Patient Involvement in Health Care Decision Making: A Review. *Iranian Red Crescent Medical Journal*. 2014;16(1):e12454. doi:10.5812/ircmj.12454.

New research and advances in medicine increase the complexity of Care and Research

Clinicians are challenged with…

Understanding the patient condition → **Formulating treatment options** → **Selecting personalized treatment plans**

…given disparate sources and varying completeness

…based on relevant guidelines and medical literature

…based on co-morbidities, conditions, contraindications, side effects for a patient's specific clinical attributes

Researchers are challenged with…

Staying up-to-date on medical literature → **Exploring and uncovering novel connections** → **Generating new insights for future research**

… like rapidly increasing volume of medical literature

…looking across scientific domains for new relationships between diseases, genes and drugs

…to develop valid hypotheses with the potential to lead to groundbreaking discoveries

73

… the number of days it will take medical data to double by 2020 [1]

80%

of the world's healthcare data is unstructured [2]

<5

hours or less per month spent reading medical journals by 81% of reporting physicians [3]

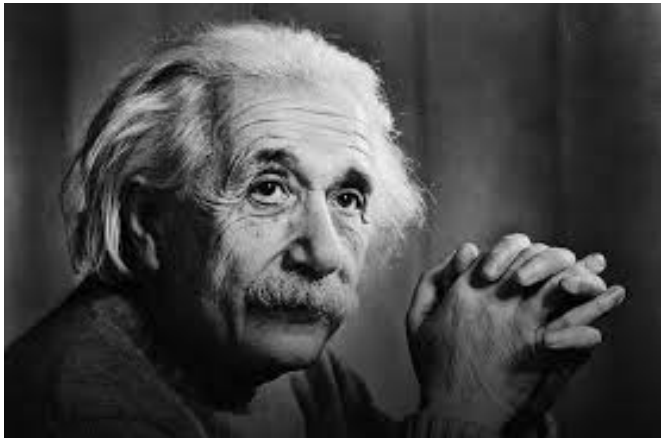
Unstructured Medical Data - a huge ocean of unused information

1. Densen P. *Transactions of the American Clinical and Climatological Association*. 2011;122:48-58.

2. https://ehrintelligence.com/news/where-is-the-value-in-physician-notes-unstructured-data

3. Smith R. The trouble with medical journals. *Journal of the Royal Society of Medicine*. 2006;99(3):115-119.

Finding information from unstructured data is Challenging



Question: Where was Einstein born?

Structured

Person	Born In
A. Einstein	Ulm

Unstructured

"One day, from among his city views of Ulm, Otto chose a watercolor to send to Albert Einstein as a remembrance of Einstein's birthplace."

What is cognitive computing?

***Cognitive**:* of, relating to, or involving **conscious mental activities** (such as thinking, understanding, learning, and remembering)[1]

Cognitive computing is a new computation paradigm that…

- learns and builds knowledge from various structured and unstructured sources of information;

- understands natural language and interacts more naturally with humans;

- Uses machine learning, designing computers to act without being explicitly programmed and developing algorithms to evolve behaviors based on data allowing prediction

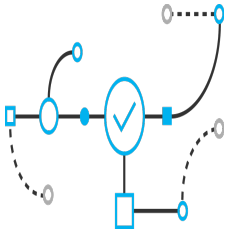
- devises complex models and algorithms that allows computers to find hidden insights without being explicitly programmed where to look.

- enhances the cognitive process of professionals to help improve decision making

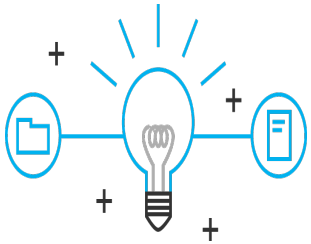
Source[1]: Merriam-Webster Dictionary. [Online]. Available at: http://www.merriam-webster.com/dictionary/cognitive

IBM Watson is a technology platform for **cognitive computing** that uses **natural language processing and machine learning** to reveal **insights** from large amounts of **unstructured data.**

Understanding



Reasoning

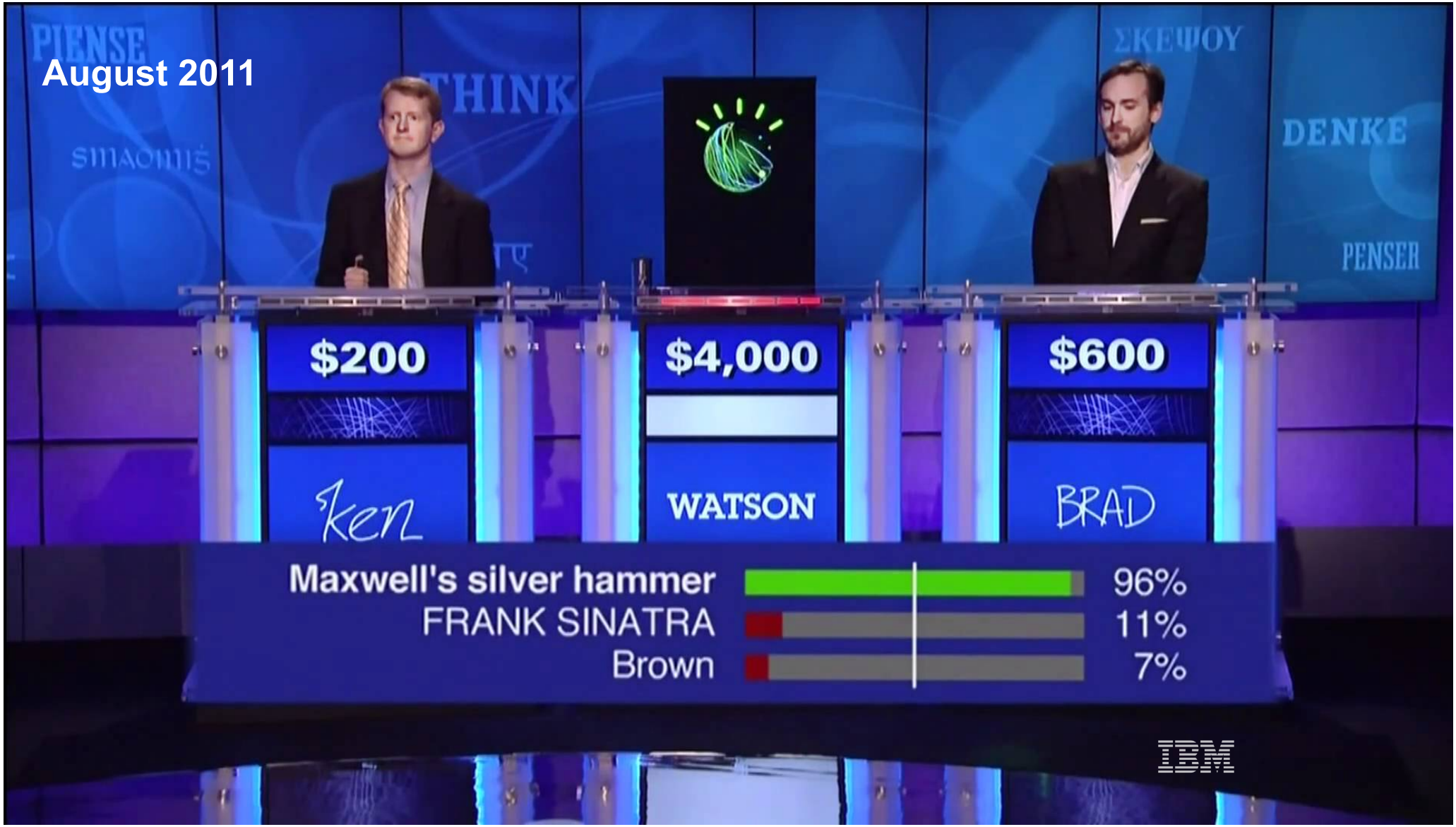


Learning

Interact

Initial Goal of IBM Watson – Augment Human Expertise

- Given
  - Rich Questions posed in **Natural Language**
  - Over a **Broad Domain of Knowledge**
- Goal is to Deliver
  - **Relevant Insights**
  - **Confidence-weighted insights**
  - **Provide Context**
  - **Fast Response Time**



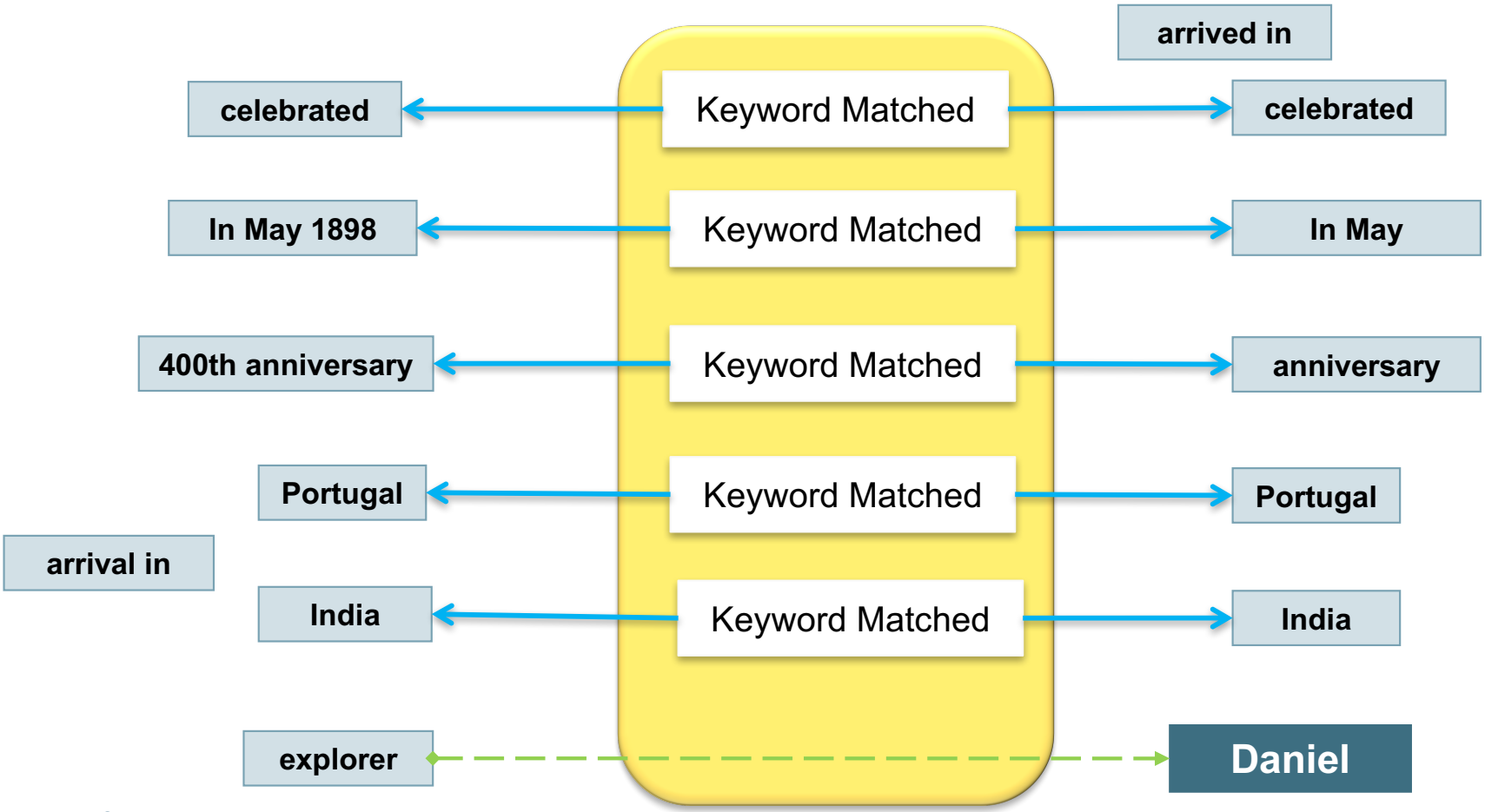
Performing keyword based search to answer a question

Question:

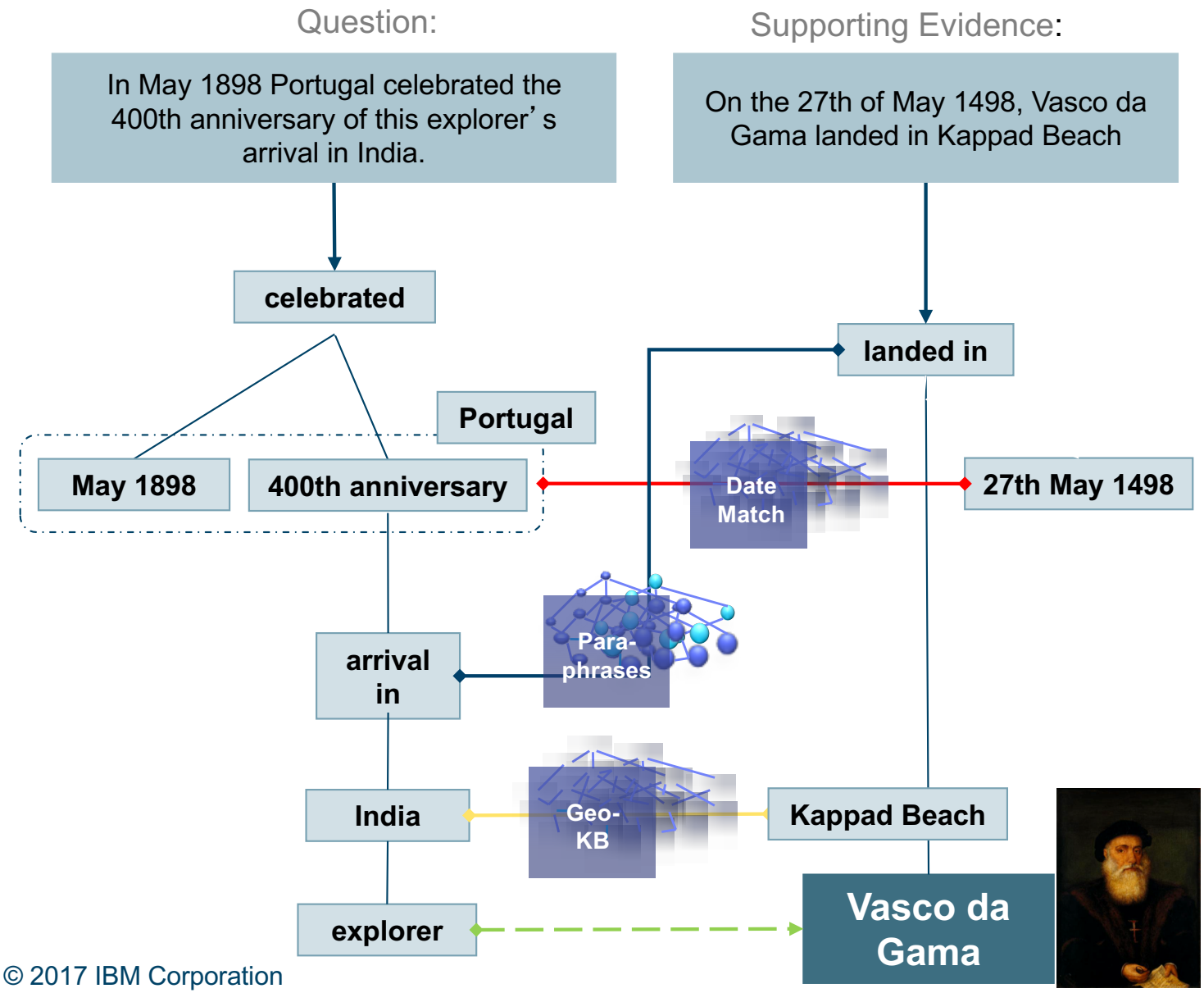
In May 1898 Portugal celebrated the **400th anniversary** of this explorer's **arrival in India**.

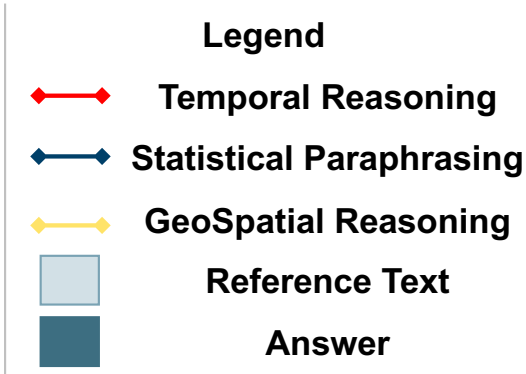
Supporting Evidence:

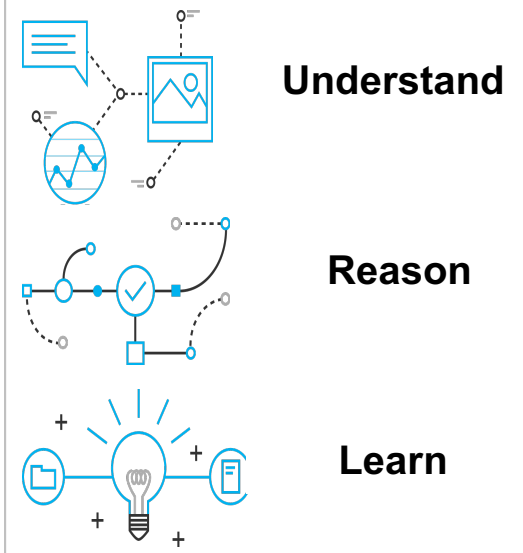
In May, Daniel **arrived in India** after he **celebrated** his **anniversary** in **Portugal**.



Cognitive is much more than a keyword based search.







Core Watson today: The Watson Developer Cloud

Close to 30 services available today – a few examples provided below

Data
Insights

Language

Speech

Vision

Access the site to see the latest additions and updates
[Watson Developer Cloud]

Sample Use Case: A company wants to understand the personality characteristics of its customers for fine grained customer segmentation and create highly personalized interaction channels, better customer care

Solution: **Personality Insights API** in Watson Developer Cloud can extract and analyze a spectrum of personality attributes to help discover insights about people and entities to fine tune marketing messages

Sample Use Case: A company wants to translate some patents from Spanish into English for its IP research

Solution: **The Watson Language Translation service** provides domain-specific translation utilizing Statistical Machine Translation techniques that have been utilized over the past few decades

Mission: *Aspire to improve lives and give hope by delivering innovation to address the world's most pressing health challenges through data and cognitive insights.*

HEALTHCARE & LIFE SCIENCES

Insights
Cognitive & Advanced Analytics

Real World Data
Structured & Unstructured

HIPAA-enabled, GXP-enabled Cloud

To do our part to drive bold and comprehensive transformation, we've built best-in-class capabilities in six key areas across the health landscape:

Oncology and Genomics
Working to help our clients transform cancer care for patients and providers

Imaging
Working to help our clients expand the role of medical imaging for better patient care

Life Sciences
Working to help our clients advance more rapid and efficient delivery of targeted and effective therapies

Value-Based Care
Working to help our clients manage cost and address quality by managing risk and populations, engaging with consumers, and making more confident decisions

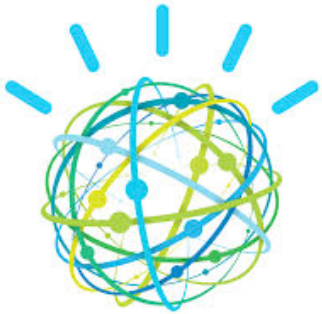
Government
Working to help our clients improve the value of health and human services, lower costs, and have a meaningful impact on people's lives

Consumer
Working to help our clients empower individuals to lead healthier lives

Two paths to innovation leveraging the power of Cognitive

Cognitive Solutions

solutions that are configured and trained to address specific use cases in Healthcare and Life Sciences industry



Cognitive Services

atomic services that address fundamental problems in processing unstructured medical information which can be rapidly combined to create meaningful solutions

Hardened industry solutions

Innovation platform for next generation apps

Watson for Oncology trained by Memorial Sloan Kettering

Ability to surface insights from a vast body of medical literature, publications and guidelines data as physicians consider evidence-based treatment options for patients.

2 Use those attributes to find candidate treatment options as determined by consulting NCCN Guidelines.

Memorial Sloan Kettering Cancer Center

3 Search a corpus of evidence data to find supporting evidence for each option.

Candidate Treatment Options

Patient Case

61 y/o woman s/p mastectomy is here to discuss treatment options for a recently diagnosed 4.2 cm grade 2 infiltrating ductal carcinoma…

Key Case Attributes

Watson Oncology

Supporting Evidence

Evidence

- Inclusion / exclusion criteria
- Co morbidities
- Contraindications
- FDA risk factors
- MSK preferred treatments
- Other guidelines
- Published literature - studies, reports, opinions from Text Books, Journals, Manuals, etc.
- …

Treatment Plans

1 Extracts key attributes from a patient's case.

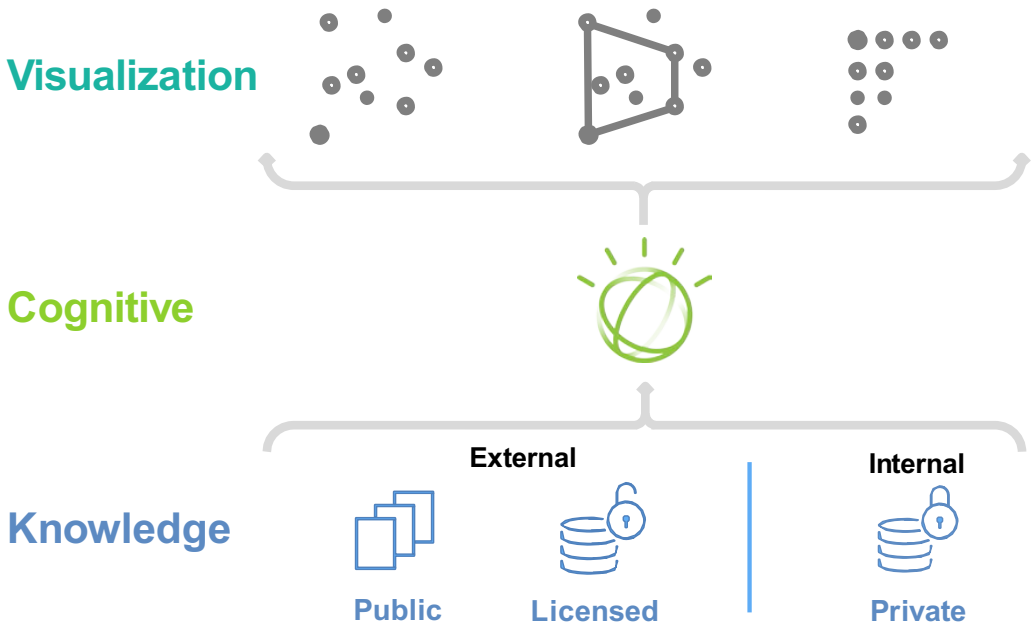
Prioritized Treatment Options + Evidence Profile

4 Use Watson analytics algorithms to rank treatment options based on evidence.

Life Sciences Cognitive Solution: Watson for Drug Discovery

Watson for Drug Discovery is a **cloud-based**, **end-to-end scalable platform** that helps life science researchers discover new disease pathways, new drug targets and additional drug indications

Three Core WDD Components



The Watson Advantage

Key Capabilities

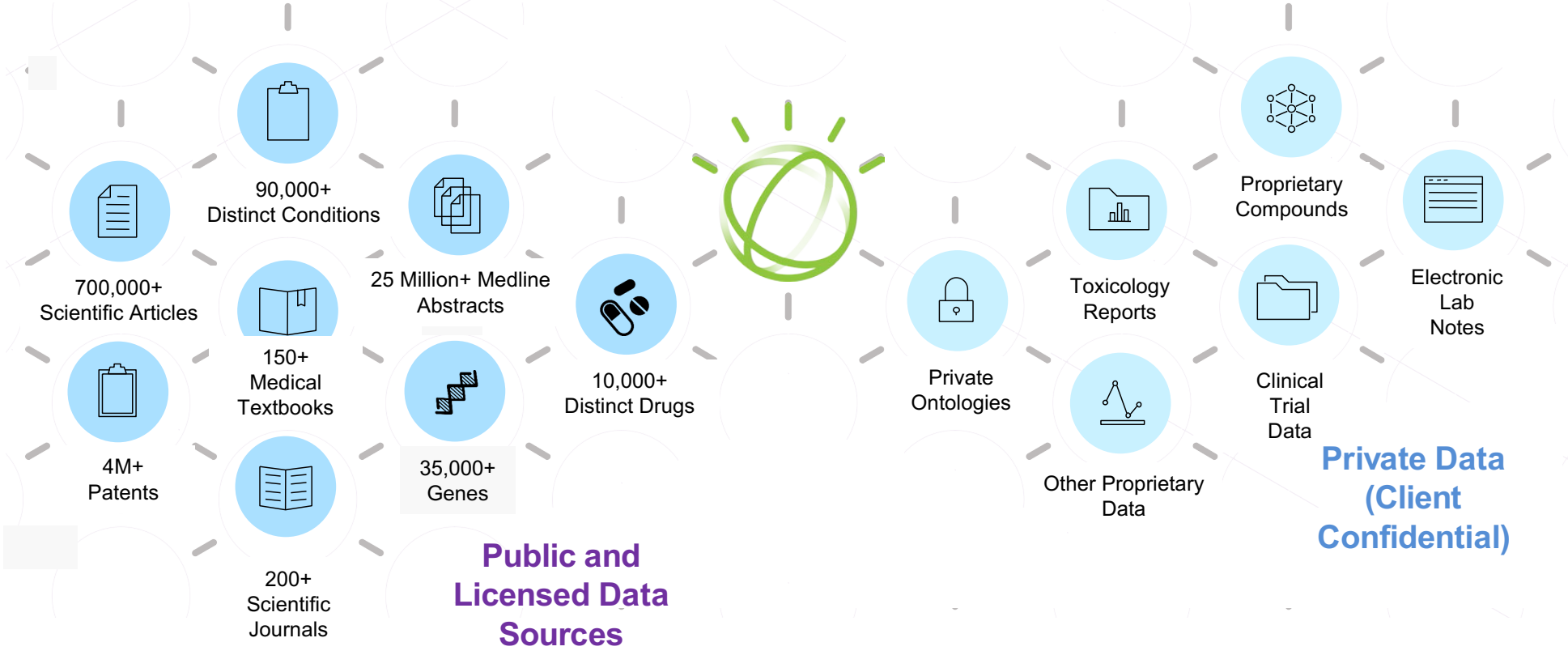
- **Aggregates** diverse content
- **Cognitive** technology
- **Scalability**
- **Domain understanding**
- **Agility / speed**

Key Benefits

Helps:

- **Accelerate** insight generation
- Improve researcher **productivity**

Watson for Drug Discovery looks broadly across public, licensed and private data to unlock hidden information and deliver insights



Other Cognitive Solutions

- **Watson for Clinical Trial Matching -** enables clinicians to quickly match patients with potential trials for cancer treatment using cognitive computing combined with natural language processing.
- **Watson for Genomics -** can help oncologists deliver precision medicine to their patients by providing information personalized to a patient's tumor genomics using relevant information extracted from the massive volumes of medical literature.
- **Watson for Patient Safety* –** will support the detection, evaluation, and coding of adverse events contained in thousands of pages of spontaneous reports and medical literature.

* Not available – Solution is currently under development, available as a Proof-of-Concept

Cognitive Services Platform

- Watson cognitive solutions address some of the most difficult data and analytics challenges in healthcare & life sciences industry
- However in order to scale we need a **cognitive innovation platform** that allows rapid development of cognitive solutions
- Watson Health Cognitive Services Platform is designed to assist application developers to **rapidly build apps** using available cognitive services in a HIPAA-enabled environment
- A **growing portfolio of healthcare services** are under development and are expected to be made available in the future
- Some of these are microservices while others are more coarse grained

Conclusion

- Cognitive Computing is able to combine machine learning and natural language to reveal insights from large amounts of unstructured information
- Cognitive Computing can help transform the Healthcare and Life Sciences industry by uncovering data-embedded within unstructured information and generate insights
- IBM Watson has a family of Healthcare and Life Sciences solutions that can help address some of the most difficult problems for our customers
- At IBM Watson Health we are building a Cognitive Innovation Platform for Healthcare that is designed to allow rapid development of healthcare apps leveraging a set of cognitive services that address some of the fundamental challenges in processing unstructured medical content

Backup

IBM Watson Health

Understand

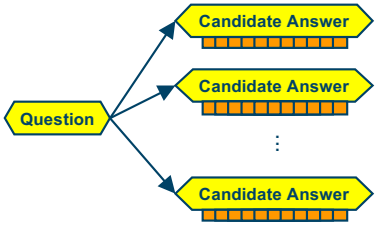
Structured and Unstructured Data

Consumes large amounts of data and interprets and understands natural language

Deep semantic and contextual understanding of the data

Reason

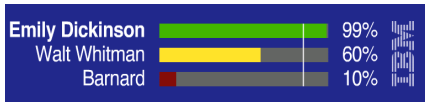
For Possible Answers



Identifies many answers to questions and gathers supporting evidence

Candidate answers with supporting evidence

Supporting Evidence to Generate Confidence

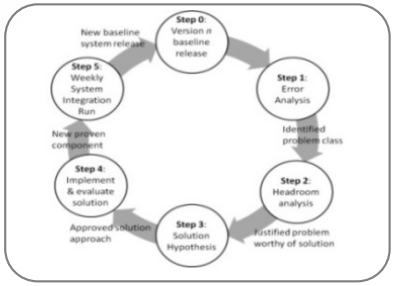


Evaluates hypotheses and quantifies confidence in answers

Candidate answers ranked by confidence score

Learn

From Past Experience to Predict Better Outcomes



Adapts and learns to improve results over time

Improved accuracy based on learning from additional evidence, additional questions and feedback

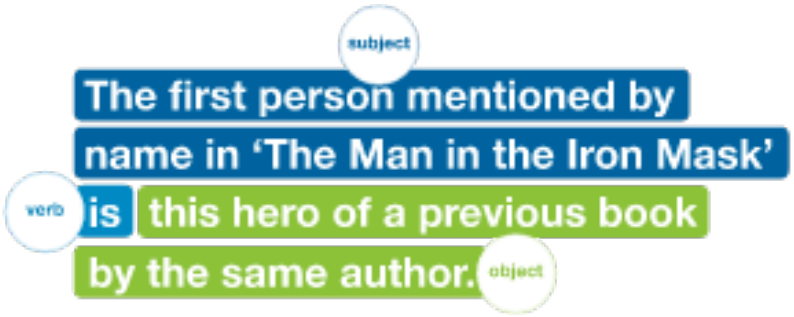
How Watson answers questions

First Watson learns a new subject..

- All related materials are **curated and loaded** into Watson, such as Word documents, PDFs and web pages
- Watson taught on **relevant concepts, relationships** in that subject
- Sample **questions and answers pairs** used to **train Watson** on the subject **by SMEs**
- Watson is **updated** as new information is published

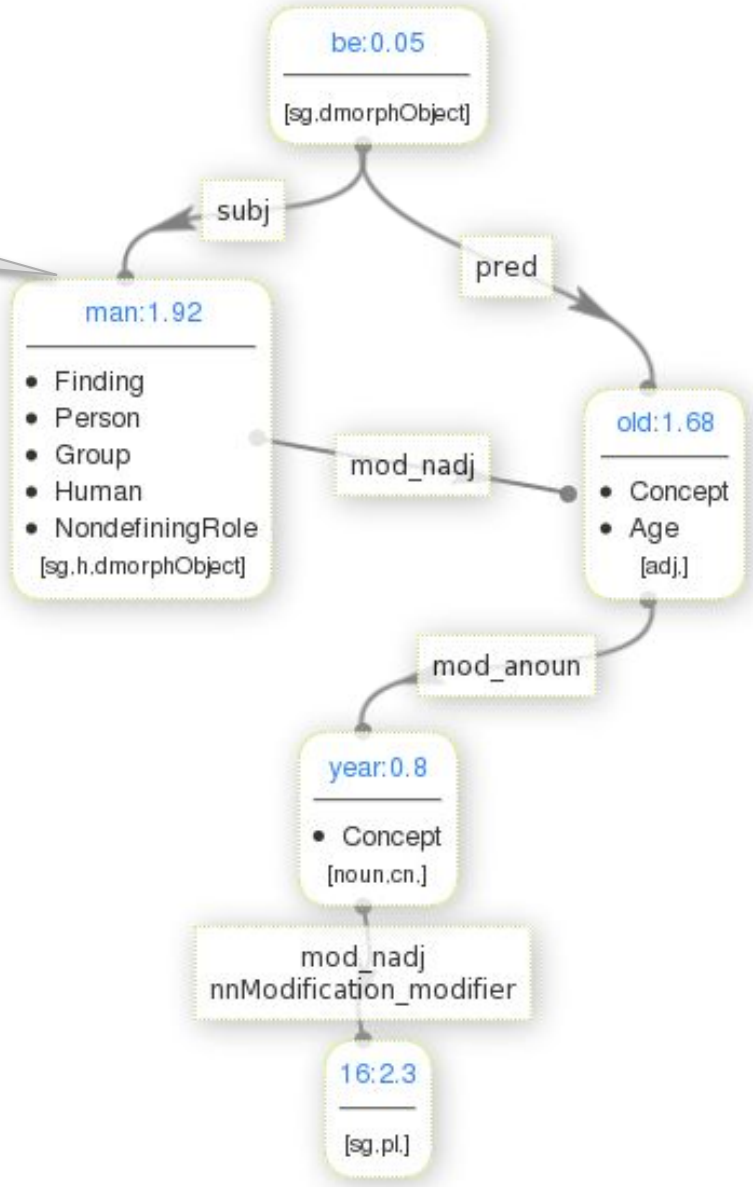
Then Watson answers a question..

- Watson can **search** millions of documents to find thousands of possible answers
- **Collects evidence** and uses **scoring algorithms** to rate the quality of this evidence
- **Ranks** all possible answers based on the score of its supporting evidence and as per training from SMEs



Understand: Sentence Parsing

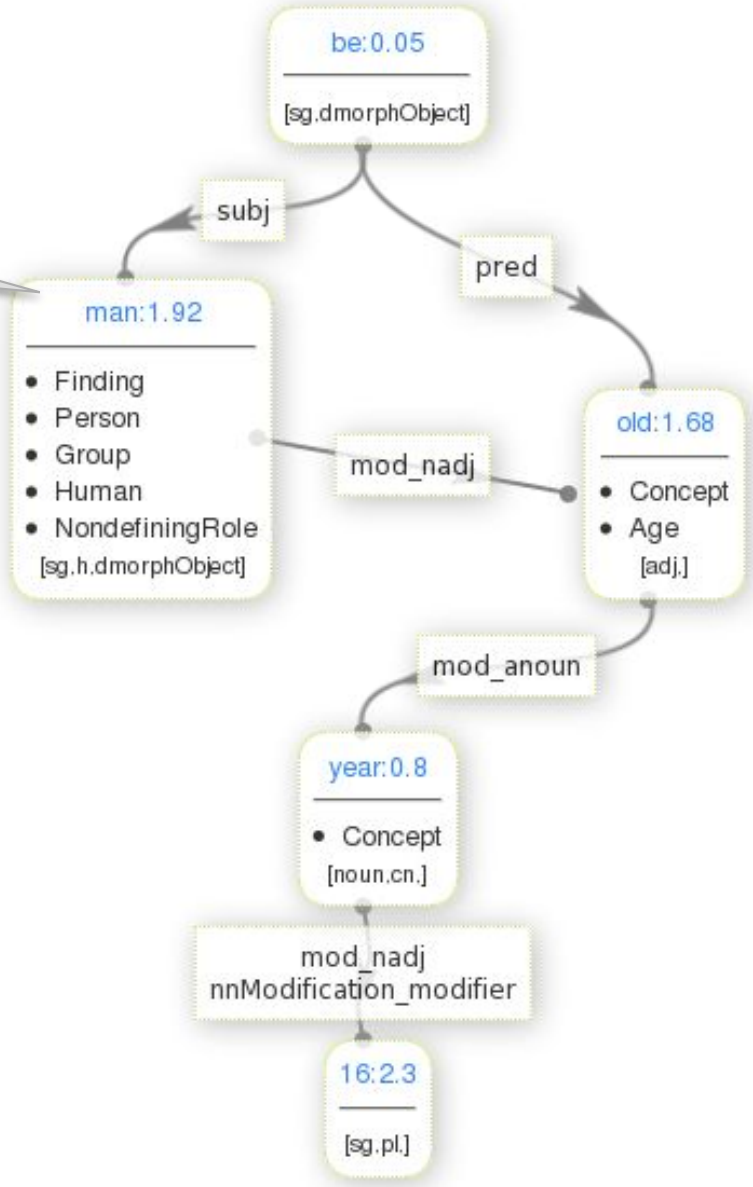
The man is sixteen years old.



- Diagram the sentence
  - Look for verbs, nouns, subjects, etc.
  - Look for punctuation, clauses, conjunctions, etc.
  - Sentence **structure and syntax** provides insight into the meaning
- Standardize the sentence
  - Lemma words
  - Number standardization
  - Many more

Understand: Named Entity Detection

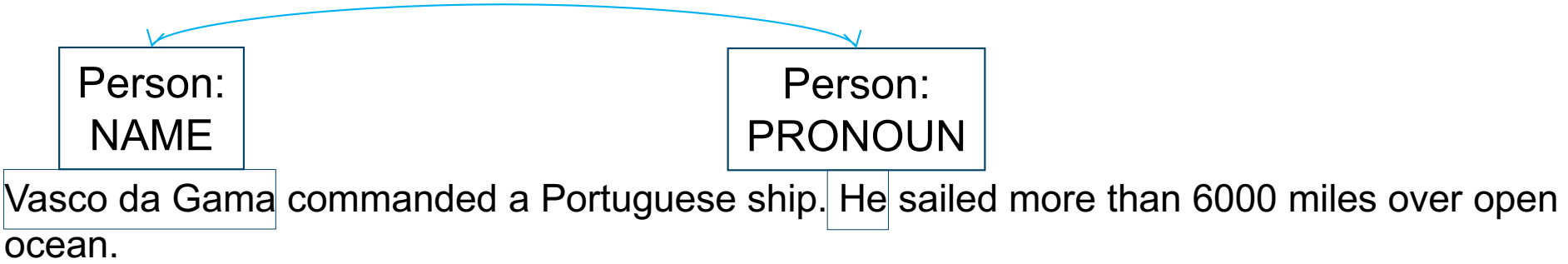
The man is sixteen years old.



- What do the words represent?
  - "Louvre" probably refers to a museum
  - "Porsche 911" probably refers to a car
- Man
  - may refer to a human
  - may refer to all people
  - may be a specific person in the sentence
- How rare are these words? Rare words are often important words in the detection of concepts

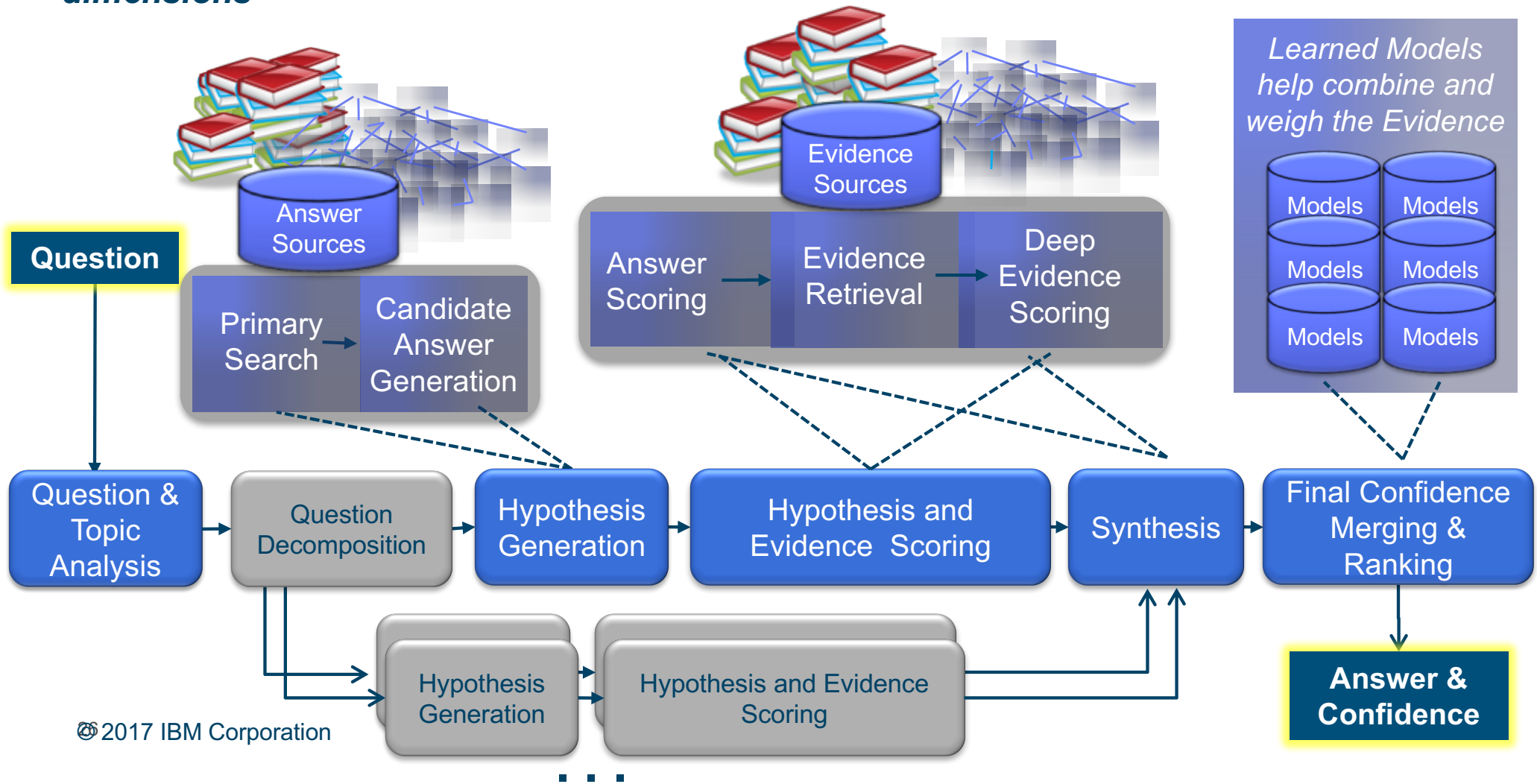
Understand: Inference

- Relies on results of grammar, named entity detection, etc.
- Determines when some text refers back to some previously mentioned entity
- Watson knows that “He” refers to “Vasco da Gama” because this relationship is expressed in the text. **Watson only knows what he can read.**



The DeepQA architecture inside Watson

Generates many hypotheses, ***collects a wide range of evidence*** *and balances the combined confidences of* ***over 100 different analytics that analyze the evidence form different dimensions***



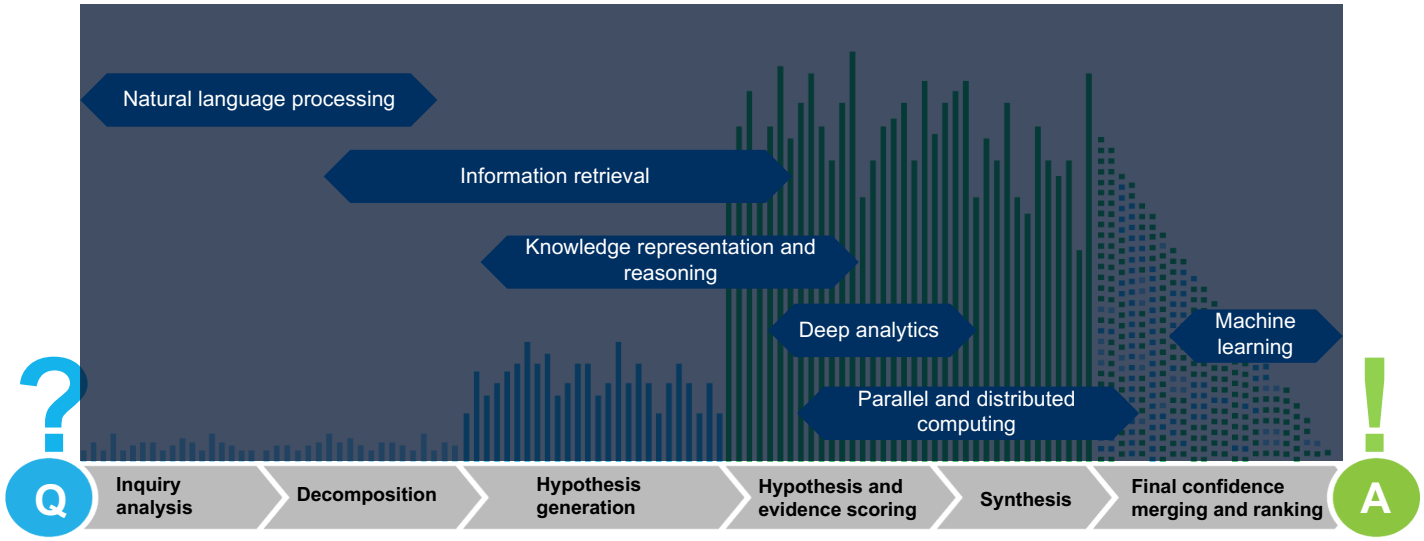
DeepQA Architecture

Multiple interpretations

Hundreds of answer sources
- Primary search
- Candidate answer generation

Tens of thousands of evidence sources and scores
- Answer scoring
- Evidence retrieval
- Deep evidence scoring

Learned models
- Combine and weigh evidence



Watson for Clinical Trial Matching

Business challenge:

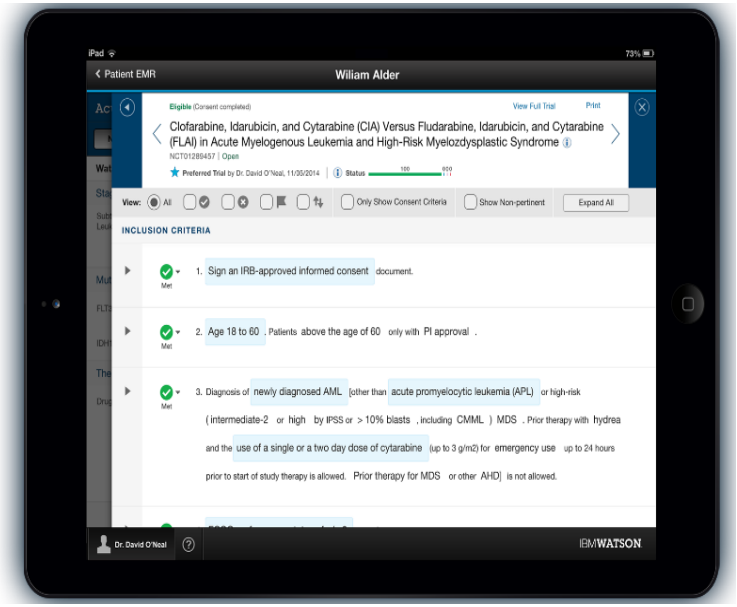
- Clinicians have **no easy way to search across eligibility criteria** of relevant clinical trials for their patient

Watson solution:

- Use patient data to identify candidate trials for which the patient might be eligible by providing criteria level evaluation based on a patient's attributes

Two use cases:

- **Point of care**: assess patient eligibility against all available trials
- **For the Sponsor:** provide the sponsor insight into the recruitment pipeline for their trial at a specific site



Initial focus is oncology, Watson is trained in breast, lung, colon and rectal cancer, with other tumor types to follow

15%
Cancer patients are aware of clinical trials as a treatment option [1]

20%
.. of oncology clinical studies are completed on time [2]

<5%
Of cancer patients enroll in a clinical trial [1]

>12,000
Active clinical trials worldwide [3]

1 . Madsen LT, Kuban DA, Choi S, et al. Prostate Cancer Clinic. *Journal of the National Comprehensive Cancer Network : JNCCN*. 2014;12(7):993-998.

2. http://www.drugdevelopment-technology.com/features/featureclinical-trial-patient-recruitment/

3. National Cancer Program - http://www.cancer.ucla.edu/patient-care/enroll-in-a-clinical-trial

IBM launched an initiative to accelerate a new era of genomic medicine

Challenges

As the cost of Next Generation Sequencing decreases, we anticipate that there will be an increase in tumor genome sequencing resulting in massive quantities of genetic data to analyze.	Clients stated that it can take from days to weeks to perform a comprehensive manual analysis of the genetic alterations for one patient	Identifying alterations driving the patient cancer and matching them with molecular targeted therapies using multiple data sources is extremely complex and labor-intensive

Value

"Using Watson's cognitive computing capabilities, I hope it will be possible for oncologists like me to quickly mine insights from the immense amount of genomic data that's becoming available about individual patients by using Watson to identify potential drugs that target our patients' specific genetic profiles."
– Dr. Lukas Wartman, Cancer Survivor and Assistant Director, Cancer Genomics, The Genome Institute at Washington University.

The more exciting part is that in 30 percent of patients, Watson found something new—so that's 300-plus people where Watson identified a potential treatment for consideration that a well-meaning, hard-working group of physicians hadn't found – Dr. Ned Sharpless, head of the University of North Carolina's Lineberger Comprehensive Cancer Center.

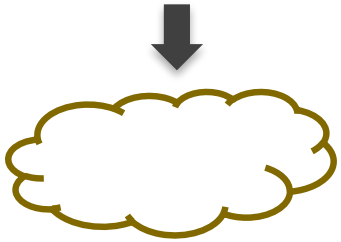
Success

Launched and available in two offerings:
WfG (standalone)
Watson Genomics from Quest Diagnostics® (End-to-End)

Watson for Genomics Overview

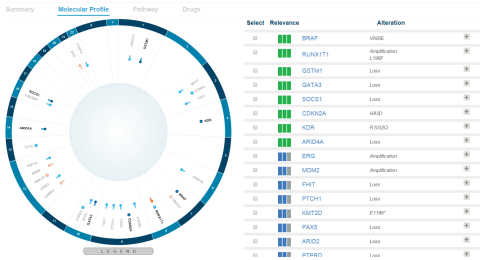
Case Sequenced

VCF / MAF, Log2, Dge, Fusion
Encryption

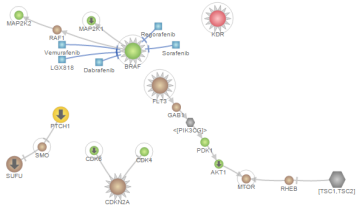


Service Analysis, Reports, & Visualizations

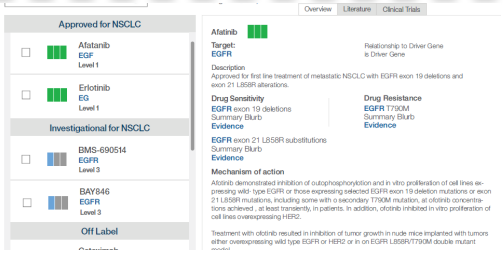
Molecular Profile Analysis



Pathway Analysis



Drug Analysis



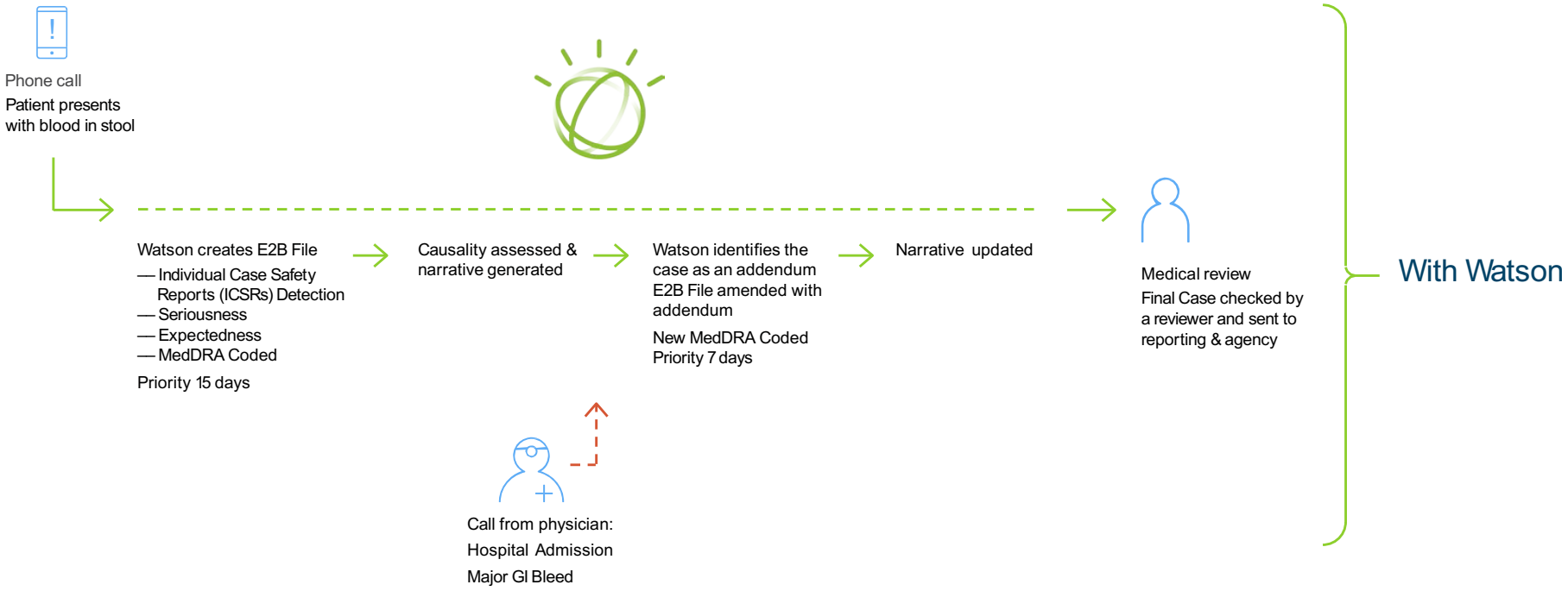
Content

- 20+ Content Sources Including:
  - Medical Articles
  - Drug Information
  - Clinical Trial Information
  - Genomic Information
  - OncoKB by MSKCC

Functionality Highlights

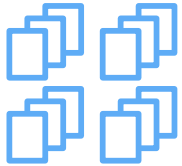
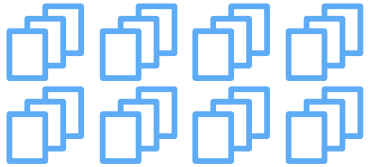
- "Born in the cloud" multi-user and multi-tenant solution with a single code base
- No customization, configuration or integration required for initial use
- Security rich environment managed by IBM and industry standards
- Patient data uploaded to WfG is de-identified (de-identified mutated DNA)
  - Accepted input data includes somatic mutations, copy number variations, gene expression and fusion
  - Supports gene panels, whole exome and whole genome sequenced files
  - Natural Language Processing (NLP) used to extract information from extensive medical literature (over 23 millions articles)
  - 20+ structures and unstructured data sources ingested
- Analytics engine to identify relevant alterations, drugs and clinical trials for specific types of cancer
- Report and interactive visualizations of the molecular profile, drugs and pathways
- Summary report shows target therapeutic options categorized by FDA approved for the patient cancer type, Investigational and FDA approved for other cancer types
- Evidences presented via hyperlinks to sources for easy drill down

What if case processing for life sciences companies could become a largely automated process?



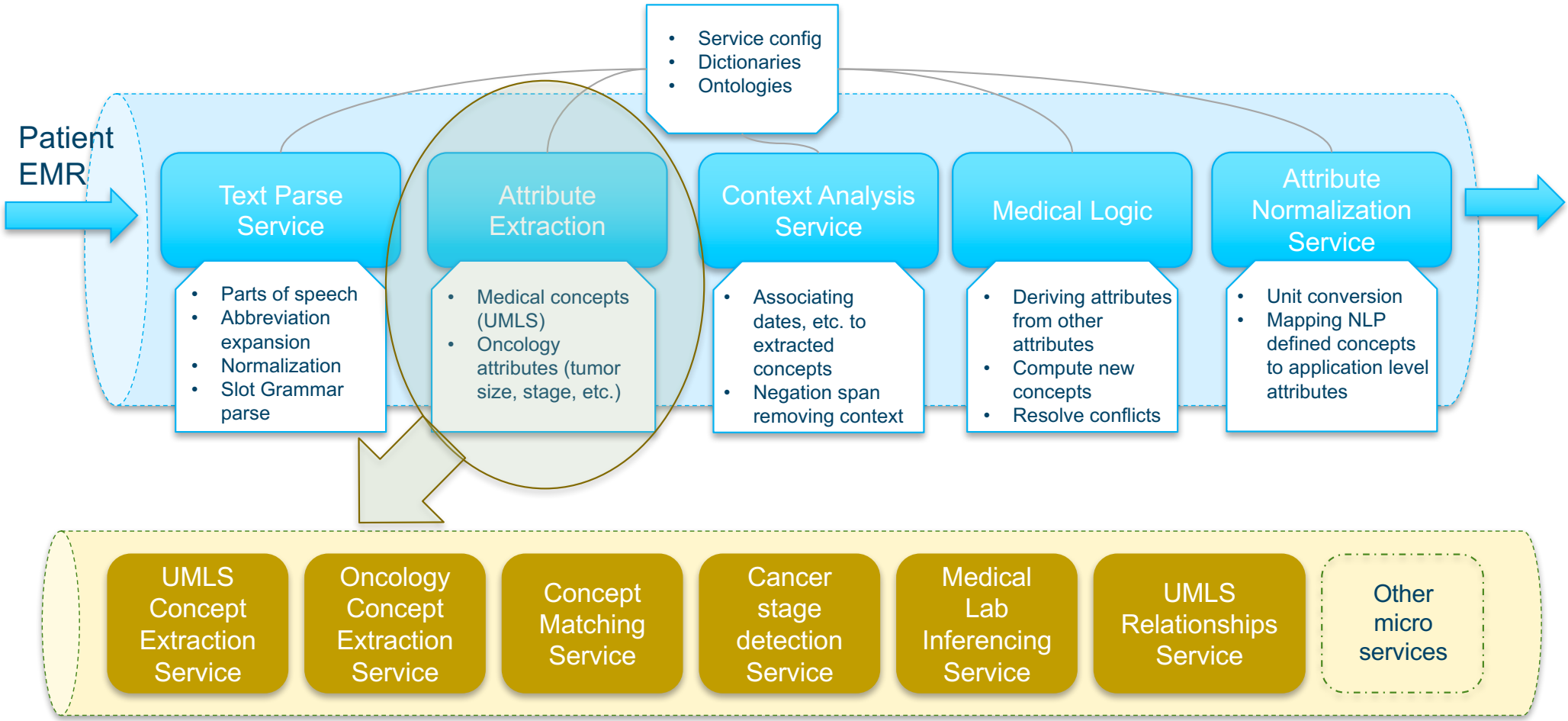
Watson for Patient Safety uses cognitive computing to help increase speed and efficiency of case processing

With Watson, we aim to transform these processes by reducing the time and manual effort required, while maintaining a high level of quality, consistency and accuracy

Current Process	Reports & Literature	Intake	Case Processing
			
With Watson	Reports & Medical Literature	Intake	Case Processing
			

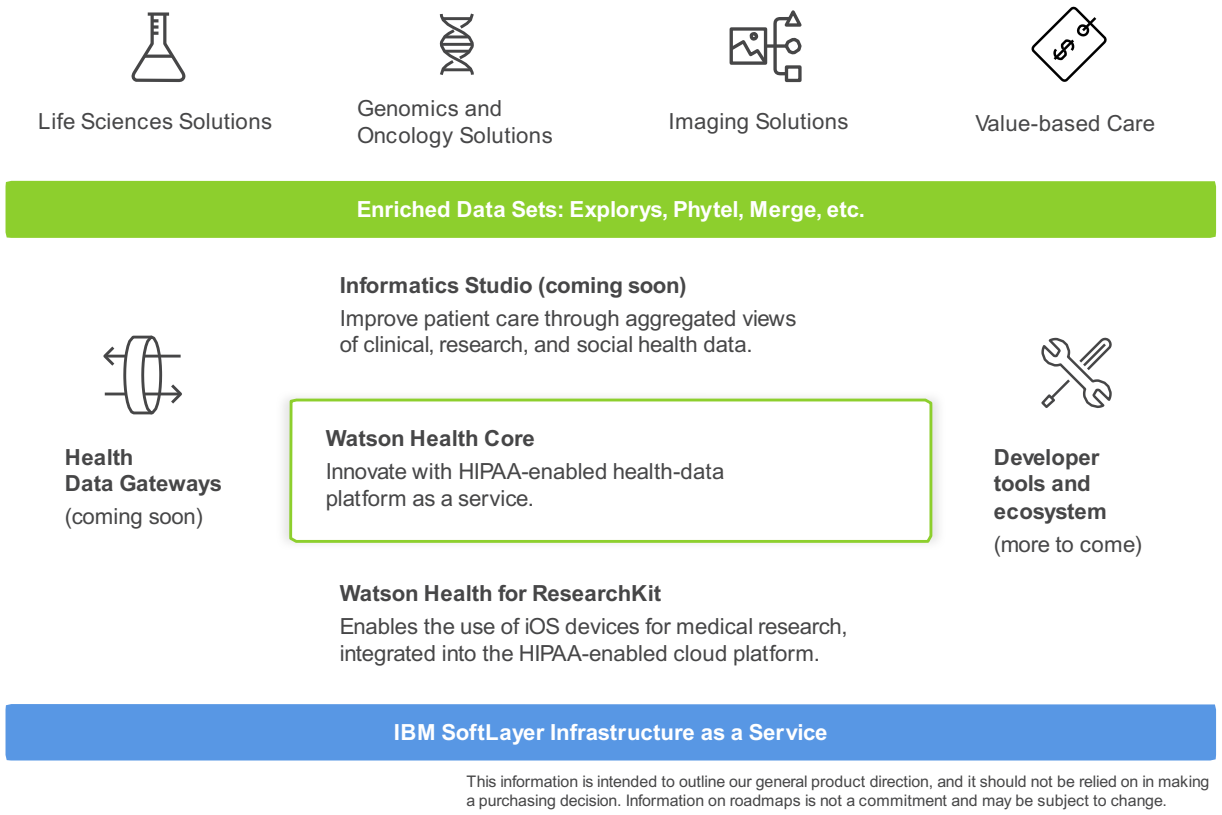
Developers can rapidly build healthcare apps leveraging the healthcare cognitive services platform

Sample Use Case: Build a cognitive pipeline that will take in patient EMR data (unstructured) and extract Oncology specific attributes (structured)



Watson Health Core Services and the Watson Health Portfolio

Watson Health Core offers a landing zone where multi-dimensional data can be captured and normalized for other health and research applications to use..



This information is intended to outline our general product direction, and it should not be relied on in making a purchasing decision. Information on roadmaps is not a commitment and may be subject to change.