Watson™ Beyond Jeopardy!™: Adaptation to the Medical Domain

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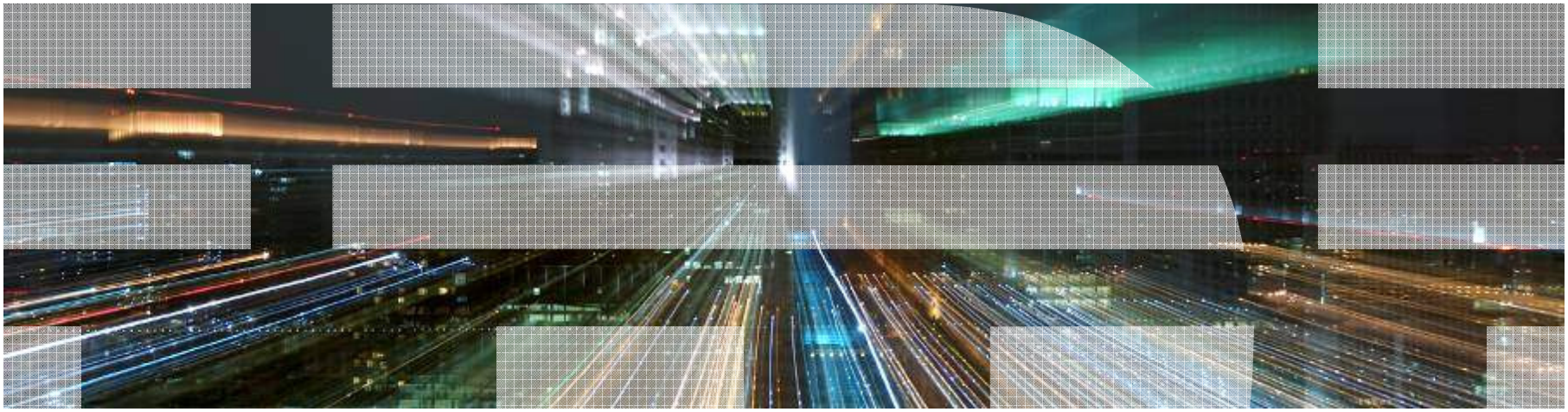
Research Work by the Watson Technologies Team



WATSON AND THE JEOPARDY! CHALLENGE

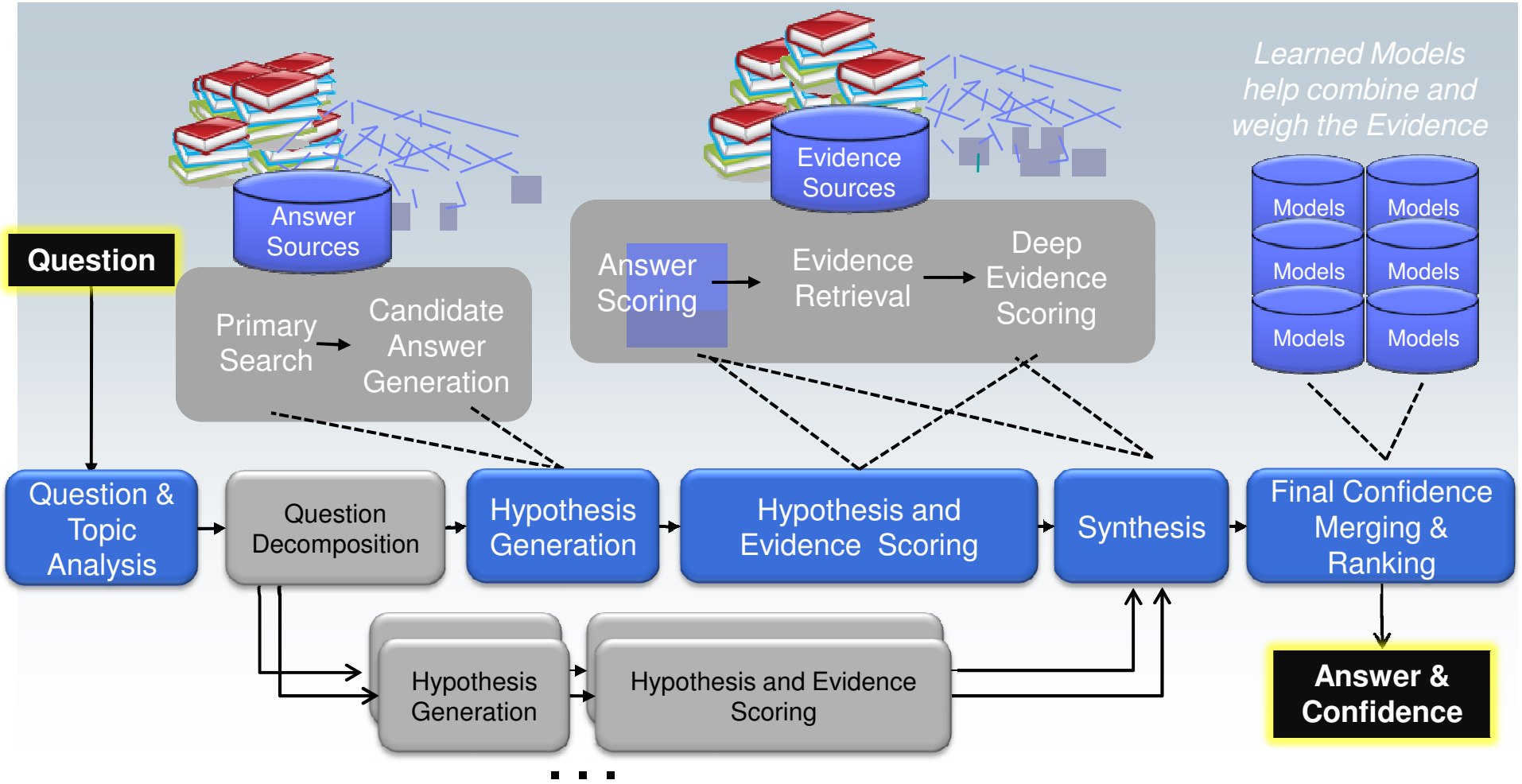
Automatic Open-Domain Question Answering

A Long-Standing Challenge in Artificial Intelligence to emulate human expertise

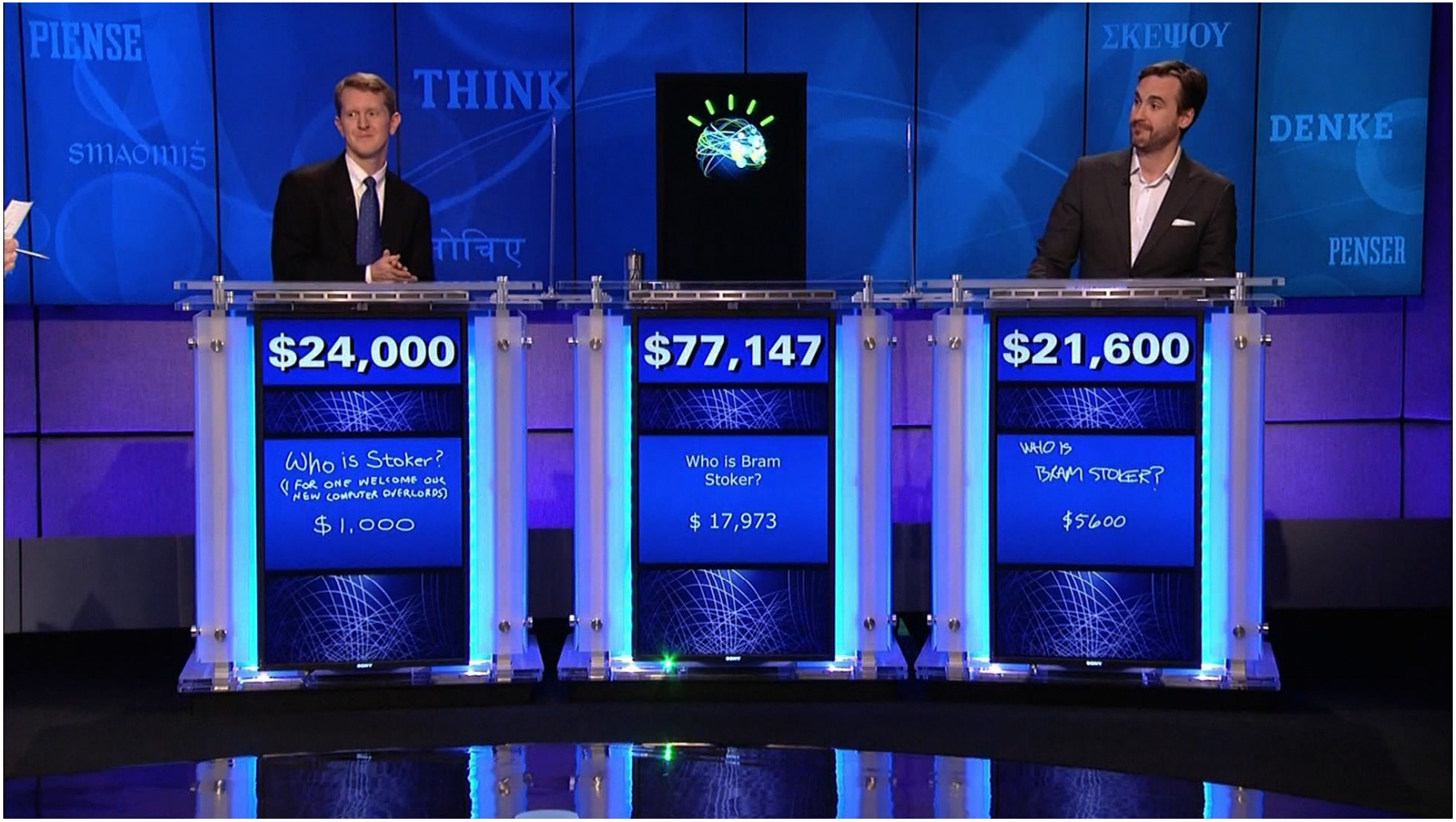
- Given
  - Rich **Natural Language Questions**
  - Over a **Broad Domain of Knowledge**
- Deliver
  - **Precise Answers:** Determine what is being asked & give precise response
  - **Accurate Confidences:** Determine likelihood answer is correct
  - **Consumable Justifications:** Explain why the answer is right
  - **Fast Response Time:** Precision & Confidence in <3 seconds

DeepQA: The architecture underlying Watson

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



With Precision, Accurate Confidence and Speed, the rest was History



Watson: A New Era of Computing

System Intelligence

Tabulation

Punch cards
Time card readers

Programmatic

Search	Discovery
Deterministic	Probabilistic
Enterprise data	Big Data
Machine language	Natural language
Simple outputs	Intelligent options

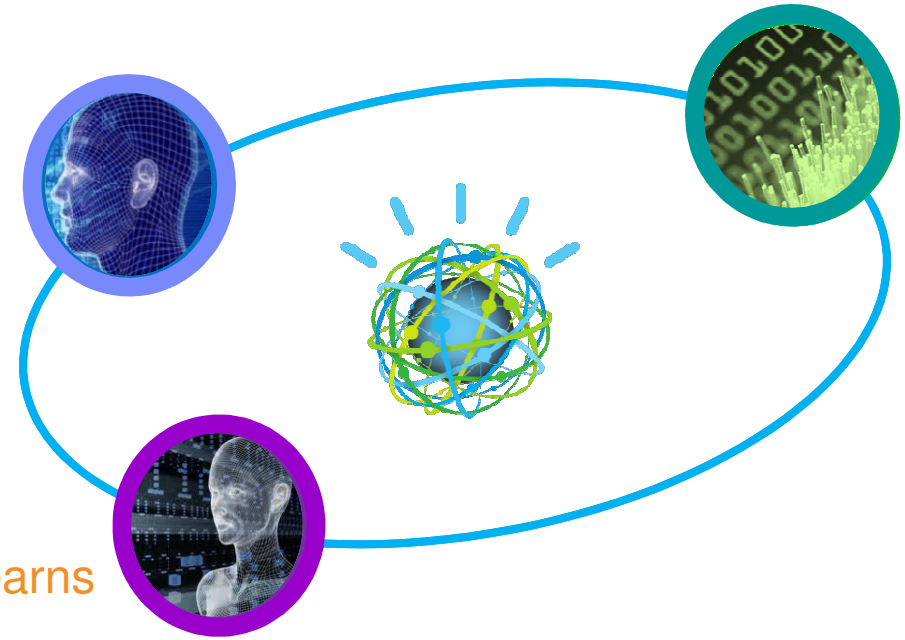
Cognitive

1900 1950 2011

Watson Beyond Factoid Question Answering

1 Understands natural language input

2 Generates and evaluates evidence-based hypothesis



3 Adapts and learns from user selections and responses

WATSON IN HEALTHCARE

Use of Question Answering in Medical Diagnosis

After Watson's win on Jeopardy!, people assumed that anything that could be phrased as a question could be correctly answered by Watson:

Watson, "Given my medical record <insert hundreds of pages of structured and unstructured data here>, what's wrong with me?"

But that isn't what Watson was designed for:

- Watson wants a single sentence question
- Watson wants to find passages based on concepts in the question
- Watson wants to explore candidates found in relevant passages
- Watson wants to align answer-bearing passages with questions

The New Watson Challenge

We accepted the implied challenge to facilitate the reasoning process over a complex scenario:

Input

Complex natural language description of a problem

Output

Evidence-based inference chains leading to hypotheses

Our first domain of exploration is medical diagnosis because of its mature, complex and meaningful problem solving nature

Sample Patient Scenario from US Medical Licensing Exam

A mother brings her 5-year-old son into your office. The boy has papular and pustular lesions on his face. A serous honey-colored fluid exudes from the lesions. A Gram stain of the pus reveals many neutrophils and Gram-positive cocci in chains. The organism is non-motile, catalase-negative, beta-hemolytic on blood agar, and is bacitracin sensitive. What organism is the most likely cause of the disease in this patient?

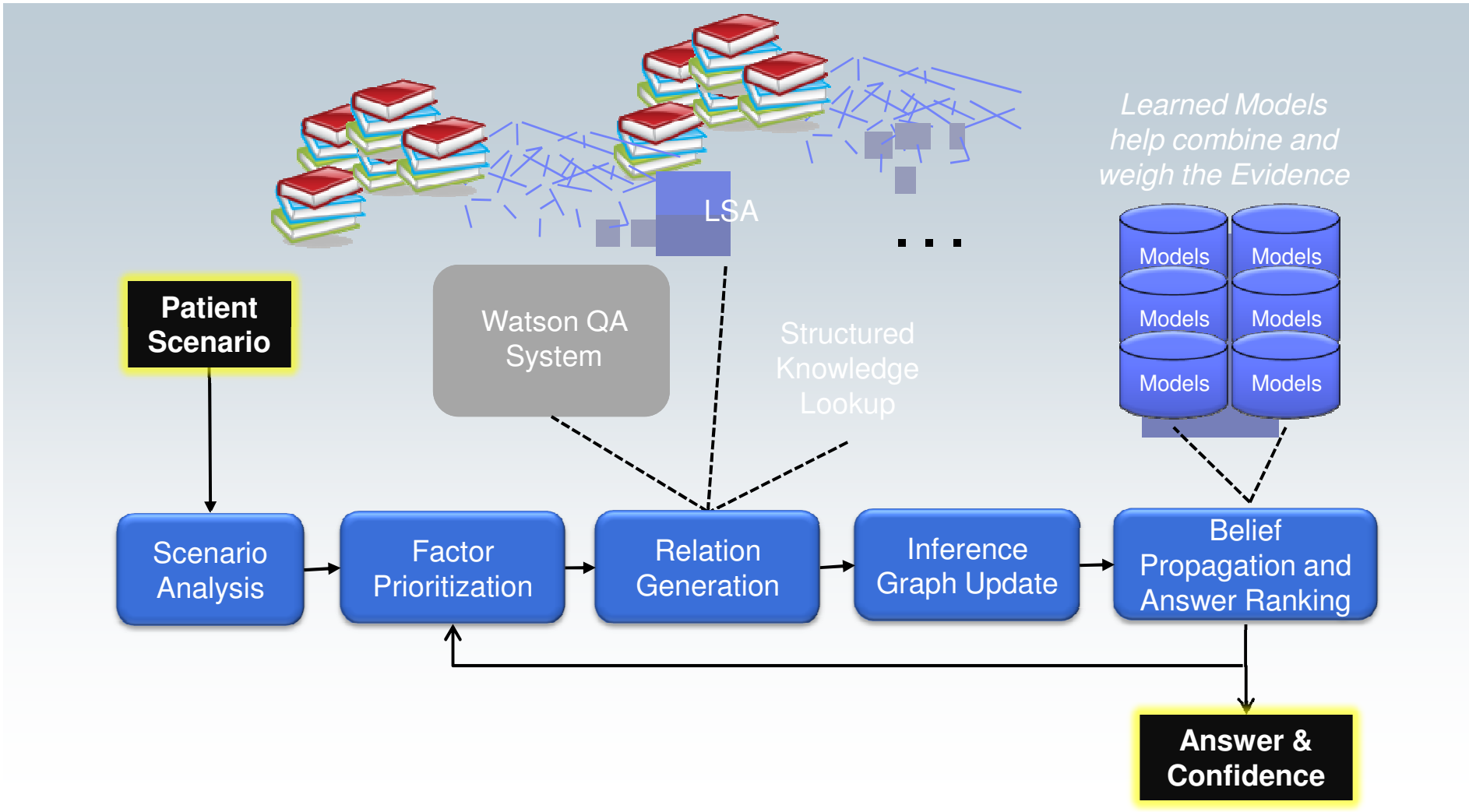
(A) Streptococcus pneumoniae
(B) Staphylococcus aureus
(C) Peptostreptococcus
(D) Streptococcus pyogenes
(E) Staphylococcus epidermidis

A 70-year-old man comes for a follow up with his cardiologist. There are no specific complaints. Findings at the physical exam are BP- 130/80 mmHg, HR- 80 beats/min, and appearance of pale mucous membranes. Lungs are clear to auscultation, and there is no edema of lower extremities. Fecal occult blood test (FOBT) was negative. Blood test shows hypochromic microcytic RBCs. Further exams show low serum iron, low total iron-binding capacity (TIBC) and increased ferritin. What is the most probable diagnosis in this patient?

(A) Anemia of chronic disease
(B) Anemia secondary to iron deficiency
(C) Beta thalassemia
(D) Megaloblastic anemia
(E) Sideroblastic anemia

- The answers are not one step away
- Finding them requires *connecting the dots*
- Shallow language understanding is not enough
- Discovering rationalized paths through the content becomes a key value

WatsonPaths: Beyond Factoid QA



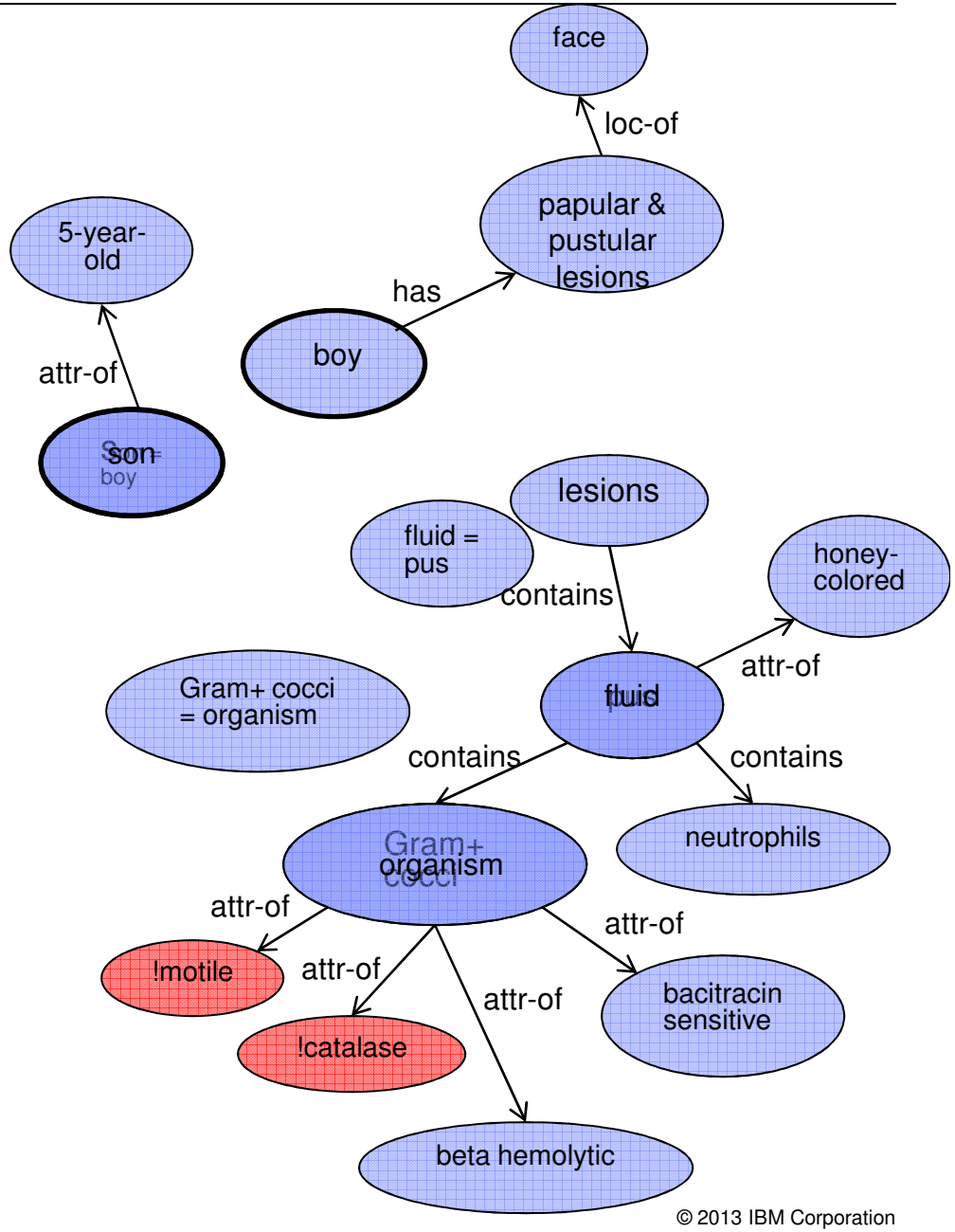
Processing Input Scenarios

A mother brings her 5-year-old son into your office. The boy has papular and pustular lesions on his face. A serous honey-colored fluid exudes from the lesions. A Gram stain of the pus reveals many neutrophils and Gram-positive cocci in chains. The organism is non-motile, catalase-negative, beta hemolytic on blood agar, and is bacitracin sensitive. What organism is the most likely cause of the disease in this patient?

- Objectives:
  1. Figure out what's wrong with the patient
  2. Identifying effective treatment/next steps
- Identify critical information from scenario for diagnosis
  - Parsing
  - Co-reference resolution
  - Negation detection
  - Clinical factor identification

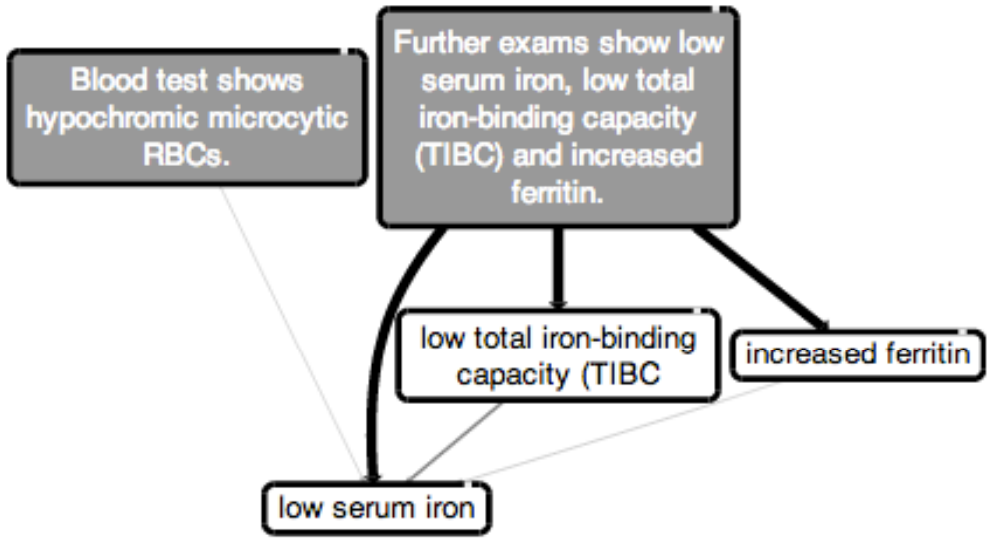
Scenario Analysis Results

A mother brings her 5-year-old son into your office. The boy has papular and pustular lesions on his face. A serous honey-colored fluid exudes from the lesions. A Gram stain of the pus reveals many neutrophils and Gram-positive cocci in chains. The organism is non-motile, catalase-negative, beta hemolytic on blood agar, and is bacitracin sensitive. What organism is the most likely cause of the disease in this patient?



WatsonPaths for Medical Diagnosis

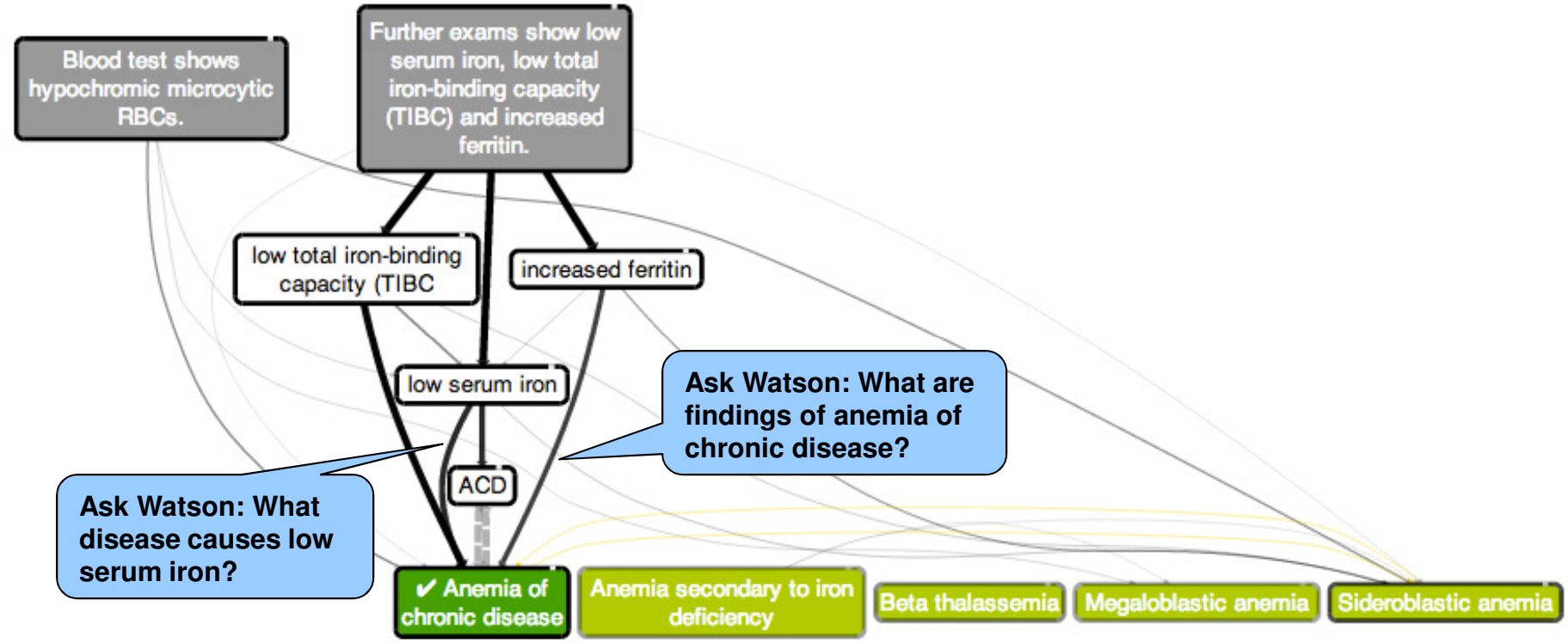
A 70-year-old man comes for a follow up with his cardiologist. There are no specific complaints. Findings at the physical exam are BP- 130/80 mmHg, HR- 80 beats/min, and appearance of pale mucous membranes. Lungs are clear to auscultation, and there is no edema of lower extremities. Fecal occult blood test (FOBT) was negative. Blood test shows hypochromic microcytic RBCs. Further exams show low serum iron, low total iron-binding capacity (TIBC) and increased ferritin. What is the most probable diagnosis in this patient?



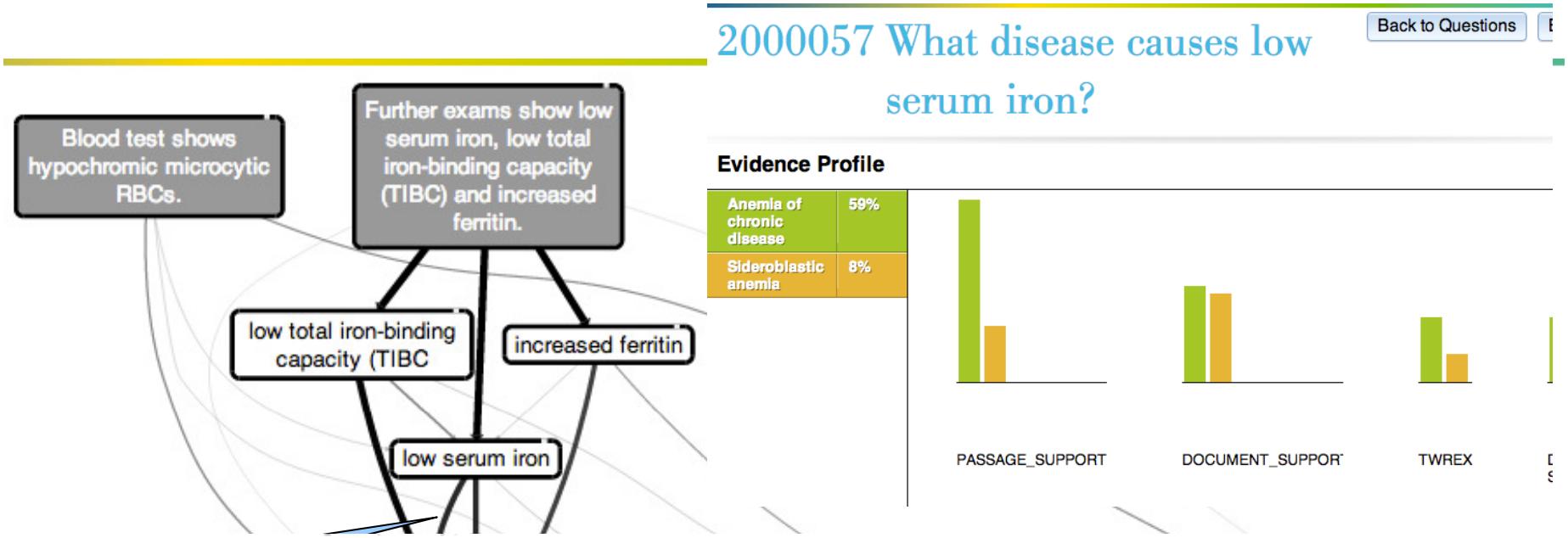
Megaloblastic anemia | Sideroblastic anemia

Anemia secondary to iron deficiency | Beta thalassemia | ✔ Anemia of chronic disease

WatsonPaths for Medical Diagnosis (Cont'd)



WatsonPaths for Medical Diagnosis (Cont'd)



100% **"Rheumatoid arthritis"** *Corpus: Web Corpus Expansion*

▸ Details

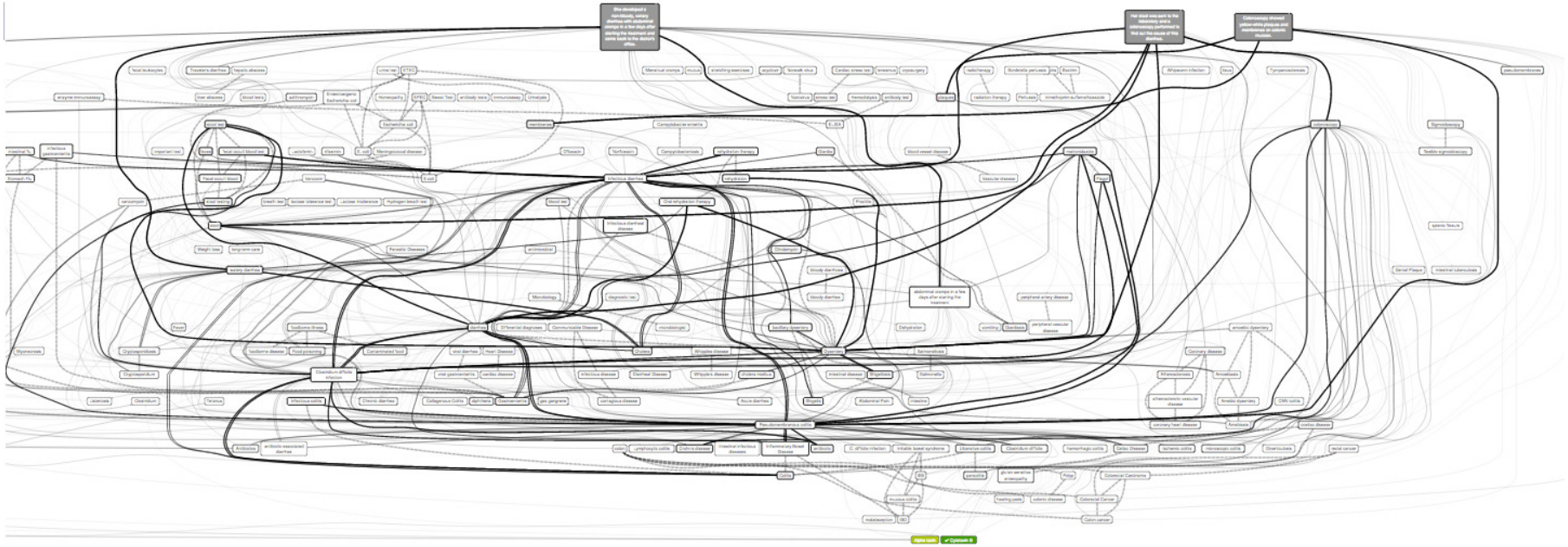
In most cases, the reduced red cell mass is caused by the **anemia of chronic disease**, a normocytic-normochromic process characterized by a low concentration of serum iron, a low serum iron-binding capacity, and a normal or increased serum ferritin concentration.

65% **"Iron deficiency anemia"** *Corpus: Web Corpus Expansion*

▸ Details

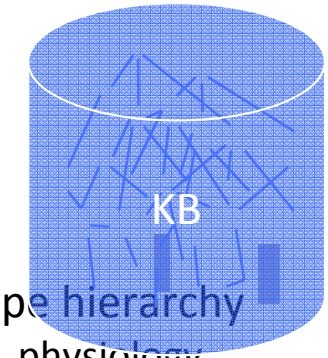
Increased stainable iron in macrophages. **Sideroblastic anemia** is suspected in patients with microcytic anemia or a high RDW anemia, particularly with increased serum iron, serum ferritin, and transferrin saturation (see Anemias Caused by Deficient Erythropoiesis: Iron Deficiency Anemia)

WatsonPaths: Leveraging Watson and Beyond



WatsonPaths builds complex inference graphs by relying on various systems (including Watson) to generate relations and confidence between nodes. With this capability WatsonPaths can answer questions that the base Watson system cannot. It provides a powerful and interactive decision support paradigm over large volumes of unstructured content.

Leveraging Existing Medical Resources

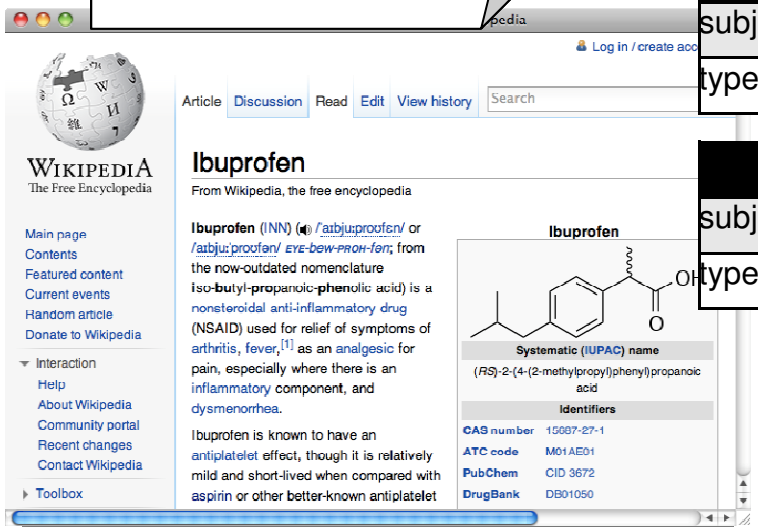


- UMLS (Unified Medical Language System) from NLM
  - ~100 sources, sort of merged
  - ~3M unique concept identifiers (not unique concepts), organized in a type hierarchy
    - activities, anatomy, chemicals/drugs, devices, disorders, genetics, organisms, physiology, procedures, ...
  - ~350 relation types; ~30M unique relation instances
    - diagnoses, treats, finding_site_of, has_causative_agent, contraindicates, …
- Sample Uses of UMLS
  - In Watson QA system
    - Type Coercion: does a candidate answer match the type the question is seeking
    - Candidate generation
    - Term matching
  - In WatsonPaths
    - Clinical factor identification
    - Relation generation in inference graph
    - Term matching

Mining over medical corpus: Prismatic

As with other NSAIDs, ibuprofen may be useful in the treatment of severe orthostatic hypotension

Lasix (furosemide), a diuretic, and ibuprofen, an NSAID, can be taken together



Rule-based relation detector identifies hyponymy relations in text

Frame01	
subj	Ibuprofen
type	NSAID

Frame02	
subj	Lasix
type	diuretic

Frame03	
subj	NSAID
type	drug

Ibuprofen isa NSAID

Lasix isa diuretic

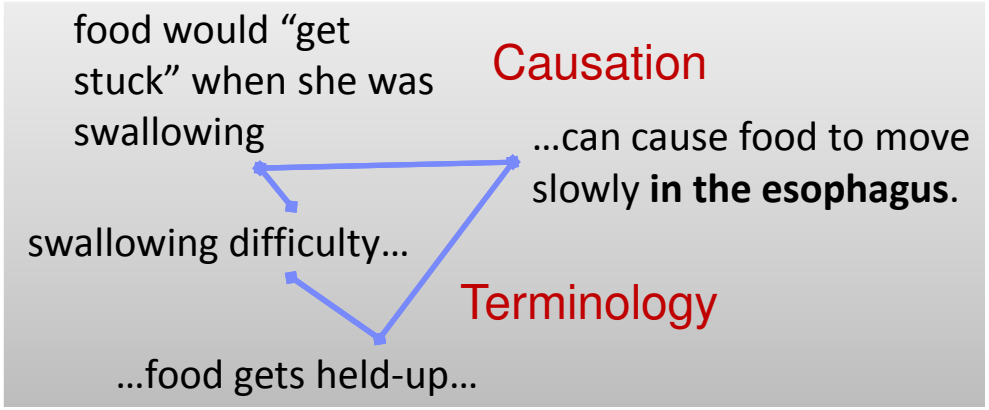
NSAID isa drug

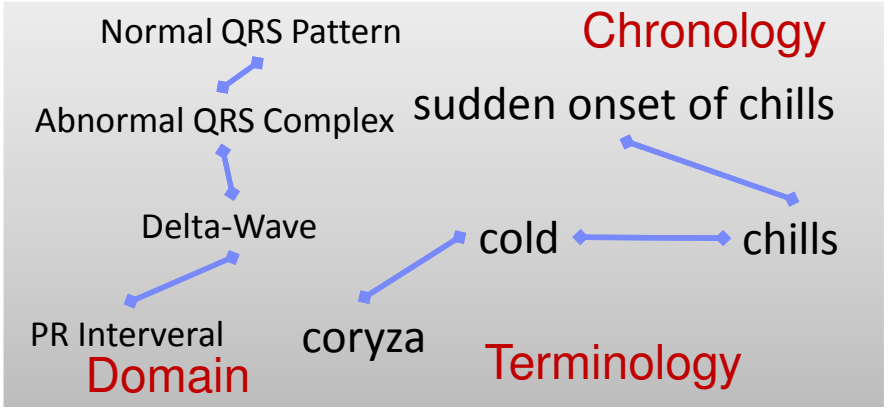
.

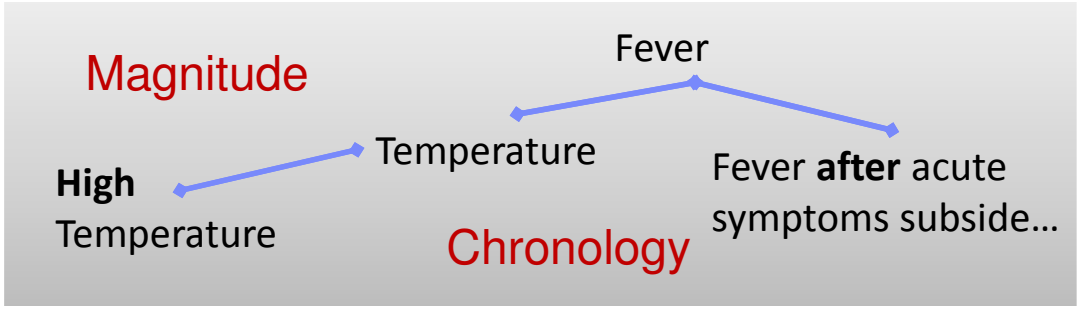
.

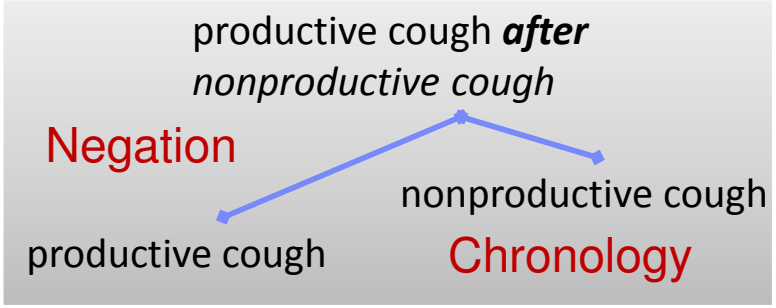
200M

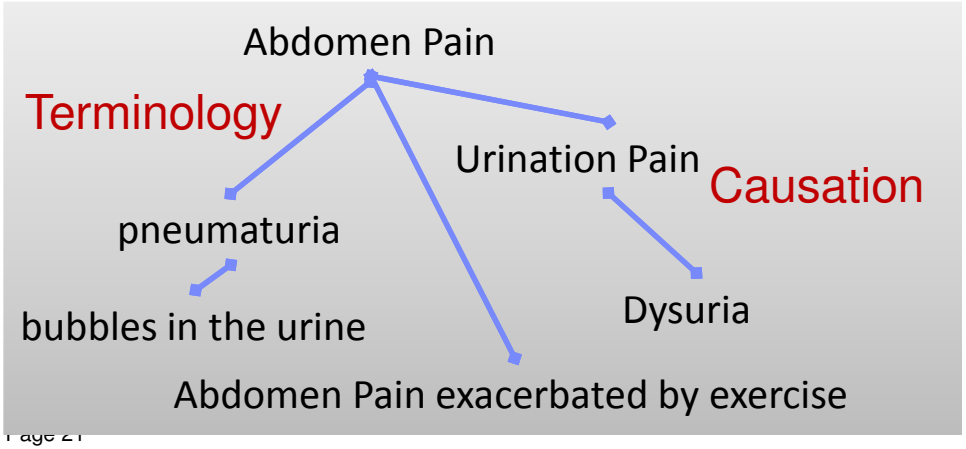
Complexity of Language in the Medical Domain

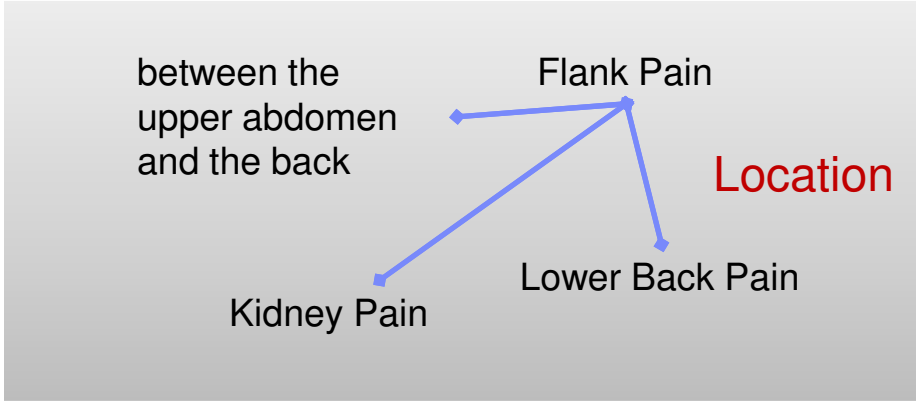












Sign/Symptom Matching

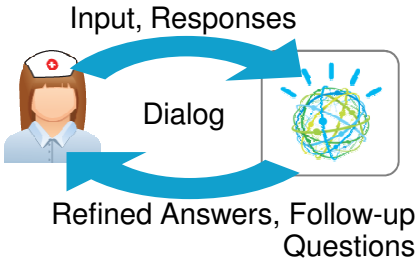
Syndrome of sore throat, fever, **sepsis**, and **unilateral neck swelling**	…cause **septic thrombophlebitis** of the internal jugular vein (Lemierre syndrome). Most patients have fever, sore throat, odynophagia, and **swelling in the neck down to the hyoid bone**
Nasal mucosal atrophy and **foul-smelling crusts in the nasal passages**	Atrophic rhinitis is characterized by progressive nasal atrophy, mucosal colonization with Klebsiella ozaenae or other organisms and **foul smelling nasal discharge**
Syndrome characterized by hypokalemic metabolic alkalosis, mild hypotension, **calluses on the knuckles** and **enamel erosion**	Many individuals with bulimia have **skin abrasions on their knuckles** from inducing vomiting. The most common effect of anorexia and bulimia is **tooth enamel erosion**.
Flexing patient's right hip and knee to elicit pain is used to diagnose this condition	For example, the obturator sign is present when the **internal rotation of the thigh elicits pain** (i.e., pelvic appendicitis), and the psoas sign is present when the **extension of the right thigh elicits pain** (i.e., retroperitoneal or retrocecal appendicitis)

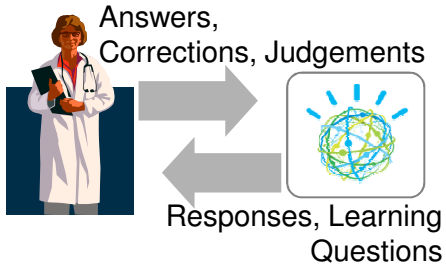
Paraphrases/Entailment

Question Text	Passage Text	Learned Axiom
Murmur associated with this condition is harsh, systolic, diamond-shaped, and increases in intensity with Valsalva	A systolic murmur that increases with the valsalva maneuver and disappears with squatting suggests hypertrophic cardiomyopathy	X suggests Y => X associated with Y
Class of drugs causing regression of polyposis in familial adenomatous polyposis	NSAIDs have been shown to induce adenoma regression in patients with familial adenomatous polyposis	X has been shown to induce Y => X causes Y
Intravenous treatment for cyanide poisoning	Antidotes for cyanide poisoning include amyl nitrate, sodium nitrate, and intravenous sodium thiosulfate.	Antidotes for X include Y => Y is treatment for X
Syndrome characterized by narrowing of the extra-hepatic bile duct from mechanical compression by a gallstone impacted in the cystic duct	Mirizzi's syndrome, a rare condition in which a gallstone impacting the cystic duct obstructs the common bile duct by edema and extrinsic compression	X obstructs Y => narrowing of Y by X
Preferred corrective treatment for acute episodes of angioedema in patients with hereditary angioedema	For acute episodes of angioedema in hereditary angioedema, adminster intravenous, purified, nanofiltered C1-INH concentrate as first-line therapy	For X, administer Y as first-line therapy => Y is preferred treatment for X

Taking Watson beyond Jeopardy!: Recap

Understanding	Interacting	Explaining	Learning





Rich Problem Scenarios	Interactive Dialog Teach Watson	Comparative Evidence Profiles	Continuous Training & Learning Process

Additional Business Applications

Healthcare / Life Sciences: Diagnostic Assistance, Evidence-Based, Collaborative Medicine

Tech Support: Help-desk, Contact Centers

Enterprise Knowledge Management and Business Intelligence

Government: Improved Information Sharing and Education

THANK YOU