

AI and ML in Healthcare

Lecture 01: An Overview

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Spring, 2023

MUNI

Outline

- 1 Course Outline
- 2 Motivations and Key Challenges
 - Motivations
 - The One Challenge to Rule Them All
 - Examples of More Specific Challenges
- 3 Field Highlights
 - A Bit of History
 - Biomedical Knowledge Representation
 - Glimpses of the Present
- 4 Useful References
- 5 Wrapping Up

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Scope of the Course



The photo's original source is the blog-post at <https://tinyurl.com/vxhbn5z4>, copyrighted by Asia Citro (license unknown, author unavailable for an explicit permission).

Your Background and Motivations



Structure of the Course (1/2)

- Weeks 01-02: **overview** of biomedical and healthcare informatics
 - ▶ Two introductory lectures:
 - ★ Today is about relevant **challenges** and selected **technologies**
 - ★ The next one will showcase possible **solutions** to selected **problems**
 - ▶ You'll also form **working groups** and get your first **assignments**
- Weeks 03-06: **independent** work in groups
 - ▶ An in-depth **study** of selected **papers** (one per group)
 - ▶ Coming up with a proposal of a **project** based on the studied paper
 - ▶ Weekly **update meetings** (online or in person) with each group
- Week 07: **hackathon** no. 1 (tentative topic: deep vs. classical ML)
 - ▶ In-person **presentations** of the results of the **paper study**
 - ▶ In-person **presentations** of the related **project proposals**
 - ▶ **Kicking off** the projects in the working groups
 - ▶ Possibly **re-shuffling** the groups if/as needed
 - ▶ Note: may last until **late** (bring **refreshments!**)

Structure of the Course (2/2)

- Weeks 08-09: **independent** work in groups
 - ▶ An in-depth **study** of selected papers (one per group, **related** to the **previous** one)
 - ▶ **Progressing** with the **projects**
 - ▶ Weekly **update meetings** (online or in person) with each group
- Week 10: **hackathon** no. 2 (tentative topic: structured or unstructured, that is the question)
 - ▶ In-person **presentations** of the results of the second **paper study**
 - ▶ An intense **project session** in the working groups
 - ▶ Note: once again, may last until **late** (bring **refreshments!**)
- Week 11: **independent** work in groups
 - ▶ **Finalising** the **projects**
 - ▶ **Preparing** the project **presentations**
 - ▶ Weekly **update meetings** (online or in person) with each group
- Week 12: in-person **project presentations, colloquium**
- Week 13: a **closing** session (hackathon no. 3, just refreshments, or even nothing at all, depending on the group consensus)

Assessment Criteria

- Rather **qualitative**
- Based on **active participation** in
 - ▶ the study of the assigned papers
 - ▶ the weekly update meetings
 - ▶ the collaborative project work
 - ▶ the hackathons
- **Corroborated** by the final **colloquium**

Your Take on the Course Outline



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Motivation?

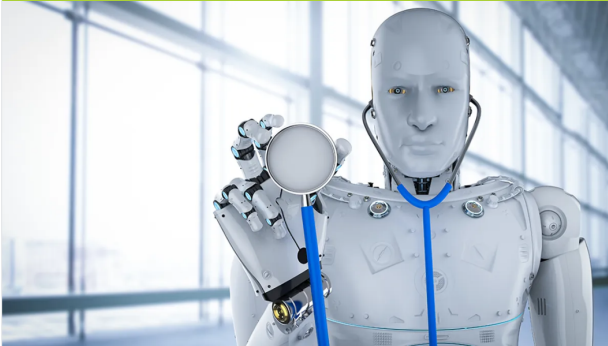
TECHNOLOGY

ChatGPT Can Pass Part Of The US Medical Licensing Exam

"ChatGPT is now comfortably within the passing range."

 **JAMES FELTON**
Senior Staff Writer

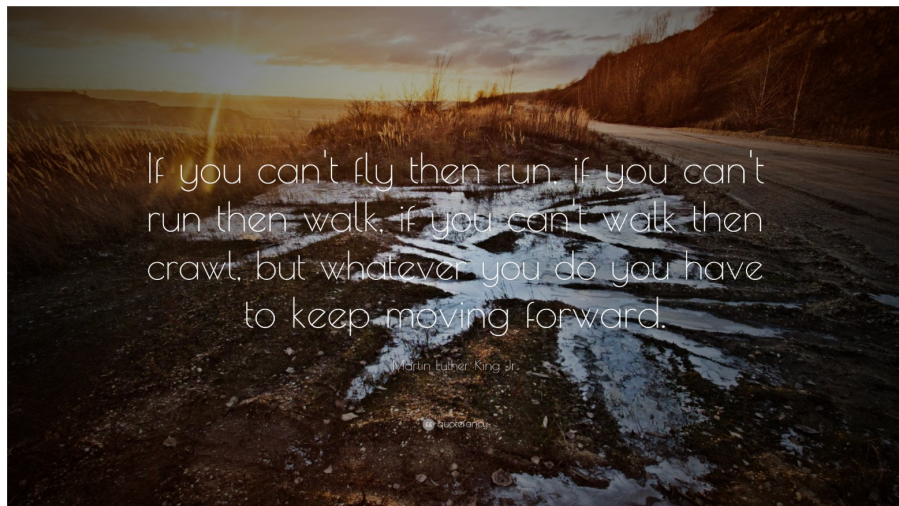
Jan 24, 2023 5:01 PM
2 Comments 580 Shares



We're still a long way from Robo Doc. Image credit: Phonlamai Photo/Shutterstock.com

Screenshot taken from an IFLScience article at <https://tinyurl.com/uau8yh84>.

Motivation!



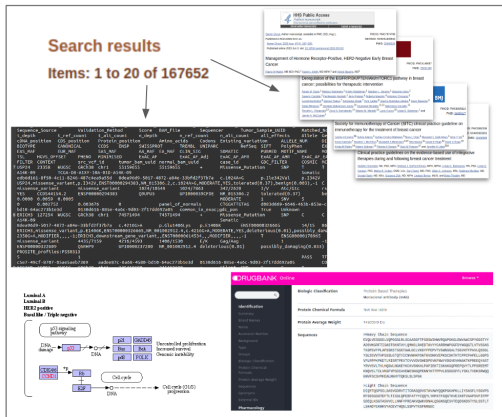
A Martin Luther King's quote, as framed in pictures at <https://tinyurl.com/ywavasv> (license unknown).

Outline

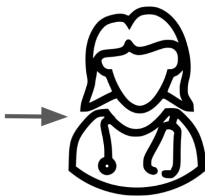
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The Perennial Grand Challenge – Information Overload

Search results
Items: 1 to 20 of 167652



The screenshot shows a search results page with a list of items and a detailed view of a specific item. The list of items includes columns for ID, Name, and other details. The detailed view shows a complex diagram of a biological pathway, likely related to the search results. The diagram includes various components such as DNA, RNA, and proteins, and is labeled with terms like "p53 signaling pathway", "DNA damage", "p53", "MDM2", "p21", "p27", "p29", "p30", "p31", "p32", "p33", "p34", "p35", "p36", "p37", "p38", "p39", "p40", "p41", "p42", "p43", "p44", "p45", "p46", "p47", "p48", "p49", "p50", "p51", "p52", "p53", "p54", "p55", "p56", "p57", "p58", "p59", "p60", "p61", "p62", "p63", "p64", "p65", "p66", "p67", "p68", "p69", "p70", "p71", "p72", "p73", "p74", "p75", "p76", "p77", "p78", "p79", "p80", "p81", "p82", "p83", "p84", "p85", "p86", "p87", "p88", "p89", "p90", "p91", "p92", "p93", "p94", "p95", "p96", "p97", "p98", "p99", "p100".



The icons' original sources: <https://tinyurl.com/48b53fwc>, <https://tinyurl.com/3vhm5xr> (Public Domain). The part of a KEGG pathway taken from <https://tinyurl.com/2x3c6bxz>.

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Genotype-Phenotype Mysteries

Malignant neoplasm of breast, C0006142 🔍

Source: ALL

1 - 25 of 6941 results

Results per page 25

Gene ↕	UniProt ↕	Gene Full Name ↕	Protein Class ↕	N. diseases _g ↕	DSI _g ↕	DPI _g ↕	pLI ↕	Score _{gda} ↕	EL _{gda} ↕
ESR1	P03372	estrogen receptor 1	Nuclear receptor	1101	0.324	0.962	1.00	1.000	None
BRCA1	P38398	BRCA1 DNA repair associa... ▶	Enzyme	747	0.367	0.923	9.2E-29	1.000	strong
BRCA2	P51587	BRCA2 DNA repair associa... ▶	Nucleic acid binding	656	0.379	0.846	2.4E-25	1.000	strong
TP53	P04637	tumor protein p53	Transcription factor	2494	0.236	0.962	0.53	1.000	None
PIK3CA	P42336	phosphatidylinositol-4,5-bis... ▶	Kinase	1511	0.292	0.923	1.00	1.000	None

Results of a search using the DisGeNet database (c.f. <https://www.disgenet.org/>).

Protein Structure Puzzles

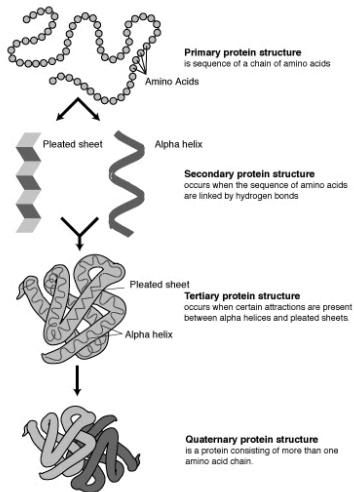


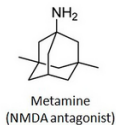
Image in Public Domain, courtesy of National Human Genome Research Institute.

Protein Function Conundrums

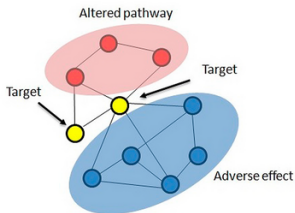
<input type="checkbox"/>	AKT1S1	Proline-rich AKT1 substrate 1	protein binding	IntAct	Homo sapiens
<input type="checkbox"/>	AKT1S1	Proline-rich AKT1 substrate 1	negative regulation of protein kinase activity	UniProt	Homo sapiens
<input type="checkbox"/>	AKT1S1	Proline-rich AKT1 substrate 1	negative regulation of TOR signaling	UniProt	Homo sapiens
<input type="checkbox"/>	AKT1S1	Proline-rich AKT1 substrate 1	regulation of apoptotic process	UniProt	Homo sapiens
<input type="checkbox"/>	AKT1S1	Proline-rich AKT1 substrate 1	regulation of neuron apoptotic process	UniProt	Homo sapiens

Results of a search using the Gene Ontology (c.f. <http://geneontology.org/>).

Needles and Haystacks of Drug Design



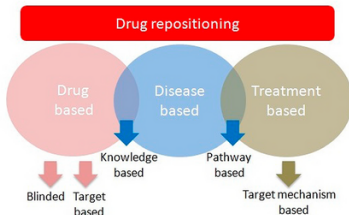
(A)



(B)



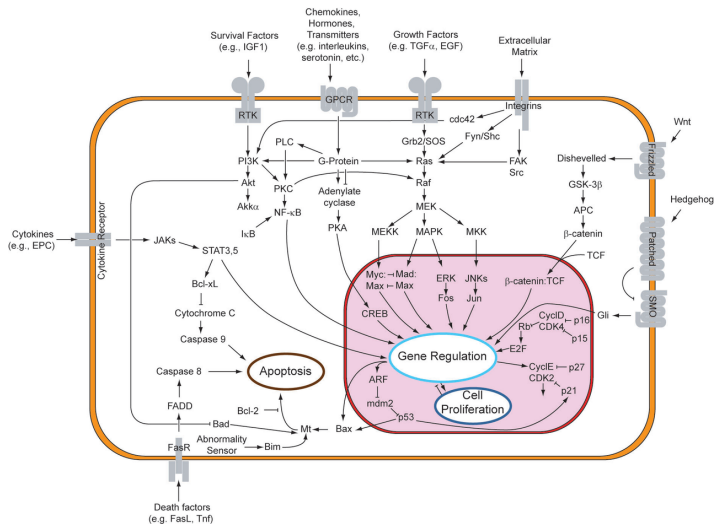
(C)



(D)

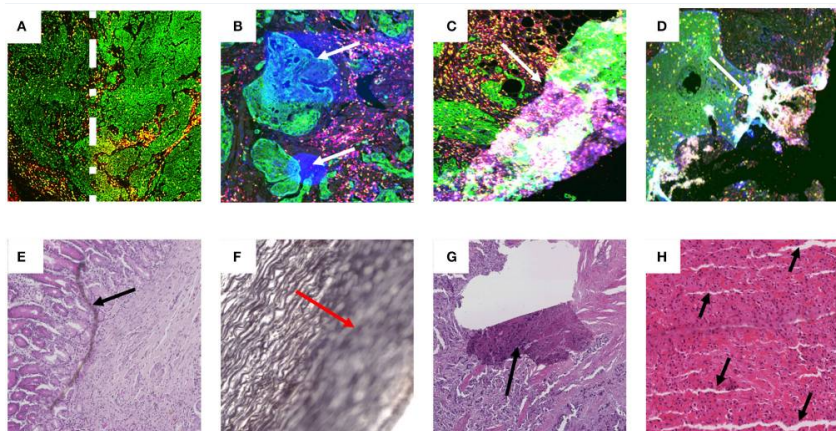
The drug target graphics comes from the special issue of the Biomedicines journal on Molecular Imaging as a Tool for Personalized Medicine (c.f. <https://tinyurl.com/yd9b6ryf> for details on attribution).

Signalling Tangles




The image is based on en:Image:Signal_transduction_pathways.jpg from Wikimedia Commons which was released to the public domain by en:User:Roadnottaken.

Image Mazes



The WSI image originally provided in <https://doi.org/10.3389%2Ffmed.2019.00264>.

Publication Deluge (1/3)

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4,796,866 results << < Page of 479,687 > >>

RESULTS BY YEAR

↕ ↓



1783 2028

TEXT AVAILABILITY

Abstract

Free full text

Full text

ARTICLE ATTRIBUTE

Associated data

Global Cancer Incidence and Mortality Rates and Trends—An Update.
1 **Torre LA, Siegel RL, Ward EM, Jemal A.**
Cite Cancer Epidemiol Biomarkers Prev. 2016 Jan;25(1):16-27. doi: 10.1158/1055-9965.EPI-15-0578. Epub 2015 Dec 14.
Share PMID: 26667886 [Review](#).
There are limited published data on recent **cancer** incidence and mortality trends worldwide. We used the International Agency for Research on **Cancer's** **CANCER**Mondial clearinghouse to present age-standardized **cancer** incidence and death rates for 2003-2007 ...

Clinical, Prognostic and Therapeutic Significance of Heat Shock Proteins in Cancer.
2 **Saini J, Sharma PK.**
Cite Curr Drug Targets. 2018;19(13):1478-1490. doi: 10.2174/1389450118666170823121248.
Share PMID: 28831912 [Review](#).
High expression of these proteins is reported in an array of **cancers**, such as breast, prostate, colorectal, lung, ovarian, gastric, oral and esophageal **cancer**. Ample amount of investigations were carried out on a variety of **cancers** suggesting HSPs as a promis ...

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Publication Deluge (2/3)

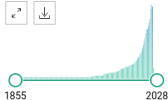
PubMed.gov

[Advanced](#) [Create alert](#) [Create RSS](#) [User Guide](#)

Sorted by: Best match

MY NCBI FILTERS

RESULTS BY YEAR



TEXT AVAILABILITY

- Abstract
- Free full text
- Full text

ARTICLE ATTRIBUTE

415,521 results

Page of 41,553

Diagnosis and Molecular Classification of Lung Cancer.

1 Rodriguez-Canales J, Parra-Cuentas E, Wistuba II.
Cite Cancer Treat Res. 2016;170:25-46. doi: 10.1007/978-3-319-40389-2_2.
PMID: 27535388 [Review](#).

Share **Lung cancer** is a complex disease composed of diverse histological and molecular types with clinical relevance. The advent of large-scale molecular profiling has been helpful to identify novel molecular targets that can be applied to the treatment of particular lu ...

Recent advances in the management of lung cancer.

2 Jones GS, Baldwin DR.
Cite Clin Med (Lond). 2018 Apr 1;18(Suppl 2):s41-s46. doi: 10.7861/clinmedicine.18-2-s41.
PMID: 29700092 [Free PMC article](#). [Review](#).

Share Historically, the prognosis for individuals diagnosed with **lung cancer** has been bleak. However, the past 10 years have seen important advances in treatment and diagnosis which have translated into the first improvements seen in **lung cancer** survival. Th ...

Publication Deluge (3/3)

PubMed.gov

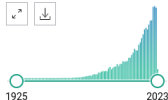
Sorted by: Best match

MY NCBI FILTERS

28,397 results

Page of 2,840

RESULTS BY YEAR



TEXT AVAILABILITY

- Abstract
- Free full text
- Full text

ARTICLE ATTRIBUTE

- Associated data

ARTICLE TYPE

- Books and Documents

Extensive-Stage Small-Cell Lung Cancer: First-Line and Second-Line Treatment Options.
1

Cite Zugazagoitia J, Paz-Ares L.
J Clin Oncol. 2022 Feb 20;40(6):671-680. doi: 10.1200/JCO.21.01881. Epub 2022 Jan 5.
Share PMID: 34985925 Review.

Extensive-stage small-cell **lung cancer** is a therapeutically challenging disease. After more than two decades without clinical progress, the addition of programmed cell death protein 1 axis blockade to platinum-based chemotherapy has demonstrated sustained overall su ...

Non-Small Cell Lung Cancer, Version 5.2017, NCCN Clinical Practice Guidelines in Oncology.
2

Cite Ettinger DS, Wood DE, Aisner DL, Akerley W, Bauman J, Chirieac LR, D'Amico TA, DeCamp MM, Dilling TJ, Dobelbower M, Doebele RC, Govindan R, Gubens MA, Hennon M, Horn L, Komaki R, Lackner RP, Lanuti M, Leal TA, Leisch LJ, Lilenbaum R, Lin J, Loo BW Jr, Martins R, Otterson GA, Reckamp K, Riely GJ, Schild SE, Shapiro TA, Stevenson J, Swanson SJ, Tauer K, Yang SC, Gregory K, Hughes M.
Share J Natl Compr Canc Netw. 2017 Apr;15(4):504-535. doi: 10.6004/jnccn.2017.0050. PMID: 28404761

This selection from the NCCN Guidelines for Non-Small Cell **Lung Cancer** (NSCLC) focuses on targeted therapies and immunotherapies for metastatic NSCLC, because therapeutic recommendations are rapidly changing for metastatic disease. ...

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A Bit of History – Expert Systems (1/2)

- A system for **emulating human decision** capabilities
- Two key parts
 - ▶ A **knowledge base** – facts and rules (typically IF-THEN in the US tradition, or more expressive First Order Logic in the European tradition)
 - ▶ An **inference engine** – an automated reasoning module for answering queries and/or deducing new information (typically backward/forward chaining or a Prolog interpreter)
- **Foundational research** in 1940s-1950s, official **definition** in 1960s, **flourishing** till 1980s
- Succumbed to the **AI winter** of the 1990s, **resurrection** in 2000s (rule-based systems developed by SAP, Oracle, etc.)
- Now more or less **replaced** by or **integrated** with **data mining** and (deep) **machine learning** frameworks

A Bit of History – Expert Systems (2/2)

- **Medicine** has been one of the most important **driving factors**
- MYCIN – the first big **success story**
 - ▶ Developed in 1970s by some of the **leading figures** in biomedical informatics
 - ▶ An **expert system** for identifying **bacteria** causing severe **infections**
 - ▶ KB of about **600 rules**, **backward chaining** inference engine with **uncertainty support**
- Iterative **QA process** via series of simple yes/no questions to the **physician**
- **Never** actually used in **practice**
- Still, its treatment plans had **high acceptability** rating of 65% (**comparable** to a panel of 5 Stanford **experts**)

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Biomedical Knowledge Representation – Why Bother?



Original source: <https://xkcd.com/1838>.

Controlled Vocabularies

- Resources for **organising knowledge** for subsequent **retrieval**
- Motivated by the need for **standardised tagging** of **information** units
 - ▶ Evolved in library and information science (**paper-based** at first)
 - ▶ Useful for **machine-aided** information retrieval, too
- **Prerequisite** for more sophisticated **knowledge organisation systems**
 - ▶ Subject headings, thesauri, taxonomies, . . .
 - ▶ Ontologies, rule bases, knowledge graphs, . . .

Ontologies

- Representation, formal naming and definition of general **categories** (also called concepts or classes) and **individuals** falling under them
- **Properties** of the categories and individual entities, **relationships** between them
- **Metadata** and **annotations** that do not affect the formal meaning
- Typically based on subsets of first order **predicate logic**, such as **Description Logics**
- May allow for expressive **deductive** reasoning
- Sophisticated, but pretty **heavy-weight** and **expensive** to create and maintain

Interoperability Standards (1/2)

- **Specifications** for representation, storing and exchange of data, information and knowledge
- **Defined** and **agreed on** by relevant stakeholders (both from academia and industry)
- **Accepted** and **used** by a broad community of independent **practicians**

Interoperability Standards (2/2)

- **Examples** of standards endorsed by **US-based** bodies:
 - ▶ *LOINC* – health measurements, observations, and documents; *RxNorm* – normalized names for clinical drugs; *SNOMED CT* – set of standards for electronic exchange of clinical health information; *UMLS* – integrates key terminology, classification and coding standards (all NLM)
 - ▶ *Standard for Safety for Medical Device Interoperability* (FDA/ANSI)
 - ▶ *Digital Imaging and Communications in Medicine* (DICOM; National Electrical Manufacturers Association)
 - ▶ *HL7* – a set of international standards for transfer of clinical and administrative data between software applications (HL7 International/ANSI)
- **Examples** of standards endorsed by **EU-based** bodies:
 - ▶ *ICD-11* – global standard for recording health information and causes of death (WHO)
 - ▶ *MedDRA* – clinically validated international medical terminology dictionary-thesaurus, primarily used in pharmacology, pharmacovigilance and clinical research (ICH)

Biomedical KR Example – MeSH

- Temporal Central Focal Epilepsy
- Temporal-Central Focal Epilepsies
- Benign Childhood Epilepsy With Centro-Temporal Spikes
- Benign Childhood Epilepsy With Centro Temporal Spikes
- BCECTS

Previous Indexing:

- [Epilepsy, Partial \(1986-1996\)](#)

[All MeSH Categories](#)

[Diseases Category](#)

[Nervous System Diseases](#)

[Central Nervous System Diseases](#)

[Brain Diseases](#)

[Epilepsy](#)

[Epilepsies, Partial](#)

Epilepsy, Rolandic

[All MeSH Categories](#)

[Diseases Category](#)

[Nervous System Diseases](#)

[Central Nervous System Diseases](#)

[Brain Diseases](#)

[Epilepsy](#)

[Epileptic Syndromes](#)

Epilepsy, Rolandic

Biomedical KR Example – GALEN

Galen Ontology

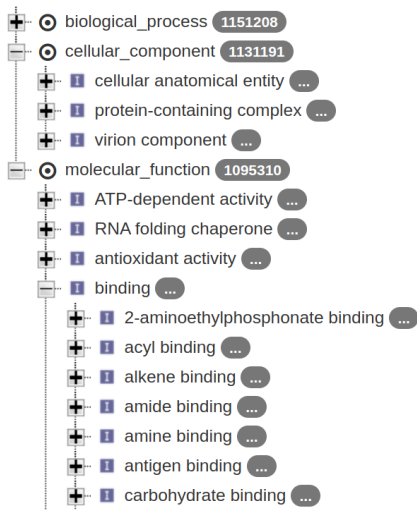
Last uploaded: January 16, 2007

Summary Classes Properties Notes

- Attribute
 - ApplicationAttribute
 - hasCommonFinding
 - hasPrecedence
 - hasSymptom
 - isIndicationFor
 - DomainAttribute
 - ConstructiveAttribute
 - ModifierAttribute
 - SpecificationLevelAttribute
 - TemporalAttribute
 - WrapperAttribute
 - ClinicalRecordAttribute
 - hasUsualReporter
 - isCharacterisedBy
 - isDiseaseMainlyCharacterisedBy
 - isMainlyCharacterisedBy
 - isNotCharacterisedBy

Screenshot taken from NCBO's BioPortal (c.f., <https://tinyurl.com/ye34eb4p>).

Biomedical KR Example – Gene Ontology



Screenshot taken from the AmiGO browser (c.f., <http://amigo.geneontology.org/>).

Biomedical KR Example – UMLS



UMLS

Metathesaurus Browser

Kidney Failure

UMLS CUI: C0035078

Add to List

Semantic Types: [Disease or Syndrome](#)

Definitions (6)

A severe irreversible decline in the ability of kidneys to remove wastes, concentrate URINE, and maintain ELECTROLYTE BALANCE; BLOOD PRESSURE; and CALCIUM metabolism. ...
(MSH)

Atoms (199)

Filter by Vocabulary

Reset Filters [x]

Search Atoms

Name	AUI	Vocabulary	Term Type	Code
Kidney Failure	A8594276	MTH	PN	NOCODE
KIDNEY FAILURE	A0426706	MTH	PT	647
Kidney Failure	A26669932	MSH	PEP	D051437
Renal Failure	A26602673	MSH	ET	D051437
Failure, Kidney	A18463381	MSH	PM	D051437

Broader Concepts (19)

- Acute kidney failure and chronic kidney disease (N17-N19)
- Decreased renal function
- Disorder of kidney and ureter, unspecified
- GENERAL CONDITIONS OF THE KIDNEY AND URETER
- Kidney
- Kidney Diseases
- Kidney Failure, Acute
- kidney functional
- Kidneys and Urinary System
- Korean Standard Classification of Disease Version 5 nephritis, nephrosis, and nephrotic syndrome
- Non-Neoplastic Kidney Disorder
- Nutritional and Metabolic Diseases
- Renal failure and impairment
- Renal Insufficiency
- Urinary complication
- Urinary disease other
- Urogenital Diseases
- Urologic Diseases

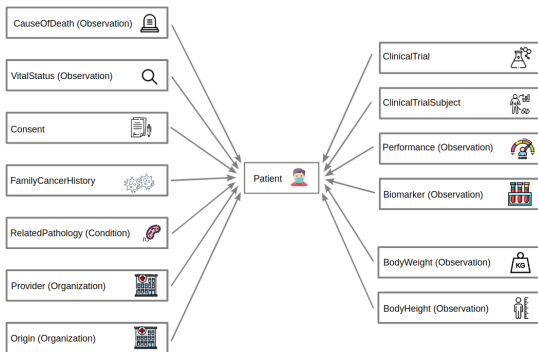
Narrower Concepts (41)

- Abnormal renal function
- Absent renal function

Screenshot taken from <https://tinyurl.com/w2pf3kra>.

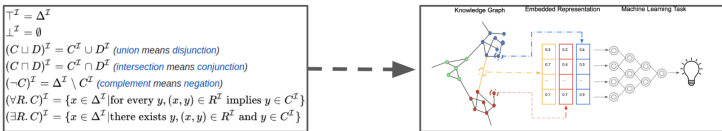
Biomedical KR Example – OSIRIS (HL7/FHIR)

- Interoperability and data sharing framework for clinical and biological data in oncology
- Established in France in 2015, re-used by a number of EU stakeholders since then



Screenshot of the top-level OSIRIS schema taken from <https://fhir.arkhn.com/osiris/>.

Knowledge Graphs as an ML-Ready KR Paradigm



- Somewhat related to **ontologies**, but departing from **formal semantics**
 - ▶ A **lightweight**, yet **powerful** graph-based KR, organising descriptions of objects and their connections/properties
 - ▶ Data instead of schema, bottom-up instead of top-down, transduction instead of deduction, . . .
- Applicable to many **domains** and **use cases**
- Straightforward automated **population** and knowledge **integration**
- Rather complex **inference** still possible
 - ▶ Link prediction, knowledge base completion, relation extraction, analogical reasoning
 - ▶ Schema induction, FOL / DL axioms can be incorporated
- **Scalable** algorithms taking advantage of the **deep learning** state of the art

The DL semantics list's original source: <https://tinyurl.com/53khkptu>. The KG embedding graphics created by Edoardo

Ramalli - Own work, CC BY-SA 4.0, <https://tinyurl.com/3dr7c76b>.

Outline

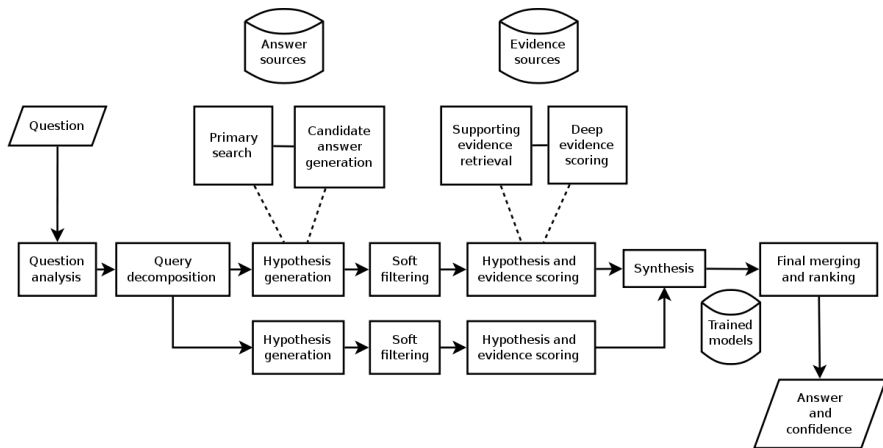
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IBM Watson for Oncology – How It Started



Original image source: a copyrighted TV show screenshot (a non-free content, used according to the fair use policy under US copyright law; for more info, c.f. <https://tinyurl.com/yvpjspyr>).

IBM Watson for Oncology – How It Worked



Original image source: <https://tinyurl.com/bjuu3chm> (own work by the Pgr94 Wikipedia user, released under CC0 1.0

Universal Public Domain Dedication).

IBM Watson for Oncology – How It's Going

Advisory Board

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TOPICS EVENTS DAILY BRIEFING BLOG

MEDICITY INFLUENCERS, OPINION, ARTIFICIAL INTELLIGENCE

Why IBM Watson Health could never live up to the promises

The failure of IBM's marketing-first approach to clinical AI was entirely predictable, but it didn't have to be this way. Here's how AI can be implemented effectively.

By JOHN FROMMELTED

Post a comment / Apr 8, 2021 at 9:00 AM

Twitter Facebook LinkedIn Email

After years of hype, IBM wants to sell Watson Health. What does that mean for health AI?

BLOG POST

By Andrew Ribbin
February 23, 2021



Advisory Board

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TOPICS EVENTS DAILY BRIEFING BLOG

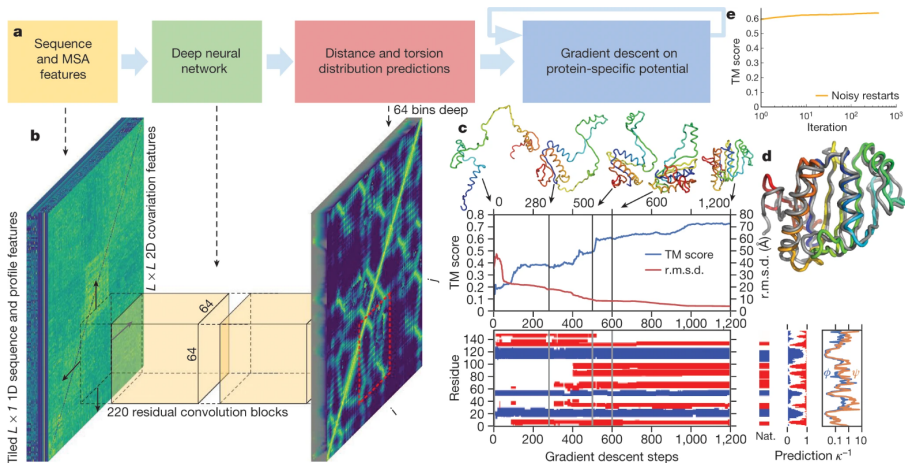
JULY 21, 2021

10 years ago, IBM's Watson threatened to disrupt health care. What happened?

Daily Briefing

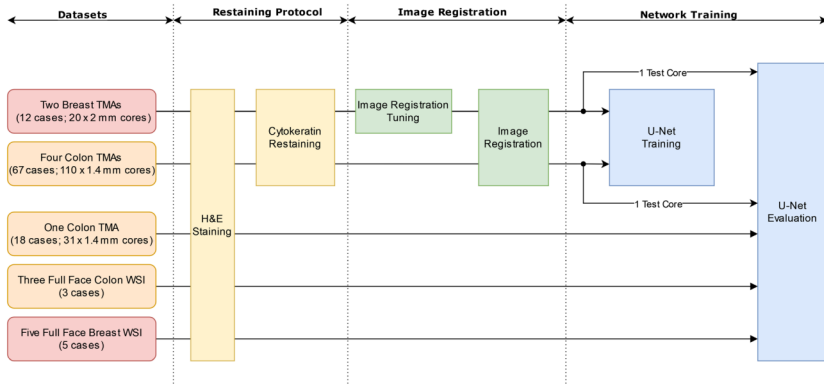
Screenshots taken from <https://tinyurl.com/3pt4j32y>, <https://tinyurl.com/yckvkcc7>, <https://tinyurl.com/2eky7nvk>, <https://tinyurl.com/2kvbmc2h>.

AlphaFold – A Breakthrough in Protein Structure Prediction



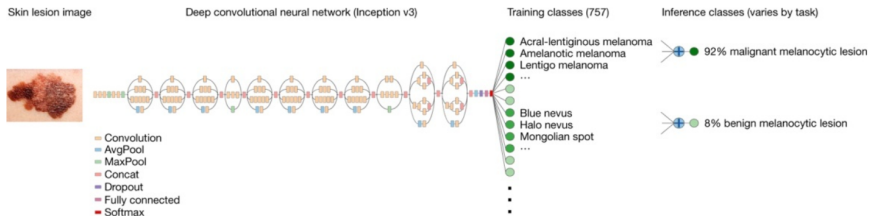
Original image source: the corresponding research paper at <https://doi.org/10.1038/s41586-019-1923-7>.

Digital Pathology – Automated Annotations of Epithelial Cells and Stroma



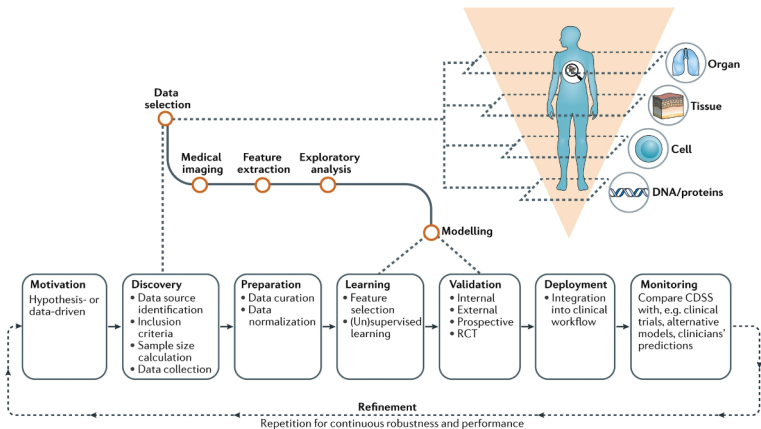
Original image source: the corresponding research paper at <https://doi.org/10.1002/cjp2.249>.

Deep Learning in Melanoma Diagnostics



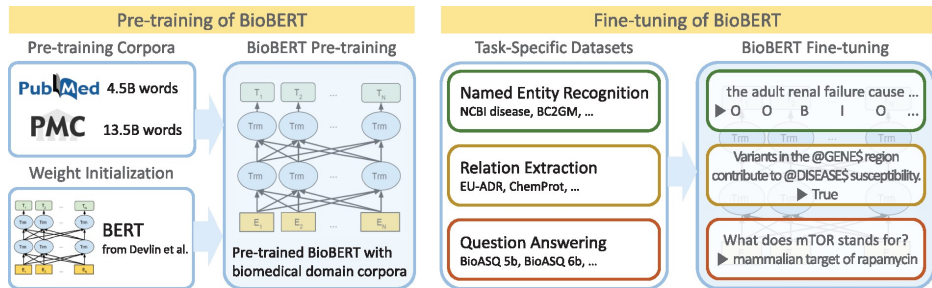
Original image source: the corresponding research paper at <https://doi.org/10.1038/nature21056>.

Radiomics – Clinical Decision Support Based on Imaging Data



Original image source: the corresponding research paper at <https://doi.org/10.1038/nrclinonc.2017.141>.

Biomedical Language Models – Making Use of the State of the Art in “AI”



Original image source: the corresponding research paper at <https://doi.org/10.1093/bioinformatics/btz682>.

Outline

- 1 Course Outline
- 2 Motivations and Key Challenges
 - Motivations
 - The One Challenge to Rule Them All
 - Examples of More Specific Challenges
- 3 Field Highlights
 - A Bit of History
 - Biomedical Knowledge Representation
 - Glimpses of the Present
- 4 Useful References
- 5 Wrapping Up

Related Overall Readings on the Field and Biomedical KR

- Shortliffe, Edward H., et al. Biomedical informatics: computer applications in health care and biomedicine. Springer, 2014.
- Buchanan, Bruce G., and Edward H. Shortliffe. Rule based expert systems: the Mycin experiments of the Stanford Heuristic programming project (the Addison-Wesley series in artificial intelligence). Addison-Wesley Longman Publishing Co., Inc., 1984.
- Smith, Barry, et al. "Relations in biomedical ontologies." Genome biology 6.5 (2005): 1-15.
- Musen, Mark A., et al. "The national center for biomedical ontology." Journal of the American Medical Informatics Association 19.2 (2012): 190-195.
- Hoehndorf, Robert, Michel Dumontier, and Georgios V. Gkoutos. "Evaluation of research in biomedical ontologies." Briefings in bioinformatics 14.6 (2013): 696-712.
- Li, Michelle M., Kexin Huang, and Marinka Zitnik. "Graph representation learning in biomedicine and healthcare." Nature Biomedical Engineering (2022): 1-17.

Related Readings on (Deep) Machine Learning

- Rajkomar, Alvin, Jeffrey Dean, and Isaac Kohane. "Machine learning in medicine." *New England Journal of Medicine* 380.14 (2019): 1347-1358.
- Ching, Travers, et al. "Opportunities and obstacles for deep learning in biology and medicine." *Journal of The Royal Society Interface* 15.141 (2018): 20170387.
- Esteva, Andre, et al. "Dermatologist-level classification of skin cancer with deep neural networks." *nature* 542.7639 (2017): 115-118.
- Senior, Andrew W., et al. "Improved protein structure prediction using potentials from deep learning." *Nature* 577.7792 (2020): 706-710.
- Jumper, John, et al. "Highly accurate protein structure prediction with AlphaFold." *Nature* 596.7873 (2021): 583-589.
- Lambin, Philippe, et al. "Radiomics: the bridge between medical imaging and personalized medicine." *Nature reviews Clinical oncology* 14.12 (2017): 749-762.
- Brázdil, Tomáš, et al. "Automated annotations of epithelial cells and stroma in hematoxylin–eosin-stained whole-slide images using cytokeratin re-staining." *The Journal of Pathology: Clinical Research* 8.2 (2022): 129-142.

Related Readings on Language Technologies

- Cohen, Aaron M., and William R. Hersh. "A survey of current work in biomedical text mining." *Briefings in bioinformatics* 6.1 (2005): 57-71.
- Neumann, Mark, et al. "ScispaCy: fast and robust models for biomedical natural language processing." *arXiv preprint arXiv:1902.07669* (2019).
- Lee, Jinhyuk, et al. "BioBERT: a pre-trained biomedical language representation model for biomedical text mining." *Bioinformatics* 36.4 (2020): 1234-1240.
- Gu, Yu, et al. "Domain-specific language model pretraining for biomedical natural language processing." *ACM Transactions on Computing for Healthcare (HEALTH)* 3.1 (2021): 1-23.

Related Readings on Clinical Decision Support Systems

- Berner, Eta S. Clinical decision support systems. Vol. 233. New York: Springer Science+ Business Media, LLC, 2007.
- Bright, Tiffani J., et al. "Effect of clinical decision-support systems: a systematic review." *Annals of internal medicine* 157.1 (2012): 29-43.
- Yang, Qian, Aaron Steinfeld, and John Zimmerman. "Unremarkable AI: Fitting intelligent decision support into critical, clinical decision-making processes." *Proceedings of the 2019 CHI conference on human factors in computing systems*. 2019.
- Antoniadis, Anna Markella, et al. "Current challenges and future opportunities for XAI in machine learning-based clinical decision support systems: a systematic review." *Applied Sciences* 11.11 (2021): 5088.
- Hanajíková, Michaela. "A review of clinical decision support systems applicable to precision oncology." BS thesis, Faculty of Informatics, Masaryk University (2022). Text available at: https://is.muni.cz/auth/th/o8vzq/hanajikova_michaela_thesis_final.pdf

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Summary and Outlook

- Covered **today**:
 - ▶ Overview of the **course**
 - ▶ Overview of the **field**
 - ▶ Selection of **further readings**
- Outline of the **next week**:
 - ▶ **Using AI/ML technologies** – selected examples
 - ▶ Finalising the **course structure**, **meeting times**, etc.
 - ▶ Finalising the **working groups**
 - ▶ Assignment of **papers** to the groups

Action Items

- Everyone:
 - ▶ Put together a list of **individual interests** relevant to the field (now)
 - ▶ Identify our “**clinical experts**” central to each working group (now)
- I:
 - ▶ Send a poll on class **re-scheduling** preferences (by Thu 16/02)
 - ▶ Send a poll on progress **meeting** preferences (by Thu 16/02)
 - ▶ Suggest a viable **re-scheduling** of the classes (by Sun 19/02)
 - ▶ Compile the **first batch** of **papers** to study (by Wed 22/02)
- You:
 - ▶ Give me your class and meeting time **preferences** (by Fri 17/02)
 - ▶ Form **working groups** (by Wed 22/02)

Questions

