

BioMedical NLP

Class 1

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Organization

Materials:

slides, book, conference/workshop proceedings

Workshops:

[Biomedical Natural Language Processing Workshop \(BioNLP\)](#)

[Special Interest Group on Biomedical Natural Language Processing - ACL Anthology](#)

[Workshop on Computational Linguistics and Clinical Psychology - ACL Anthology](#)



Organization

Topics we will discuss:

8. CONȚINUTURI

CONTENT

8.1. Curs

Course

Introduction, main problems, relationship with other disciplines /

Introducere in domeniu, probleme, relatii cu alte discipline

Resources and frameworks for bio-medical NLP /
Resurse si unelte pentru NLP în domeniul medical

Medical information retrieval and information extraction /

Regasirea informatiei si extragerea informatiei din date medicale

Processing Electronic Health Records (EHRs) /

Procesarea dosarelor medicale electronice

Medical Named Entity Recognition (NER) /
NER medicale

Mental health problems. Computational approaches /

Abordari computationale ale problemelor mentale

Depression. NLP based approaches /
Abordari computationale ale depresiei

Physical and mental health in social media: information and misinformation /

Sanatatea si social media: informatie si dezinformare

Ethical issues and privacy protection in processing medical data /

Probleme de etica si confidentialitate in procesarea datelor medicale

Recent research topics (main conferences and workshops ACL, EMNLP, NAACL; BioNLP, CLPsych etc.) /

Teme recente de cercetare in domeniu (articole recente din principalele forumuri si workshopuri asociate - ACL, EMNLP, NAACL; BioNLP, CLPsych etc)



BioMedical NLP

Universal end goal for using technology in biomedicine: All in all, general end goal: **improving quality of life through understanding life processes.**

Useful for: doctors, patients, other actors in the medical system (insurance, policy makers); researchers, maintainers of resources used in biology/medicine research



BioMedical NLP

BioMedical NLP = part of the wider area of Artificial Intelligence for Medicine / bio-informatics

BioMedical NLP = the use of **NLP methods** for helping biology and medicine research, clinical practice, and adjacent areas



Relations to other disciplines

- medicine...
- psychology
- genetics/genomics
- biology
- other NLP subdomains: information retrieval, NER, knowledge representation
- other types of AI/ML in medicine:
 - computer vision
 - robotics
 -



Relations to other disciplines

Why general NLP is not enough

- most NLP has focused on different types of data (news, ...)

- we do have large volumes of data in biological and medical domain

 - problems around privacy and organizing data

 - problems with annotating data - requires expertise

- general sense representations don't do a good job for medical terms; specific meanings, important distinctions

Relations to other disciplines

Why general NLP is not enough

Semantic class	Examples
Cell lines	<i>T98G, HeLa cell, Chinese hamster ovary cells, CHO cells</i>
Cell types	<i>primary T lymphocytes, natural killer cells, NK cells</i>
Chemicals	<i>citric acid, 1,2-diiodopentane, C</i>
Drugs	<i>cyclosporin A, CDDP</i>
Genes/proteins	<i>white, HSP60, protein kinase C, L23A</i>
Malignancies	<i>carcinoma, breast neoplasms</i>
Medical/clinical concepts	<i>amyotrophic lateral sclerosis</i>
Mouse strains	<i>LAFT, AKR</i>
Mutations	<i>C10T, Ala64 → Gly</i>
Populations	<i>judo group</i>

Figure 22.31 A sample of the semantic classes of named entities that have been recognized in biomedical NLP. Note the surface similarities between many of the examples.

From *Speech and Language Processing: An Introduction to Speech Recognition, Computational Linguistics and Natural Language Processing: Second Edition*, Daniel Jurafsky & James H. Martin. C



Relations to other disciplines

Why general NLP is not enough

Biomedical Term	Category	BERT	SciBERT	PubMedBERT (Ours)
diabetes	disease	✓	✓	✓
leukemia	disease	✓	✓	✓
lithium	drug	✓	✓	✓
insulin	drug	✓	✓	✓
DNA	gene	✓	✓	✓
promoter	gene	✓	✓	✓
hypertension	disease		✓	✓
nephropathy	disease		✓	✓
lymphoma	disease		✓	✓
lidocaine	drug		✓	✓
oropharyngeal	organ			✓
cardiomyocyte	cell			✓
chloramphenicol	drug			✓
RecA	gene			✓
acetyltransferase	gene			✓
clonidine	drug			✓
naloxone	drug			✓

From [Biomedical NLP Group - Microsoft Research](#)



Relations to other disciplines

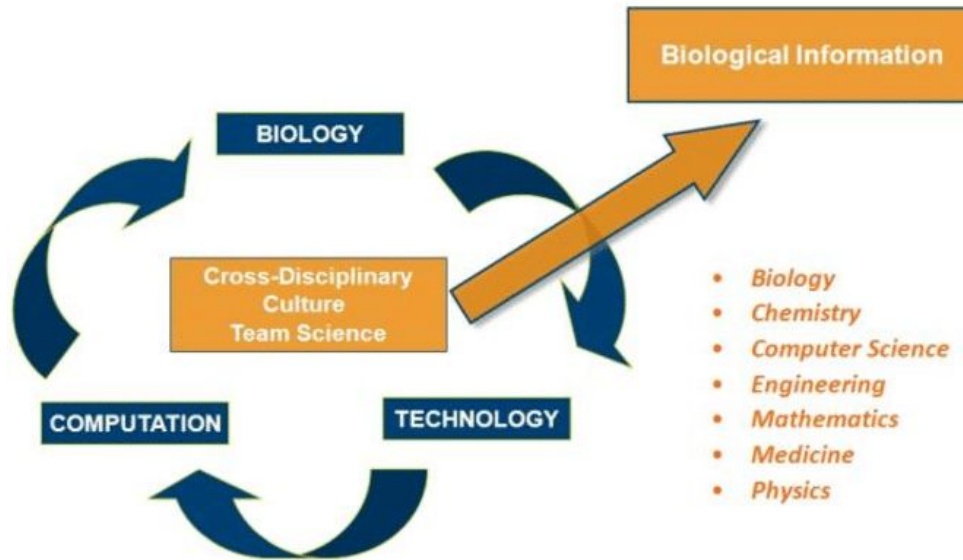
Applications in: “Everything from automated screening and diagnosis, adaptive clinical trials, operations research, global health, precision medicine, home health and wearables, genomic analysis, drug discovery and design, robotics, and many more.”

Interdisciplinary - Healthcare ecosystem:

“This includes AI developers, tech companies, policymakers and regulators, healthcare system leadership, pharmaceutical and device industry, frontline conditions, ethicists, even patients and patient caregivers.

Today in NLP still relatively niche community (smaller than the MT subdomain for example), not all include mental health (but we will); a few workshops: ...

Relations to other disciplines



*Holy trinity of the biological crossdisciplinary culture-"biology drives technology drives analytical tools revolutionizes biology."
Biological breakthroughs require technological innovations which in turn necessitate new computing tools. New technological and computing tools, in turn, allow for the exploration of new biological frontiers.*

(Systems Biology and P4 Medicine: Past, Present, and Future)



Importance of BioMedical NLP

Why is it important?...

- helping with medical decisions in rare cases (diagnosis, predicting side effects, effectiveness...) based on medical records databases
- advancing research through retrieving information in existing research
- health assistant, insights (health data collected from various sources, smartwatches, social media activity etc)

Importance

The image is a screenshot of the PubMed.gov homepage. At the top left is the NIH logo and the text "National Library of Medicine" and "National Center for Biotechnology Information". At the top right is a "Log in" button. The main heading is "PubMed.gov". Below it is a search bar with the placeholder text "Search PubMed" and a "Search" button. An annotation box labeled "Search Box- Traditional/Comprehensive Searching" points to the search bar. Below the search bar is a link to "Advanced" search. An annotation box labeled "Advanced Search Feature" points to this link. Below the "Advanced" link is a paragraph: "PubMed® comprises more than 30 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher web sites." Below this paragraph are four main sections: "Learn", "Find", "Download", and "Explore". Each section has an icon and a list of links. An annotation box labeled "Clinical Queries Feature For Searching" points to the "Find" section. An annotation box labeled "MeSH Database" points to the "Explore" section.

NIH National Library of Medicine
National Center for Biotechnology Information

Log in

PubMed.gov

Search PubMed Search Box- Traditional/Comprehensive Searching Search

Advanced

PubMed® comprises more than 30 million citations for biomedical literature from MEDLINE, life science journals, and online books. Citations may include links to full-text content from PubMed Central and publisher web sites.

Advanced Search Feature

Clinical Queries Feature For Searching

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FTP
Batch Citation Matcher

Explore
MeSH Database
Journals

MeSH Database

Importance

NER Annotation Recheck Back

Dog Bite

CHIEF COMPLAINT: Dog bite to his right lower leg.

HISTORY OF PRESENT ILLNESS: This 50-year-old white male earlier this afternoon was attempting to adjust a cable that a dog was tied to. Dog was a German shepherd, it belonged to his brother, and the dog spontaneously attacked him. He sustained a bite to his right lower leg. Apparently, according to the patient, the dog is well known and is up-to-date on his shots and they wanted to confirm that. The dog has given no prior history of any reason to believe he is not a healthy dog. The patient himself developed a puncture wound with a flap injury. The patient has a flap wound SYMPTOM also below the puncture wound, a V-shaped flap, which is pointing towards the foot. It appears to be viable. The wound SYMPTOM is open about may be roughly a centimeter in the inside of the flap. He was seen by his medical primary care physician and was given a tetanus shot and the wound SYMPTOM was cleaned and wrapped, and then he was referred to us for further assessment.

PAST MEDICAL HISTORY: Significant for history of pulmonary fibrosis DISEASE and atrial fibrillation DISEASE. He is status post bilateral lung transplant back in 2004 because of the pulmonary fibrosis DISEASE.

ALLERGIES: There are no known allergies.

MEDICATIONS: Include multiple medications that are significant for his lung transplant including Prograf, CellCept CHEMICAL, prednisone CHEMICAL, omeprazole CHEMICAL, Bactrim CHEMICAL which he is on chronically, folic acid CHEMICAL, vitamin D CHEMICAL, Mag-Ox, Toprol-XL, calcium CHEMICAL 500 mg DOSAGE, vitamin B1, Centrum Silver, verapamil CHEMICAL, and digoxin CHEMICAL.

FAMILY HISTORY: Consistent with a sister of his has ovarian cancer DISEASE and his father had liver cancer DISEASE. Heart disease DISEASE in the patient's mother and father, and father also has diabetes DISEASE.

SOCIAL HISTORY: He is a non-cigarette smoker. He has occasional glass of wine. He is married. He has one biological child and three stepchildren. He works for

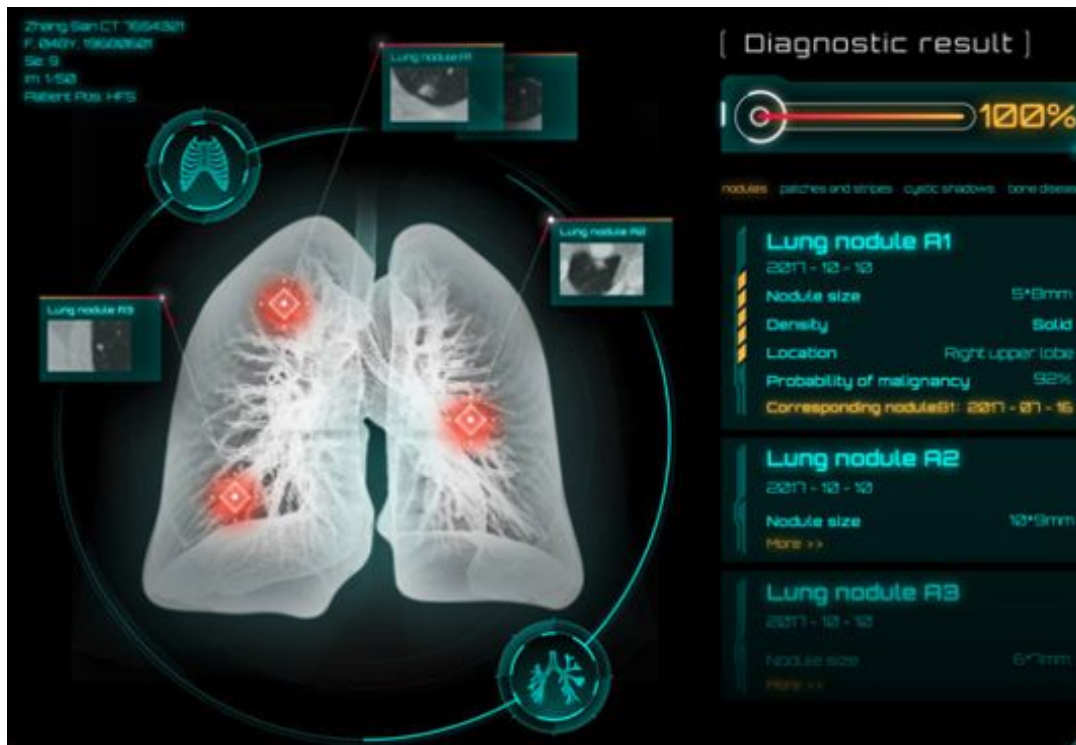


Importance

Some examples of AI for healthcare:

- someone has a rare side effect in some treatment, doctors look into other patient's medical records to make a decision
- detecting skin cancer with AI
- classifying tumors in radiology images
- the relevance of some genes for some diseases (discovered through analyzing occurrence in large amounts of research articles) leads to producing new targeted drugs

Importance



Importance

AI 'outperforms' doctors diagnosing breast cancer



Fergus Walsh

Medical correspondent

@BBCFergusWalsh

🕒 2 January 2020

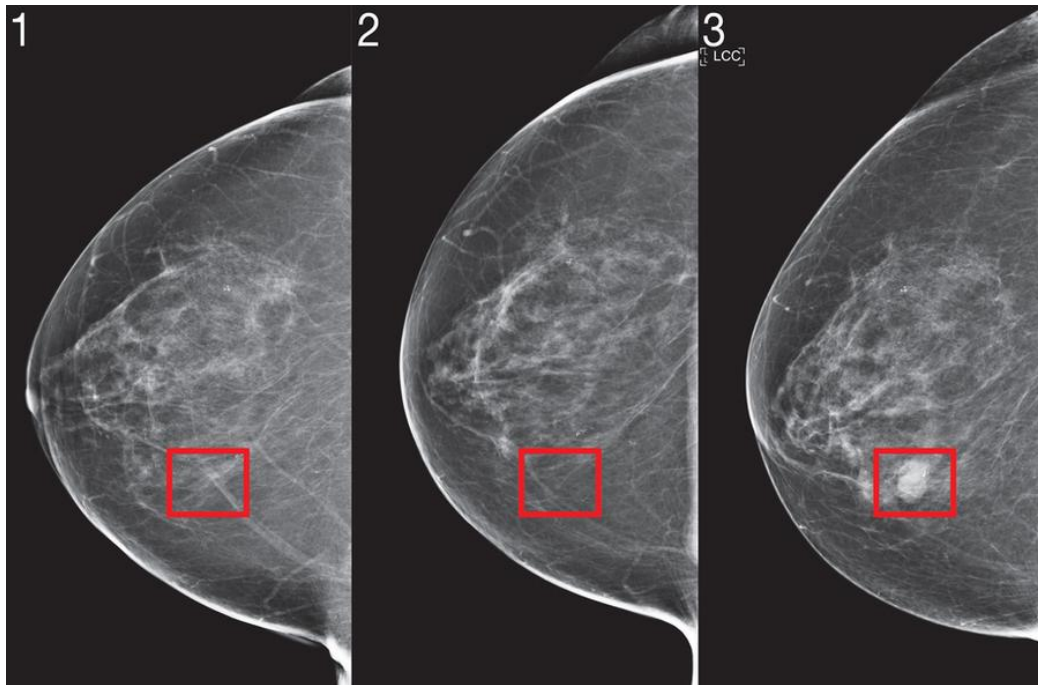


<https://www.bbc.com/news/health-50857759>





Importance





Importance

Innovations in Healthcare: the Role of Technology

1/2 of deaths preventable in Romania (1/3 in EU)

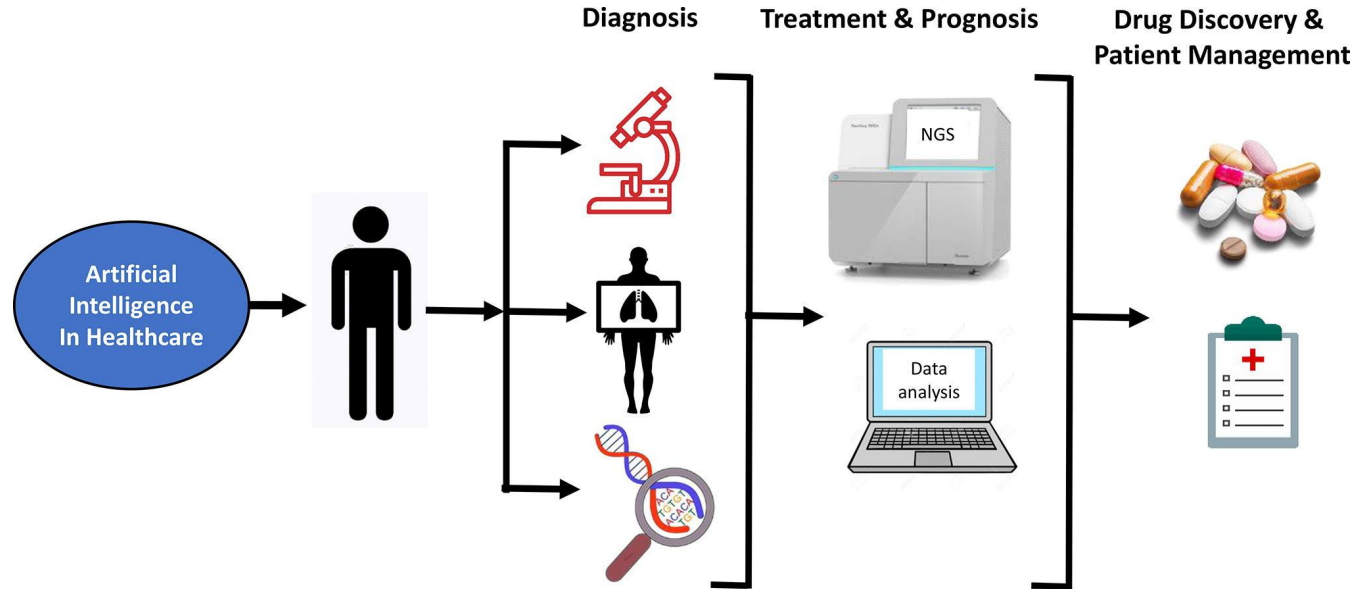
Large percentage of ineffective drugs across different diseases (“one size does not fit all”)

Recent **paradigm shift** in healthcare: the age of **personalized medicine** - individual phenotypes & genotypes to determine predisposition to disease (P4 medicine, “Virtual Patient Model”, computer-aided drug discovery)

Example innovation: targeted treatments for cancer based on genetic profile, increase effectiveness of treatment and life expectancy (e.g. small cell lung cancer)

Problem: the increase in data required for medical decisions > human cognitive capacity => technology to the rescue

Importance



Importance





Importance





Importance

Example:

BioNTech a anunțat dezvoltarea unui nou instrument de monitorizarea a evoluției SARS-CoV2, Early Warning System, bazat pe inteligență artificială, care ar putea scurta timpul până la detectarea variantelor la risc înalt.

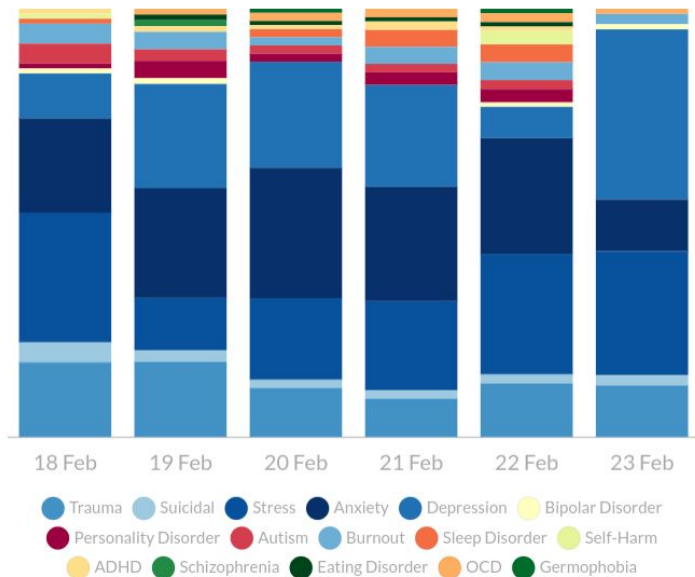
Prin modelarea datelor structurale legate de proteina spike și folosirea algoritmilor AI în cadrul platformei DeepChain, care prelucrează informațiile din bazele de date internaționale cu genomuri virale SARS-CoV-2, sistemul a permis detectarea cu două luni înainte a peste 90% din variantele raportate de OMS.



Importance

Source: Symantec

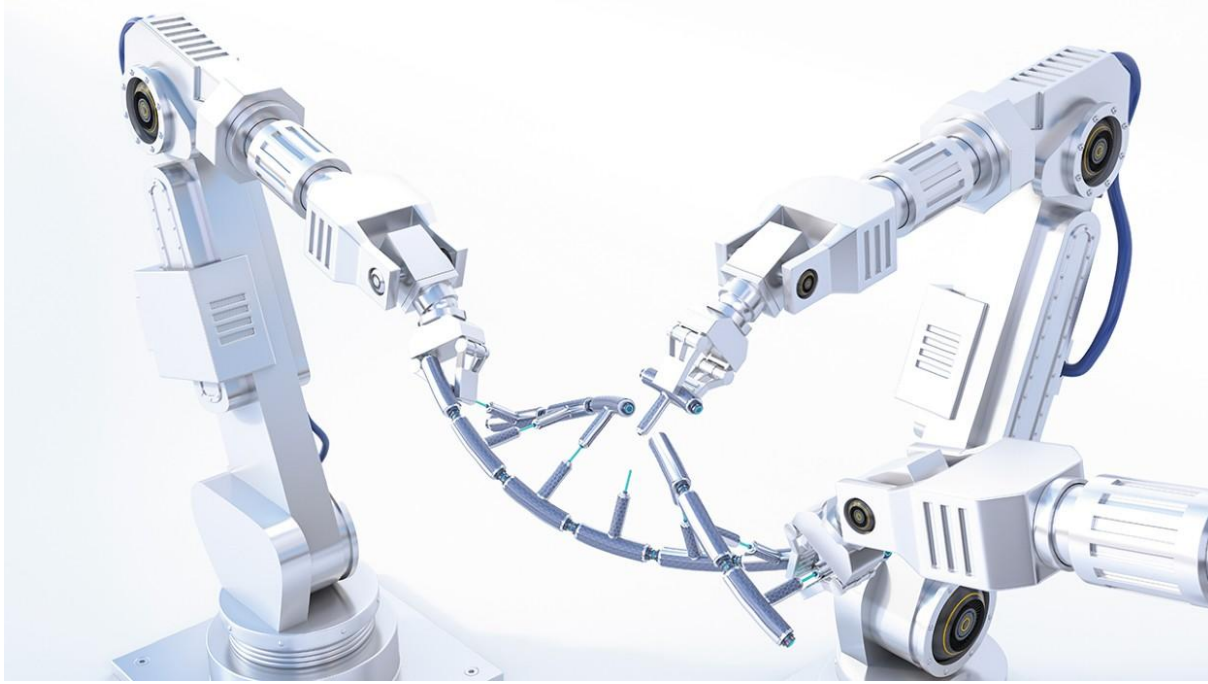
Most discussed mental health issues in the last 7 days



Powered by symanto

[Mental Health and
Coronavirus | Live Impact
Insights](#)

Importance





Importance

**TABLE 1 | SELECTED RECENT FINANCINGS OF COMPANIES
APPLYING AI IN DRUG DISCOVERY**

Company	Date	Headline
Schrödinger	February 2020	Drug discovery software company closes \$232 million IPO backed by Bill Gates and David Shaw.
Insitro	May 2020	Insitro raises \$143 million in Series B funding, to help drive its machine learning-based drug discovery approaches further.
AbCellera	May 2020	AbCellera raises \$105 million in Series B funding round to expand its antibody drug discovery platform.
Relay Therapeutics	July 2020	Relay Therapeutics, which focuses on understanding protein motion to design drug candidates, closes \$400 million IPO.
Atomwise	August 2020	Sanabil Investments co-leads \$123 million Series B funding round for Atomwise to support the development of its molecule

[Tapping into the drug
discovery potential of AI](#)



Types of data and users in bio-medical NLP

2 major areas:

- Mining clinical text <- improve healthcare outcomes
- Mining of biological publications <- advance knowledge of biology and medicine (discovery and understanding of fundamental physiological and pathological processes)

(borders disappearing in the case of personalized medical care based on fundamental biological studies)

3rd direction:

- User-generated data: social media etc; monitoring physical and mental health



Types of data and users in bio-medical NLP

Differences between subdomains and data types:

- types of text/data (heterogenous unstructured data in clinical domain vs papers in biological domain vs user-generated data);
- types and content of knowledge;
- available tools
 - scarcity of primary data in the case of the clinical domain vs papers in biological domain;
 - more lexical tools available for the clinical domain



Types of users

- clinicians: question-answering, document retrieval, ...
- coders: people assigning disease and procedure codes



Types of users

- model organisms database curators (model organisms e.g. mice, worm C elegans, zebra fish and genes in each): they are “crowd-produced”, they need curators to triage and organize source information; need tools like document triaging, NER tools
- biologists doing experimental work: since mid-1990s, technical advancements allowed them to work on thousands and 30,000 genes at a time (as opposed to one) => need text mining to gather statistics about their behavior from previously published literature : text mining, information extraction, paper summarization; leveraging text mining on papers to perform data analysis such as clustering genes



History of BioMedical NLP



History of BioMedical NLP - clinical

1960s:

1966: **ELIZA** - system capable of detecting medical terms in free text using pattern matching (Weizenbaum 1966) <https://web.njit.edu/~ronkowitz/eliza.html>
one of the first chatbots in NLP (chatbot therapist);

1969: **APME** (automatic processing of medical English) - generate semantic interpretation of input medical text with the goal of identifying diagnoses (Pratt et al). Was rule-based and made use of SNOP lexicon (Systematized Nomenclature of Pathology) - terms in different semantic categories, primitive grammar



History of BioMedical NLP - clinical

1970s:

first program for AI in medicine at Stanford (SUMEX-AIM) for clinical decision support

Resulted in:

- clinical applications, AI applications for diagnosis (infectious disease, diabetic retinopathy images), cancer drugs
- AI Handbook Project - materials to explain AI for healthcare audience (to improve their practice)

Initial ideas started to get real results along with other applications in AI, along with increase in data volume and computational power



History of BioMedical NLP - clinical

1980s:

identify biomedical concepts in patients' problem lists (e.g. SCAMP (Shapiro 1980));

Linguistic String Project - LSP: mapped facts extracted from clinical text into a structured database (Friedman et al 1983)

present:

more sophisticated systems being developed and used in clinical centers for extracting facts from clinical text, e.g. MedLEE (Medical Language Extraction and Encoding System),

using lexicon, grammar, formal sentence representation, used for:

- adverse event discovery,
- risks of developing breast cancer,
- association between diseases and drugs
- ...



History of BioMedical NLP - biomedicine

1982:

GenBank - earliest genomic database

1990s: changes in the way biological scientists worked, with advances in genomics and bioinformatics - now can analyze 10,000s genes in one experiment (instead of one).

=> need to identify patterns and organize data

need to automatically analyze published papers (NLP) in order to identify new findings and populate gene databases

building massive databases of all known genes in multiple organisms + gene function



History of BioMedical NLP - biomedicine

1998:

earliest paper on biological text mining (*Fukuda et al 1998, Blaschke et al 1999, Craven & Kumlien 1999*)

- named entity recognition,
- rule-based information extraction,
- machine learning based information extraction



History of BioMedical NLP - biomedicine

The first attempts were developed by biologists and not aligned with latest advances in NLP

“Model organism databases” - repositories of facts about specific genes for species of interest
- they were driving information extraction from biomedical literature

e.g.

- MedMiner (1999): literature exploration of gene-drug and gene-gene relationships (Tanabe et al 1999) (based on GeneCard + extracted from PubMed/MEDLINE);
- iHOP (2004) organized literature around gene/protein of interest (Hoffman & Valencia 2004);
- Textspresso (2004) linked gene names in papers to WormBase entries (Muller, Kenny & Sternberg 2004);
- ARROWSMITH application for information extraction (Smalheiser & Swanson 1999)



Open questions & challenges

Unresolved issues around using **AI in clinical medicine** (from the beginning):

- workforce displacement
- skill atrophy
- algorithmic and user bias
- patient privacy
- medical-legal responsibility
- oversight and regulations



Examples implemented systems



Open questions & challenges

TODO

- “is biomedical NLP efficient?” (see chapter 2)
- ethical problems
- fake news
- mental health
- current state and expected development
- most exciting recent developments, including biomedical AI?
(See workshop proceedings)
-